Development of remote monitoring system for aquaculture water quality based on Internet of Things

Zewen Zhang2,a, Wenwu Mao1,*, Zijie Wang1, Xiaolin Tan1, Fan Wu1, Dengkui Wang3, Xiong Fang4

1College of Engineering Science and Technology, Shanghai Ocean University, Shanghai, China
2College of Food Science and Technology, Shanghai Ocean University, Shanghai, China
3College of Fisheries and Life Science, Shanghai Ocean University, Shanghai, China
4Fishery Machinery and Instrument Research Institute, Chinese Academy of Fishery Sciences, Shanghai, China

*Corresponding author e-mail: wenwumao@126.com, ajiezhang@shou.edu.cn

Abstract: In order to know aquaculture water quality situations in the real time, ease work strength of aquaculture workers, and improve aquaculture efficiency, this paper develops the remote monitoring system for aquaculture water quality based on Internet of Things, including selection of water quality monitoring parameters, overall design of monitoring system, type selection of single chip microcontroller and sensor, design of monitoring system software, and water quality parameter sampling design. The aquaculture workers could understand information of aquaculture water body such as dissolved oxygen concentration, pH value, ammonia-nitrogen content, and temperature through remote monitoring system, and remotely control the aquaculture water quality for targeted purpose.

1. Introduction

In aquaculture, water quality environment is one of the important factors affecting survival of marine products. Under the aquaculture environment of nonconforming water quality, marine products are unable to grow and breed normally; in serious pollution, the marine products may be dead massively. At present, the monitoring and control of aquaculture water quality is mainly based on experience of workers and the work load is heavy. Meanwhile, the water quality environment of aquaculture is complex and changing. Different types of fish have different requirements for water quality. The same type of fish also has different requirements for water quality in various development stage. Thus, the requirement for work strength and experience of aquaculture workers is further improved. Therefore, the systematic monitoring affects important water quality parameters of fish culture and applies remote control so as to greatly reduce work strength of workers, improve aquaculture efficiency and reduce aquaculture risks.
2. Main water quality parameters affecting fish culture

2.1. pH value
pH value is the judging index for acid and alkali concentration. When the pH value is low, fish is particularly sensitive to infectious diseases, and easy to fall ill, even leading to death; when pH value is high, the growth of aquatic microorganism is restricted, and putrefactive bacteria decomposition is hindered so as to reduce self-purification ability of water body and deteriorate water quality; when pH is too high or too low, the fish may die. Therefore, the size of pH directly affects growth, breeding and even survival of fish.

2.2. Dissolved oxygen
Oxygen is the foundation that fish and aquatic lives rely on. The source of dissolved oxygen is gas seepage in air and the photosynthesis of aquatic plants. Fish is sensitive to the dissolved oxygen in water. If the dissolved oxygen level is low, the fish will be reluctant to eat and their moving ability, metabolizing ability and immunity will reduce, easily causing various diseases. When the concentration of the dissolved oxygen is too low, fish may suffer difficulty in breathing and even be suffocated and died. Thus, the content of dissolved oxygen in water not only relates to fish’s eating but also affects growth, survival of fish as well as balanced and stable ecological system.

2.3. Ammonia nitrogen content
Ammonia nitrogen may lead to acute and chronic hazards to aquatic life. Hazards of chronic ammonia nitrogen poisoning: worse ingestion, slow growth, tissue injury, and lower transmission of oxygen between tissues. Fish is sensitive to ammonia nitrogen in water. Fish may die when the ammonia nitrogen content is high. Hazards of acute ammonia nitrogen poisoning: aquatic life may be excited, lose balance in water, suffer cramp and even die. When the ammonia nitrogen content is high, the fish grows slowly, and feel pressure, shrink the fin and breathe rapidly. When the ammonia nitrogen content is too high, many diseases may be caused; the bacterial infection may damage skin, stomach and intestinal mucosa of fish, further leading to bleeding of internal organs and body surface, and even death of fish caused by acute poisoning.

2.4. Nitrite
Nitrite may damage erythrocyte, make oxygen delivery capacity of blood lost, and harm functions of fish’s liver, spleen and kidney. The excessively high nitrite content will lead to worse physical strength and poor spirit of fish, showing in slow swimming on the upper area of the water body, more and thick surface mucus, light blue and white surface, and local contrafluxion. The fish will be easy to infect with various diseases and may be poisoned and died in serious cases.

2.5. Temperature
Fish is poikilothermal animal. The water temperature decides the body temperature. The water temperature not only affect appetite and metabolism of fish, but also affect breeding. Moreover, water temperature also affects dissolved oxygen content in water, chemical reaction of poisonous substances and toxicity of ammonia. For instance, When the water temperature rises, the dissolved oxygen in water will be reduced, and the fish breathe rapidly, leading to larger oxygen consumption and further reduction of dissolved oxygen and causing vicious circle; when the water temperature is too low, the fish may become dormant and stop growing. Therefore, it is necessary to check water temperature in time and adopt measures to stabilize the temperature to certain scope.

3. Main water quality parameter indexes of fish culture
Table 1 shows the main parameter indexes of fish culture, including PH, dissolved oxygen, ammonia nitrogen content, nitrite content and temperature. The normal pH value range for normal fish culture in China shall be 6.5~8.5, the non-ionic ammonia nitrogen scope shall be below 0.2mg/L, and nitrite content shall be below 0.1mg/L. Different fish species have different requirements for concentration of the dissolved oxygen. In general, the dissolved oxygen concentration 5~8mg/L is the normal range.
When the dissolved oxygen in water is insufficient, the aquatic lives grow slowly and the utilization rate of bait is low, usually resulting in gasping for air and even death. The same fish species have similar demand for dissolved oxygen concentration; different fish species or different culture periods have different applicable scope of temperature. The most suitable water temperature of common tropical freshwater fish is 26–28℃, and of tropical sea-water fish is 24–26℃. [1][2]

Table 1. Main water quality parameter indexes of fish culture

| Parameter            | Scope       | Remarks       |
|----------------------|-------------|---------------|
| PH                   | 6.5–8.5     | Normal growth |
| Dissolved oxygen     | 5–8mg/L     | Normal growth |
| Ammonia nitrogen content | ≤0.2mg/L     | Normal growth |
| Nitrite content      | ≤0.1mg/L    | Normal growth |
| Temperature          | 20–35 ℃     | Normal growth |

4. Overall solution of the monitoring system

Overall solution of the aquaculture water quality remote monitoring system can be seen in Fig. 1, mainly including: dissolved oxygen sensor, PH sensor, nitrite sensor, ammonia nitrogen sensor, temperature sensor, single-chip microcomputer, communication module, mobile HDD, client and feedback actuator. Firstly, the five sensors are used to acquire dissolved oxygen content, pH value, ammonia nitrogen content, nitrite content and temperature. The single-chip microcomputer processes the data and stores the information. Later, the values of dissolved oxygen content, pH value, ammonia nitrogen content, nitrite content and temperature in water are compared with the system setting values. If a value is beyond the normal scope of the setting value, the information will be transmitted to the monitoring center and user’s mobile for warning through communication module, so as to remind the user and launch water quality adjustment actuator according to the set module.

The single-chip microcomputer of the remote monitoring system adopts STM32F767 chip, the operating frequency of which may reach 216Hz. It has powerful instant data processing ability and could process simultaneously multiple pieces of data collected. The normal temperature range for operation shall be -40℃~85℃ and power source voltage shall be 1.7~3.6V. Besides, it provides low power consumption mode. The water quality parameter collection module adopts automatic
temperature compensation and online sensor with RS485 output standard. The temperature and dissolved oxygen content collection modules adopt RDO-206online dissolved oxygen measurement device based on fluorescence quenching method with scale of 0~20.00mg/l, operating temperature of 0~45℃ and resolution of 0.01mg/L, 0.1℃. PH value collection module adopts PHG-202 sensor, with measurement scope of 0~14pH, operating temperature of 0~65℃ and resolution of 0.01pH. The ammonia nitrogen value collection module adopts NH61-A0002 sensor, with measurement scope of 0.05-5mg/L, operating temperature of 0~50℃ and resolution of 0.01mg/L. The nitrite value collection module adopts XT-5904 sensor, with measurement scope of 0-2.00mg/L, operating temperature of 0~60℃ and resolution of 0.01mg/L.

5. Sampling process of water quality monitoring

The sampling process of aquaculture water quality monitoring can be seen in Fig.2. The sample period of system parameters shall be 15min, and each time of sampling takes 4s. The total process contains four stages, with 100ms per stage. When startup, firstly, the system will be initialized, and it will clear up system cache and input preset value of every inspection parameter on the screen. After the preset values are confirmed, the system will enter cycle set by the timer. When 100ms signal is detected, the dissolved oxygen value and temperature inspection model start to run; when 200ms signal is detected, PH detection model starts to run; when 300ms signal is detected, the ammonia nitrogen content collection model starts to run; when 400ms signal is detected, nitrite content collection model starts to run; when 500ms signal is detected, the collection data will be processed and stored; then the data collected will be compared to the preset value scope. When the data collected is beyond the present value scope, the feedback adjustment system will be launched to adjust water quality; otherwise, the system waits for next sampling cycle after current sampling is ended.

![Fig.2 Sampling process of water quality monitoring](image-url)
6. Remote monitoring client
The client of remote aquaculture water quality monitoring system based on IoT is developed based on Android and Eclipse. After registration and login, users may check data of each pool stored in the server through intelligent terminal. The upper and lower limit of pH value, dissolved oxygen, ammonia nitrogen content and nitrite content could be set according to species of fish, growing stage, culture density and weather conditions. If the real-time detection data is beyond the safety scope, as shown in Fig.3, the intelligent terminal will issue alarm to users and adjust water quality according to the mode set.

![Fig.3 Interface of remote monitoring client](image)

7. Conclusion
The remote aquaculture water quality monitoring system based on IoT is able to remotely collect and store main aquaculture water quality parameters such as dissolved oxygen, pH value, temperature, ammonia nitrogen content and nitrite content. When the real-time detection data is beyond the safety scope, water quality may be adjusted and controlled remotely according to species of fish, growing stage, culture density and weather conditions so as to greatly ease the work strength of aquaculture workers, and provide foundation and guarantee for scientific management of workers.

8. Acknowledgement
This project is subsidized by the open fund of Key laboratory of Fishery Equipment and Engineering, Ministry of Agriculture of the People’s Republic of China.

References
[1] Liu Huan. Functions of Water Analysis in Pond Aquaculture [J]. Current Fisheries, 2019, 9: 83-89
[2] Li Xinxing, Zhu Chenguang, Zhou Jing, Sun Longqing, Cao Xiamin, Zhang Xiaoshuan. Review and Trend of Water Quality Detection in Aquaculture by Spectroscopy Technique [J]. Transactions of the Chinese Society of Agricultural Engineering, 2018, 34(19): 184-194.