Engineering And Technology Journal e-ISSN: 2456-3358
Volume 3 Issue 01 January-2018, Page No-339-348
DOI:10.18535/etj/v3i1.01, I.F. - 4.449

Establishment of a Drone waste water Treatment Plants by Remote Monitor System

Yung-Yun Cheng[1], Shang-Lien Lo[2]

[1,2]Graduate Institute of Environmental Engineering, National Taiwan University, 71 Chou-Shan Rd., Taipei City, Taiwan 10673, Taiwan (ROC)

Corresponding Author: Shang-Lien Lo
Tel: +886-23625373; Fax: +886-23928821

Abstract: The effluent quality and operational performance of a wastewater treatment plant depend on the operational efficiency of the equipment used in the plant. Conventionally, general equipment maintenance in a wastewater treatment plant is often scheduled based on the maintenance staff's findings from their inspections and tests. In other words, equipment that fails to meet the requirements or has sustained damage is identified during inspections and tests and will be subsequently serviced. This maintenance method requires large amounts of time, manpower and material resources, from the detection of abnormal equipment to the completion of maintenance.

This study proposes an improved concept of maintenance and service that is capable of predicting which equipment requires maintenance and servicing in a plant, thereby reducing the probability of equipment malfunctions or failures. A wireless sensor network and cloud computing are used to effectively manage and monitor a wastewater treatment plant; the water levels, operational conditions and important water quality parameters in each treatment unit are continuously monitored, and the monitoring data are uploaded in a timely fashion to the database of a cloud monitoring and control platform. Whether an anomaly has occurred in the wastewater treatment system is determined by comparing the monitoring data with the critical water levels, abnormal equipment conditions and continuous water quality monitoring data that are stored in the intelligent database. When the equipment sends abnormal signals, the intelligent system will alert the operators, who will then implement proper treatments or adjustments to achieve predictive maintenance. The advantages of this system are that it can prevent water quality deterioration, prevent the effluent quality from exceeding the discharge standards as a result of equipment damage and shorten the duration of abnormal equipment operation. This predictive maintenance and management system can more effectively utilize the maintenance staff's time than other techniques. The intelligent cloud-computing predictive maintenance system and its advantages are demonstrated with a case study of the Rong Lake Wastewater Treatment Plant in Kinmen County.

Keywords: cloud computing, wireless sensor network, water quality analysis, intelligence

Introduction

Most of the research examining the operational efficiency of wastewater treatment plants focuses on the optimal design of treatment units and parameters, whereas the operational conditions of these plants and each treatment unit are often ignored. Operational conditions, such as the normal chemical feed, normal equipment operation, effective water depth and optimal operation, are often the key factors that affect water quality treatment efficiency. The abilities of the operators can even more significantly affect the treatment efficiency. Appropriate manpower planning to reduce risk, ensuring proper operational quality during nighttime non-staffed periods and training the staff on methods for determining water quality and yield are the focuses of research on the operational optimization of wastewater treatment plants.

In wastewater plant, the units operation was depends on operator, it may cause unstable effluent, moreover, it cause huge personnel costs. Thus, how to perform management and maintenance tasks in a wastewater treatment plant is of great practical significance to improving equipment management and operating techniques as well as incorporating intelligent management. An intelligent control maintenance management system involves three main technical areas: control, maintenance and technical management. The control system aims to achieve good maintenance quality, performance control and high reliability and usability. Manpower allocation and cost are taken into consideration in breakdowns and scheduled maintenance. It is unfeasible to designate specific staff to continuously monitor a wastewater treatment system. Therefore, relevant operators are often only called to perform maintenance or adjustments after some time has passed since the occurrence of an abnormal situation. The experience of the operators is an unpredictable variable. Unreliable inspections resulting from indolence and mistakes of the inspectors and the use of excess chemicals to meet the discharge requirements are problems with current wastewater treatment management and control systems.

Application control and technical management should be more important than maintenance techniques. For example, scheduled maintenance currently remains the main maintenance method used in hydroelectric power plants and other industrial sectors. Even with scheduled maintenance, breakdown maintenance is unavoidable. Maintenance costs account for 15% of the total operating cost of a wastewater treatment plant, of which 5% is unnecessary. This is mainly because it is impossible to accurately determine the condition of the equipment (Ruan&Yu, 2000). Therefore, predictive maintenance should be performed. The rapid development of real-time monitoring, prediction, information processing, fault detection and artificial intelligence technologies in recent years has enabled the monitoring and prediction of the operational condition of equipment (Fu et al., 2004).

The Internet of things (Io T)is an information network linking the Internet and conventional telecommunication networks, and it allows interaction and cooperation of regular physical objects with independent functions. The current research trend is to combine autonomous control with the IoT. In the future, the IoT may become a nondeterministic open network, in which self-organizing or intelligent physical and virtual objects are able to interact with the environment and autonomously perform operations based on their objectives (Atzori et al., 2010).

Wireless sensor networks (WSNs) are used extensively in the water resource field. Zia, Harris, Merrett, Rivers, and Coles (2013)employed a WSN to monitor water quality and analyze the effects of agricultural activity on water quality and used the results as a basis for watershed planning. Bogena, Huisman, Oberdörster, and Vereecken (2007)used continuous data obtained from laboratory and field experiments to analyze the spatial variation of soil moisture content. Capella, Bonastre, Ors, and Peris (2013) developed a solar energy-powered continuous nitrate monitoring network and formulated management plans based on the measurements obtained using this network. Neal, Atkinson, and Hutton (2012) established a flood forecasting model based on an arrangement of sensor nodes and the acquired data. Martin, Hubert, Lavallée, Pelletier, and Bonin (2005)implemented a WSN to manage the Quebec Urban Community's storm sewer drainage network and obtain real-time flow and water level data; in addition, they presented optimal control system parameters determined based on an economic analysis.

In the wastewater management field, Yue and Ying (2012) designed a solar panel-powered water quality monitoring system that uses WSN technology to connect thesensor nodes and the base station and transfers data collected by the sensor nodes (including pH, suspended solids and dissolved oxygen) to the management terminal. Sempere-Payá and Santonja-Climent (2012) implemented a wastewater network monitoring system capable of automatically taking measurements and transmitting images in real time and equipped with an intelligent platform in a sewage system. This monitoring system enabled relevant personnel to rapidly address issues, such as overloading of the wastewater system and illegal or wastewater discharges, and improved the measurement frequency, accuracy and timeliness, thereby ensuring more effective management of the operation of the sewer system. Lee et al. (2008)designed a real-time remote monitoring system for wastewater treatment plants, which was subsequently employed to monitor the influence loadings (i.e., flow rates) at small-scale wastewater treatment plants as well as the efficiency in treating nitrogen and phosphorous in real time while ensuring that the requirements for lower operating costs were met.

Based on these research results, there is no fixed framework model for WSNs, and their efficacy has been demonstrated in applications and frameworks in several fields. In particular, WSNs can improve the treatment efficiency of sewer collection and treatment systems and facilitate management optimization by optimizing monitoring points, acquiring and transferring data, receiving data on the management terminal, performing analyses and giving commands.

In this study, a WSN was employed to monitor the operation of a wastewater treatment plant. The WSN was connected to the existing treatment units and equipment and was used to transfer data. Cloud computing and WSN technologies were used to design and plan proper mounting points based on the conditions of the wastewater treatment plant and acquire and transfer data to the management terminal. Data analysis was performed on the server.

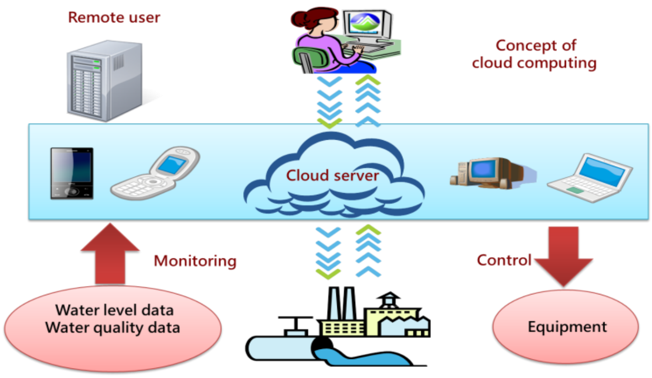


Fig. 1. Framework of the wastewater treatment monitoring system designed in this study

The main objectives of this study are as follows:

1. To apply the concepts of WSN and cloud computing to the wastewater treatment field, establish a demonstrative practice, and design an effective monitoring system.
2. To inspect, repair and expand the original water level measuring instruments, measure the original water level through the establishment of a WSN and store the data

on a server by setting up relays and controllers, connecting signals and using remote network monitoring system platform technology, which will enable remote online monitoring.

3. To set up a monitoring system in the Rong Lake Wastewater Treatment Plant in Kinmen to collect data, including the water level signals, operational conditions of the pumps and pump overload signals, and enable the operators to remotely monitor the operational conditions of the treatment units and forcibly start or stop equipment when needed, thereby laying a basis for predictive maintenance.

Materials and methods

A remote monitoring system is necessary to understand the operational conditions of a wastewater treatment plant. In this study, controllers are used to transfer data about the condition of the equipment and the water levels on site via the Internet to the control terminal. When needed, commands are given at the control terminal to monitor and control the operational conditions on site.

In this study, a wastewater treatment monitoring system is designed, which contains a wastewater treatment system and a cloud monitoring platform. The wastewater treatment system contains several wastewater treatment units, water level monitors and equipment monitors. Each of the wastewater treatment units has a wastewater storage tank, which are connected by wastewater pipelines. The wastewater will be treated by the treatment equipment in the corresponding wastewater tank after it flows into the wastewater treatment system through the inlet pipeline. The treated effluent will then be discharged through the outlet pipeline. Water level monitors are placed in the treatment units to monitor the water levels. In addition, equipment monitors are connected to the wastewater treatment equipment to monitor its operational conditions. The cloud monitoring platform, which is connected to the wastewater treatment system via the Internet, consists of a database, an intelligent database and a processor. The database stores water level data, operational condition data and water quality data uploaded by the water level monitors, equipment monitors and water quality monitors, respectively. The intelligent database, which is connected to the database, stores continuous water quality monitoring data of the wastewater treatment system recorded in the past as well as the critical water levels and abnormal equipment conditions set by the users. The processor, which is connected to the database and the intelligent database, compares the water level data with the critical water levels and the operational conditions with the abnormal equipment conditions in real time and sends an anomaly alert to the operators when an anomaly is detected. This wastewater treatment monitoring system was developed and tested by applying it to the treatment units in the Rong Lake Wastewater Treatment Plant.

The Internet-based monitoring system designed in this study is composed of three main parts: Arduino controllers, a monitoring server and server-side intelligence.

2.1 Arduino controllers

An Arduino controller is added to each existing pump control system to read all of its water level signals. In addition, operational and anomaly signals from pump motors A and B are introduced. Furthermore, to enable it to control the pump motors, the Arduino controller is designed in such a way that it is capable of actuating external relays to forcibly shut down and start the pump motors.

The Arduino controller is composed of an Arduino control panel and an external network card. The open-source Arduino system (used as the base) is equipped with a network interface and is connected to a server, thereby creating a system capable of monitoring.

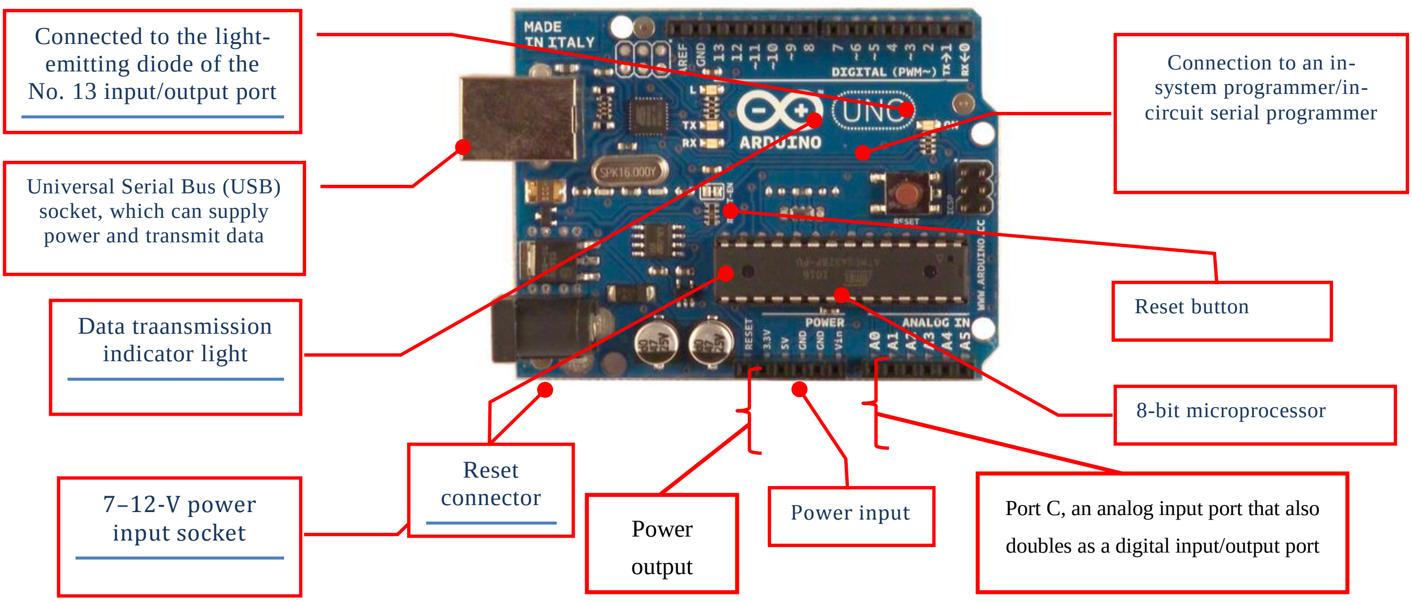


Fig. 2. Arduino Uno control panel

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Fig. 3. Specifications of the Arduino Uno system

The control panel is connected to a computer via a Universal Serial Bus (USB) interface and is powered by the computer (or an external 9-V power source). The designed program on the computer is burned into the control panel via the USB interface. The control panel has a processing/writing development environment similar to Java and C.

To allow the Arduino controller to have connectivity, a network interface daughterboard is added to the Arduino Uno motherboard (Fig. 4). A network program is written using the Internet program library of the Arduino open-source system.

Fig. 4. Arduino network interface daughter

2.2 Monitoring Server

The central monitoring server is a web server, on which Tomcat web server programs (Servlet/Java server page containers) and My SQL database servers run. The central monitoring server can be a server computer or a cloud framework depending on the load demand.

Based on the data transfer object, the monitoring server is composed of two main parts: the IoT, which is responsible for the communications between numerous Arduino controllers, monitoring programs and monitoring servers, and a data management system, which allows authorized users to remotely manage all of the controllers.

The IoT program on the monitoring server is a Java Servlet program, which analyzes the Hypertext Transfer Protocol requests sent by the controllers or monitoring programs using a customized machine-to-machine communication protocol and, based on the analysis results, processes the data and provides responses. The monitoring server accepts the connection request sent by each embedded controller and stores the sensor driver signal data sent by each embedded controller in the database.

The data management system on the monitoring server, which is composed of web page (static web page) and Servlet (dynamic web page) programs, provides an interactive webpage that shows the monitoring data and allows authorized users to monitor the real-time conditions of each pump system at anytime from any location by accessing the Internet. If an authorized user needs to start the actuator (motor) of a pump system, he/she can send a control command via the Applet monitoring program interface on the webpage. Using Applet-Servlet communication, the control command returns a Servlet program, which stores the control command in the database, returns it to the embedded controller to execute it, and then returns the execution result to the central monitoring computer.

2.2.1 Applet monitoring program

The central control server provides an Applet remote monitoring program. By remotely loading this program, an authorized system user can use a browser to connect to the central control computer to monitor the conditions of each pump system and, when needed, start or stop the motor of a pump system.

The Applet remote monitoring program first logs into the central server computer to verify the user's identity and then loads a dynamic screen corresponding to the controlled system that shows the statuses of the sensor and driver. The user can then change the driver status by clicking the icon.

2.3 Server-side intelligence

A conventional monitoring system is a distributed control system; the local controllers execute the control algorithms, and the central monitoring computer collects and displays the overall data. The area in which a monitoring system can be used (e.g., disaster early warning, rescue, medical care, pollution prevention and control, commercial and residential building security, energy conservation and carbon emissions reduction, factory automation or intelligent residential buildings) is determined by the design of the local controllers. While there is a wide variety of software and hardware local controllers, they basically function in similar ways: a local controller continuously reads in sensor data (input), executes the control algorithm, performs calculations based on the control algorithm, starts the corresponding driver (output), and then uploads the data to the central monitoring computer. The application of a local controller varies with the selected sensor driver and the designed control algorithm.

In this study, the local controllers are simplified, and complex computations are performed on the server side. All of the control algorithms are stored on the server side and controlled by the server. The local controllers only perform sensing and actuating tasks and are unintelligent. This design is a so-called centralized control system.

In a centralized control system, a server-side fault or a network disconnection will render the local controllers nonfunctional. Conventional monitoring systems are used to monitor industrial production. On a production line, the local controllers are not allowed to become nonfunctional. However, in this study, the cloud monitoring system is added to the water level control system to provide it with additional Internet monitoring capacity. As a result, a brief Internet disconnection would only affect the monitoring function but not the original water level control function. In addition, Internet connections will soon become an infrastructure that is as important to people's livelihood as water and electricity, and ensuring stable and reliable Internet access will become an important primary responsibility of the state. On the other hand, an important aspect of cloud computing technology is the dependence on reliable Internet resources.

Server-side intelligence is used to enhance the water level control intelligence. Upon receiving input and output data transferred from an Arduino controller, the server actuates the intelligent device to monitor the water level in the pump, determines various types of anomalies based on the input and output states and subsequently addresses them.

Thus, the water level control server-side intelligence not only is a backup for the original control system but, more importantly, also enhances the water level control intelligence.

2.4 Setting up the wastewater treatment monitoring system in the Rong Lake wastewater treatment plant

2.4.1 General information about the Rong Lake wastewater treatment plant

Five wastewater treatment plants—the Tai Lake, Rong Lake, Qingtian, Jincheng and Donglin Wastewater Treatment Plants (Table 1)—have been constructed in Kinmen County since the completion of the planned sewer system in May,1992.

Table 1. Summary of the current status of the wastewater treatment plants in Kinmen County

Wastewater treatment plant	Jincheng Wastewater Treatment Plant	Tai Lake Wastewater Treatment Plant	Rong Lake Wastewater Treatment Plant	Qingtian Wastewater Treatment Plant	Donglin Wastewater Treatment Plant
Treatment method	Oxidation ditch	Oxidation ditch	Oxidation ditch	Rotating biological contactor	Contact aeration
Service area	Urban area of Jincheng Township and area of Jinning Township near Jincheng Township	Area near the Tai Lake Reservoir in Jinhu Township, area near the Tianpu Reservoir in Jinsha Township and parts of the Taiwu Mountain military camp	Shamei, Jinsha Township and area near the Rong Lake Reservoir	The Taiwu Mountain military camp as well as Qionglin and Xiaojing (two areas near the Tingtian Reservoir in Jinhu Township)	Donlin, Lieyu Township
Receiving waters	The Taiwan Strait	Huanglong Lake	The Taiwan Strait	The Taiwan Strait	The Taiwan Strait
All-phase daily average sewage volume	3,000 (phase 1)/4,700 (all phases)	2,500 (phase 1)/3,700 (all phases)	3,000 (phase 1)/4,500 (all phases)	500 (all phases)	290 (all phases)
Geographic location	On the west side of Great Kinmen and near the County Gymnasium in Jincheng Township	On the east side of Tai Lake in Jinhu Township (this plant treats domestic sewage discharged by the residents of Jinhu Township)	Near Yangsha Road in Jinsha Township	In the Taiwu Mountain area in the Kinmen National Park (this plant only treats sewage discharged from the military camp)	On the south side of Lesser Kinmen and near the Taiwan Strait
Date of completion	September 2011	December 1992	August 1999	April 2000	September 2002

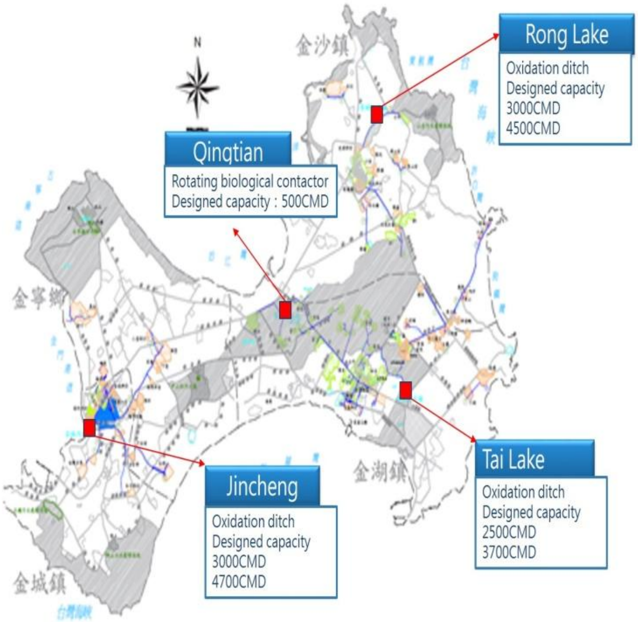


Fig. 5. Locations of the wastewater treatment plants in Great Kinmen

Fig. 5 shows the locations of the wastewater treatment plants on the island of Kinmen as well as their planned treatment capacities.

Data source: Sewer records published by the Construction and Planning Agency of the Ministry of the Interior of the Republic of China in 2011

Data source: Sewer records published by the Construction and Planning Agency of the Ministry of the Interior of the Republic of China in 2011 (this map was produced in this study)

The Rong Lake Wastewater Treatment Plant, which was completed in 1999, is the second largest of the five wastewater treatment plants, with a designed treatment capacity of 3,000 cubic meters daily (CMD). With eight sewage pumping stations and 15 km of pipelines, this plant collects domestic sewage discharged from Shamei, Jinsha Township and the area near the Rong Lake Reservoir, and it currently has a treatment capacity of approximately 600 CMD.

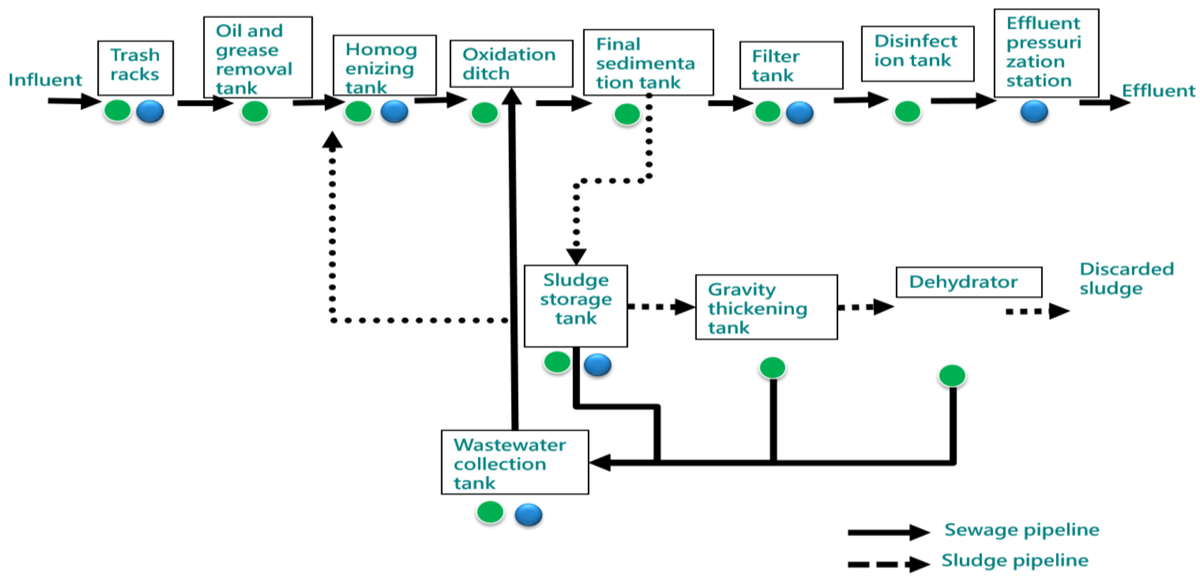


Fig. 6. Designed treatment process and units of the Rong Lake Wastewater Treatment Plant
Data source: Kinmen County Water Department (this diagram was produced in this study)

Fig. 6 shows the designed treatment units and flow of the Rong Lake Wastewater Treatment Plant in Kinmen. After flowing into the plant, sewage is first treated in several pretreatment units, namely, trash racks, a desilting and oil and grease removal tank and a homogenizing tank. After remaining in an oxidation ditch for some time, the sewage continues to flow through a filter tank and a disinfection tank. The effluent is then pressurized and discharged. The sludge is temporarily stored in a sludge storage tank. Some of the sludge is discarded after being gravity thickened and dehydrated. The remaining sludge flows back to the homogenizing tank.

2.4.2 Functional design of the monitoring system for the Rong Lake wastewater treatment plant

The monitoring system consists of two parts: a water level monitoring system and an equipment monitoring system. The water level monitoring system acquires the high, moderate and low water level data from the key pump tank units. The equipment monitoring system transfers data about the operational conditions of the equipment (e.g., aerators, motors and mud scrapers) in each unit.

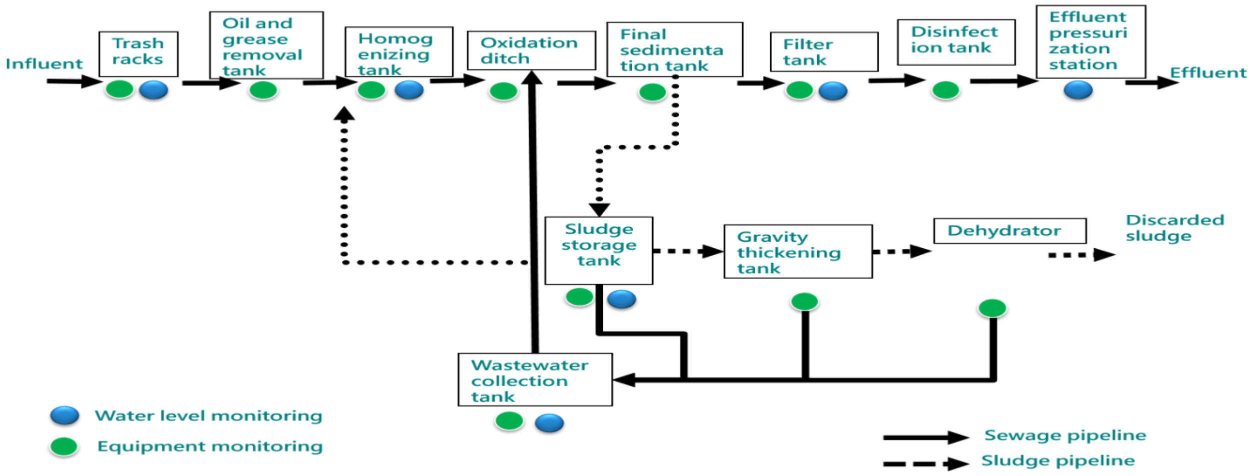


Fig. 7. Distribution and number of mounting points of the wastewater treatment monitoring system set up in the Rong Lake Wastewater Treatment Plant

In this study, the six treatment tanks with a pump unit (i.e., the trash racks, homogenizing tank, filter tank, effluent pressurization tank, sludge storage tank and sludge wastewater collection tank) each have a water level monitoring capability. The high, moderate and low water level data are transferred once every five seconds. The 47 pieces of equipment have a monitoring capability that facilitates the transfer of data about the operational conditions (i.e., in-operation (ON), out-of-operation (OFF) and abnormal (overloading)) of the equipment. The monitoring interface is capable of giving the managers or operators early warnings of abnormal operational conditions (e.g., excessively high or low water levels and durations of the continuous operation of equipment that exceed the historical records) by sending mobile phone text messages.

2.4.2.1 Equipment signals

The equipment signals are mainly acquired using relays capable of reading the motor status. Different relays should be installed based on the motor voltage (110 V or 220 V). Signals are sent to the Arduino main control panel through the movement of the relay coil (all-or-nothing). For example, if a relay is actuated and a relay connection is established, the Arduino main control panel will receive a signal of 0.

2.4.2.2 Water levels

A relay is also capable of reading the float status. When the float switch is on, the relay coil will move, and two sets of contact points will be conducted. One set will send signals to the Arduino main control panel, and the other will send signals to the water level controller. Thus, the water level can be determined.

2.4.2.3 Force start or stop

When a relay is used to forcibly start or stop equipment, it will send a signal of 1 or 0, respectively ,to the Arduino main control panel via the contact point connected to the Arduino main control panel.

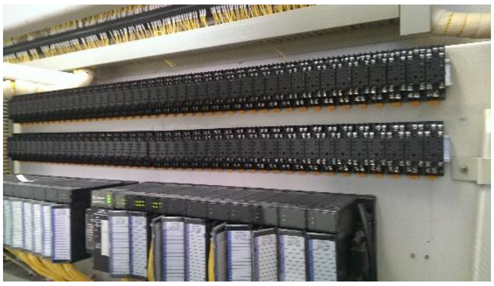
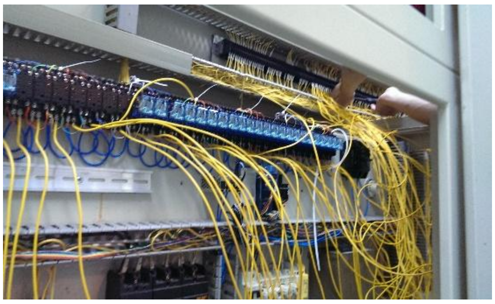
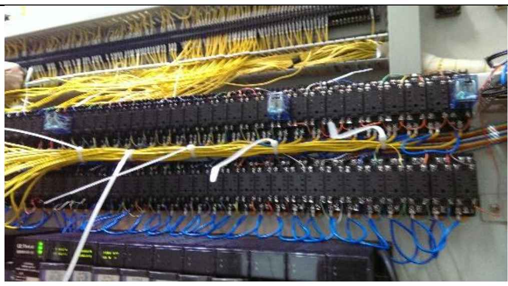
2.4.2.4 Setup

The WSN designed in this study first reads signals related to the water levels and the operational conditions of the equipment in the wastewater treatment plant, transfers them to the controllers and subsequently uploads them to the server via the network. The setup of this WSN involves the following steps

(1) Float testing and replacing;
(2) Planning and installation of relays and controllers;
(3) Planning and installation of signal wires;
(4) Controller setting;
(5) Installation of network cables;
(6) Planning and building of data points on the server;
(7) Testing.

Table 2. Photographs taken during the setup process

	
Replacing a float	Control panel

	
Fixing of aluminum tracks	Installation of relays
	
Installation of a controller	Connection between signal wires and a controller
	
Common-point connection of signal wires	Installation of control wires
	
Neatening of control wires	Completion of the setup of the monitoring equipment

In addition, to verify whether the system is operable, testing will be conducted on the day that the system is set up on site. The automatic trash racks will be compared with the data and the images shown on the management terminal to improve the system's reliability and timeliness.

2.4.2.5 Remote management center

The function of the remote management center is to acquire and display data, including water level, equipment monitoring and anomaly data.

(1) Water level data: The water level monitoring interface shows the latest water level signals from each tank in the wastewater treatment plant read by the controller, which are dynamically updated, as well as a table of water level data over time, which reflects the changes in the water levels on site. This interface also gives an anomaly alert when the received water level signal is excessively high or low.

(2) Equipment monitoring: The equipment monitoring interface shows the operational signals of the equipment transferred by the controllers, which are dynamically updated, and allows the managers to remotely forcibly start or stop the equipment to prevent undesirable situations (e.g., the equipment idles when not needed or is out of operation when needed).

(3) Anomaly data: This section of the monitoring interface shows the operational conditions of the equipment. It alerts the managers when the equipment is overloaded or tripped so that they can check the conditions of the equipment on site.

3. Results and discussion

The application of the designed WSN to the Rong Lake Wastewater Treatment Plant began with a field survey, which was conducted in March. The locations and number of mounting points were determined, the material cost was estimated, and the material was purchased in April and May. The WSN was installed and tested in June. The system officially went online in July and started acquiring data, including the on-site water levels and operational conditions of the equipment in the Rong Lake Wastewater Treatment Plant.

3.1 Water level monitoring

Water levels were monitored to understand the changes in the water level in each tank. Based on the data, the water in the sludge and wastewater collection tank rose to an excessively high level on one day in August. At 8:00 am on that day, the researchers received an alert of an excessively high water level in the sludge and wastewater collection tank in the form of a mobile phone text message. However, because they were not authorized to remotely start the pump unit, the researchers waited until 8:30 am to telephone the on-site operators to inform them of the anomaly. The operators subsequently eliminated the potential situation that might have caused flooding. The water in all of the other tanks remained at moderate levels, and no anomaly occurred within the months of the study.

3.2 Equipment monitoring

The equipment monitoring data acquired between mid-July and the time when the observation ended show that during this period, the homogenizing tank, the oxidation ditch and the final sedimentation tank all ran normally; the oil and grease removal tank, filter tank, disinfection tank, dehydrator and gravity thickening tank for sludge were ineffective at executing their functions; and the trash racks, effluent pressurization station, sludge storage tank and sludge and wastewater collection tank were occasionally active.

3.3 Operational conditions of the wastewater treatment plant

Based on the monitoring data, some of the units (including the desilting and oil and grease removal tank, the filter tank, the disinfection tank, the gravity thickening tank for sludge and the dehydrator) in the Rong Lake Wastewater Treatment Plant failed to run normally and ceased operation during the observation period.

Fig. 8 shows the actual wastewater treatment process in the plant based on the monitoring data.

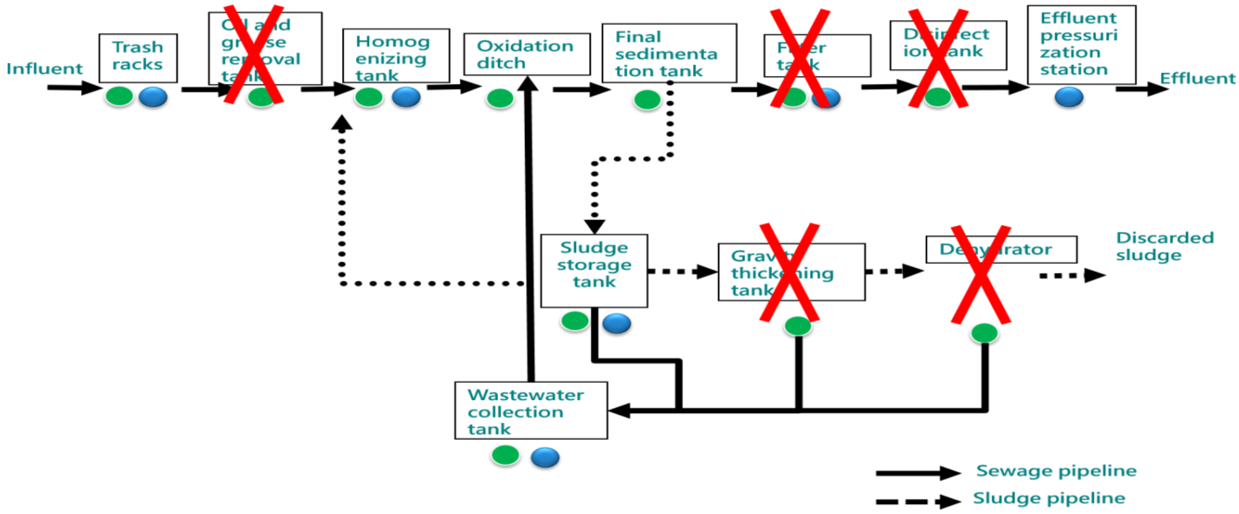


Fig. 8 Flowchart of the actual wastewater treatment process in the plant in this study

With the application of the WSN, the remote managers were able to monitor the operational conditions of the wastewater treatment plant. Due to the difference between the actual capacity and the designed capacity, some of the tanks and units in the Rong Lake Wastewater Treatment Plant were out of service. The operational conditions of this plant were found to have deviated from the original design. The following hidden problems were found in this study: 1. The desilting and oil and grease removal tank was out of operation. However, because the oil and grease content of the effluent is not explicitly listed as a test item in the relevant regulations, the oil and grease contained in the effluent may affect the receiving waters. 2. The sludge thickener and dehydrator were also out of operation. Unless there is a substitute method for treating sludge, its high water content will increase the treatment cost and impact the environment. From another perspective, although the Rong Lake Wastewater Treatment Plant was not operated based on the designed plan, its effluent still met the relevant standards. This may be because the actual volume of wastewater is lower than the design capacity; consequently, a simpler wastewater treatment process is sufficient. However, a potential problem may arise from this situation. In the future, the policy will be changed to allow more wastewater to be discharged into the sewer system, which may contain large amounts of domestic wastewater. Will the Rong Lake Wastewater Treatment Plant still have the capacity to treat this increased wastewater as effectively as intended?

4. Conclusions

Based on excellent results of the test run, the designed WSN system was installed in the Rong Lake Wastewater Treatment Plant in Kinmen to monitor the operational conditions of each unit for three months. The results showed that the system was capable of displaying data about the water levels and the operational conditions of the equipment in real time and enabled us to understand and further analyze the operational conditions of the plant. The expected goals and performance requirements were met, and the system was found to be effective.

The following work will be carried out next year:

1. Water level monitoring system for the Jincheng Wastewater Treatment Plant

   Based on the experience and results obtained from this study, a water level monitoring system will be installed in the Jincheng Wastewater Treatment Plant, which is the largest wastewater treatment plant in Kinmen that treats domestic wastewater. The changes in the water levels and the operational conditions of the equipment will be monitored remotely to determine the optimal operational parameters and mode.

2. Water quality monitoring system for the Jincheng Wastewater Treatment Plant

   The application of WSNs will be extended. In addition to water level monitoring, a WSN will also be used to acquire water quality data from each treatment unit by installing and connecting sensors, controllers and data processing modules.

References

1. Bogena, H. R., Huisman, J. A., Oberdörster, C., & Vereecken, H. (2007). Evaluation of a low-cost soil water content sensor for wireless network applications. Journal of Hydrology, 344(1), 32–42.
2. Capella, J. V., Bonastre, A., Ors, R., & Peris, M. (2013). In line river monitoring of nitrate concentration by means of a Wireless Sensor Network with energy harvesting. Sensors and Actuators B: Chemical, 177(Supplement C), 419–427.
3. Lee, M. W., Hong, S. H., Choi, H., Kim, J.-H., Lee, D. S., & Park, J. M. (2008). Real-time remote monitoring of small-scaled biological wastewater treatment plants by a multivariate statistical process control and neural network-based software sensors. Process Biochemistry, 43(10), 1107–1113.
4. Li, W.-J., Jih, Y.-J., & Yen, C. (2005). A linux embedded process visualization and control system. Journal of the Chinese Society of Mechanical Engineers, 26(6), 791–795.
5. Martin, P., Hubert, C., Lavallée, P., Pelletier, G., & Bonin, R. (2005). Global optimal real-time control of the Quebec urban drainage system. Environmental Modelling and Software, 20(4), 401–413.
6. Neal, J. C., Atkinson, P. M., & Hutton, C. W. (2012). Adaptive space–time sampling with wireless sensor nodes for flood forecasting. Journal of Hydrology, 414(Supplement C), 136–147.
7. Sempere-Payá, V.-M., & Santonja-Climent, S. (2012). Integrated sensor and management system for urban waste water networks and prevention of critical situations. Computers, Environment and Urban Systems, 36(1), 65–80.
8. Yen, C., Li, W. J., & Lin, J. C. (2003). Web-based hardware-neutral sequential controller. In IEEE international conference on robotics and automation. pp. 590–595. Taipei, Taiwan: IEEE.
9. Yue, R., & Ying, T. (2012). A novel water quality monitoring system based on solar power supply & wireless sensor network. Procedia Environmental Sciences, 12(Part A), 265–272.
10. Zia, H., Harris, N. R., Merrett, G. V., Rivers, M., & Coles, N. (2013). The impact of agricultural activities on water quality: A case for collaborative catchment-scale management using integrated wireless sensor networks. Computers and Electronics in Agriculture, 96(Supplement C), 126–138.