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Real-Time Water Quality Monitoring and Automated Disposal System for Process Industry

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Abstract:
This research study focuses on the development of a Real-Time Water Quality Monitoring and Automated Disposal System for the textile dyeing industry. The system monitors key water quality parameters pH, temperature, and Total Dissolved Solids (TDS) using IoT enabled sensors. Based on real-time sensor data, it automatically categorizes wastewater into three types reusable water, irrigation-suitable water, and chemically contaminated water. Automated solenoid valves control the flow of water to appropriate channels based on these categories. The system also features a manual mode, allowing users to manually actuate the solenoid valves as needed. Real-time data, including water quality parameters and valve operations, is displayed on the Blynk platform, enabling remote monitoring and control. Furthermore, the project explores the reuse of chemical water in cement manufacturing. This smart solution promotes sustainable water management, reduces environmental impact, and supports resource reuse within the textile dyeing and construction industries.

Keywords: pH, Turbidity, Temperature, Internet Of Things

I. Introduction
The textile dyeing industry is a crucial sub-sector within the textile industry, responsible for imparting vibrant colors and stylish designs to fabrics and textiles. This essential process requires the use of various dyes and chemicals to achieve desired colors and patterns, meeting market trends and customer expectations. However, the dyeing process generates significant volumes of wastewater, posing environmental and operational challenges. This wastewater is often colored and contains harmful dyes, chemicals, and pollutants that can negatively impact the environment if not properly managed. Traditional methods of wastewater characterization in textile dyeing industries involve randomly collecting water samples and testing them in laboratories for parameters such as pH, turbidity, TDS, and COD. This approach is time-consuming, labor-intensive, and delays timely decision-making and proper water disposal. As a result, a substantial portion of wastewater is discharged without appropriate categorization or treatment for reuse. Inefficient wastewater management contributes to high water consumption, environmental pollution, and non-compliance with regulatory standards. Consequently, there is an urgent need to adopt advanced technologies

that enhance the effectiveness of wastewater treatment and promote eco-friendly practices in the textile dyeing industry.

II. Existing Problem

In the textile dyeing industry, the production of attractive colored and patterned fabrics faces significant challenges related to wastewater management. The dyeing process generates wastewater containing dyes, chemicals, and other impurities, presenting both environmental and operational issues. Traditionally, wastewater management involves collecting samples and analyzing physical and chemical parameters like pH, turbidity, TDS, and COD in laboratories. This method is labor-intensive, time-consuming, and causes delays in decision-making and wastewater disposal. As a result, a large portion of wastewater is discharged without proper classification or treatment, leading to excessive water consumption and missed opportunities to recover valuable materials. Ineffective wastewater management not only contributes to environmental pollution due to inadequate treatment but also risks non-compliance with regulatory standards, impacting ecosystems and sustainability efforts.

III. Proposed Solution

To address the wastewater management challenges in the textile dyeing industry, this project introduces a Real-Time Water Quality Monitoring and Automated Disposal System. The system continuously tracks key water quality parameters such as pH, turbidity, and temperature through advanced sensors to ensure accurate and timely data collection. Based on control logic, wastewater is categorized into three types: Reuse Water (pH between 6.5 and 8.5, turbidity below 5 NTU), Direct Irrigation Water (pH between 6.0 and 7.5, turbidity between 5 and 10 NTU, temperature between 22-32°C), and Chemical Mixed Water (pH outside the 6.0 to 9.0 range, turbidity above 10 NTU, or temperature between 27-40°C). Solenoid valves control the discharge of wastewater into appropriate channels, optimizing system efficiency with minimal interference. The system uses IoT technology to transmit real-time data to the Blynk application, providing a graphical interface for monitoring pH, temperature, and turbidity levels remotely. A manual mode is also available, allowing users to control the valves if needed. This solution enhances wastewater treatment, promotes the reuse of treated water, and minimizes environmental harm.

IV. Hardware Description

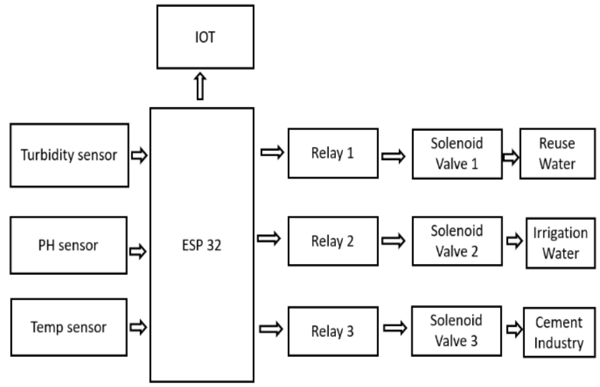

Fig.1 Block diagram

The block diagram in Fig. 1 illustrates the Water Quality Monitoring and Automated Disposal System for a textile dyeing process. Water from the dyeing process is collected in a storage tank, where sensors such as turbidity, pH, and temperature sensors continuously monitor its quality. The ESP32 microcontroller processes the sensor data to classify the water based on its quality. Depending on the sensor readings, one of three solenoid valves is triggered: Solenoid Valve 1 directs water to a recycling tank if it meets the standards for reuse, Solenoid Valve 2 sends water to an irrigation tank if it qualifies for agricultural purposes, and Solenoid Valve 3 routes chemically contaminated water to a separate storage for further treatment and transmitted to cement industry. The system also features an IoT module for remote monitoring and control via a web interface, enabling real-time data transmission and management. Visual indication is provided by LEDs that signal the active solenoid valve, giving instant feedback on the system's status. The categorized water is either stored for reuse, diverted for irrigation, or sent for treatment, optimizing water management and reducing environmental impact.

A. ESP 32

The ESP32 microcontroller serves as the central component in the Water Quality Monitoring and Automated Disposal System, performing key roles in data acquisition, decision-making, and control. It continuously collects real-time data from sensors monitoring the pH, TDS, and temperature of the wastewater. Based on these readings, the ESP32 processes the data and determines the appropriate category for the water—whether it can be reused, used for irrigation, or requires further treatment due to chemical contamination. The microcontroller then triggers the respective solenoid valves to direct the water to the correct destination. Additionally, the

ESP32 leverages its built-in Wi-Fi module to transmit data to the Blynk platform, allowing for remote monitoring and manual control if necessary. This connectivity ensures that users can view real-time water quality parameters and operate the system as needed. By automating these processes and providing a manual override feature, the ESP32 enhances the efficiency and effectiveness of the wastewater management system in the textile dyeing industry.

B. PH SENSOR

In the Water Quality Monitoring and Automated Disposal System, the pH sensor plays a crucial role in assessing the acidity or alkalinity of the wastewater. It is interfaced with the ESP32 microcontroller via the A0 pin (GPIO 34), providing an analog voltage output that corresponds to the pH level. The ESP32's analog-to-digital converter (ADC) then processes this analog signal into a digital value, which is used to determine the precise pH level of the water. This data is essential for categorizing the wastewater into three types: Reuse Water (pH between 6.5 and 8.5), Irrigation Water (pH between 6.0 and 7.5), and Chemical Mixed Water (pH outside these ranges). By integrating the pH sensor with the ESP32, the system offers real-time, continuous monitoring and automated categorization, increasing operational efficiency. The pH readings are also transmitted to the Blynk platform for remote monitoring and control.

C. TURBIDITY SENSOR

This sensor operates on the principle of light scattering by suspended matter in wastewater. The sensed voltage, which is an analog signal, is fed into the A1 pin of the ESP32. The ADC of the ESP32 takes this Analog input and converts it into a digital number for the turbidity value recording. It is important to accurately assess the turbidity level of the water to determine its cleanness, categorize it, and make a decision on its treatment or disposal. This data is necessary for making calculations about how many suspended solids are contained in liquid and controlling solenoid valves operation for controlling wastewaters. Furthermore and crucially, the turbidity readings were incorporated into the Blynk interface.

D. TEMPERATURE SENSOR (DS18B20)

In the Water Quality Monitoring and Automated Disposal System, the DS18B20 temperature sensor plays a crucial role in monitoring the heat levels of wastewater. Connected to the ESP32 microcontroller through the D4 pin, the sensor operates within a range of -55°C to 125°C with an accuracy of ±0.5°C. It communicates via the 1-Wire protocol, allowing the ESP32 to accurately receive and process the temperature data. This information is vital for categorizing wastewater, as specific temperature ranges are required for different water uses. For instance, water intended for irrigation must have a temperature between 22°C and 32°C, while chemically mixed water is classified within a range of 27°C to 40°C. The continuous monitoring of these temperature values ensures the proper treatment and disposal of wastewater, optimizing system performance.

The temperature data is also displayed in real-time on the Blynk platform, enabling remote monitoring and control of the water management process. By ensuring that the wastewater is handled under ideal temperature conditions, the DS18B20 sensor helps improve efficiency, reduce environmental pollution, and enhance wastewater management practices in the textile dyeing industry.

E. SOLENOID VALVE

Solenoid valves are integral to the automated wastewater management system, controlled by the ESP32 microcontroller through its digital outputs solenoid valve 1 connected to D16, valve 2 to D17, and valve 3 to D18. These valves are responsible for directing wastewater based on real-time sensor data related to pH, turbidity, and temperature. Depending on the water quality, the system categorizes it as reusable water, irrigation water, or chemically contaminated water needing further treatment. The ESP32 processes the sensor data and, via relays, automatically activates the appropriate solenoid valve to route the wastewater to its designated category. This automated control enhances the efficiency of the treatment process by ensuring that each type of wastewater is properly managed. Additionally, the Blynk platform provides remote monitoring and control, allowing operators to adjust the system in real-time. The manual mode offers further flexibility, enabling manual valve operation when needed. The relays play a critical role in safely switching the solenoid valves, ensuring smooth and reliable operation of the wastewater management system.

F. RELAY

Interfacing the relay with the ESP32 microcontroller allows for safe control of the solenoid valve, which operates at a higher voltage, typically 24V. Since the ESP32 outputs only 5V, the relay acts as an intermediary, enabling the low-power ESP32 to switch the solenoid valve on and off securely. The relay is connected to the ESP32 through a control pin, known as IN, which toggles the relay to open or close the circuit connected to the solenoid valve. The 5V and GND pins of the ESP32 are connected to the VCC and GND of the relay, while the common (COM) and normally open (NO) terminals of the relay are linked to the solenoid valve. When the ESP32 sends a signal via the IN pin, the relay closes the circuit, allowing current to flow and activating the solenoid valve. This setup ensures that the solenoid valve is effectively controlled by the ESP32 while also providing electrical isolation, protecting the microcontroller from the higher operating voltages required by the valve.

V. Technical Description

A. System Description

The Real-Time Water Quality Monitoring and Automated Disposal System employs ESP32-based hardware as the central processing and control unit. The system is equipped with various sensors, including a pH sensor, DS18B20 temperature sensor, and TDS sensor, to enable continuous monitoring of water quality parameters. These sensors are connected to the ESP32 via its analog and digital input pins, allowing for the collection of real-time data. Solenoid valves are used to regulate the flow of water and are controlled by a relay module connected to the ESP32's digital output pins D16, D17, and D18. The relay module functions as a switch, enabling or disabling the solenoid valves to direct the wastewater toward designated outlets for reuse, irrigation, or chemical disposal.

While the ESP32 supplies a low voltage of 3.3V, the relay module and solenoid valves operate at higher voltages, typically 24V, ensuring safe control of more powerful devices. The system also integrates the Blynk IoT platform for real-time monitoring and control, enabling remote visualization of sensor data and manual operation of solenoid valves from a user-friendly interface. This hardware configuration provides an automated, efficient, and flexible solution for managing wastewater quality in industrial processes, ensuring optimal water utilization and treatment.

B. Schematic Diagram

The schematic in Fig. 2 illustrates the detailed workings of the Real-Time Water Quality Monitoring and Automated Disposal System, which is built around the ESP32 microcontroller. Various sensors, including pH, TDS, turbidity, COD, and a float sensor, are installed in a water tank to continuously monitor the water quality. These sensors send real-time data to the ESP32, which processes the readings and controls the activation of three solenoid valves to direct the water to the appropriate storage areas based on its quality.
Solenoid Valve 1 directs reusable water into a recyclable water storage tank, Solenoid Valve 2 handles irrigation water, and Solenoid Valve 3 manages chemically contaminated water, routing it to a chemical storage area for further treatment then it is transmitted to cement industry. The IoT platform, powered by the Blynk app, enables remote monitoring and control, offering users real-time graphical data on parameters such as pH, TDS, and temperature, ensuring an efficient and automated water management system.

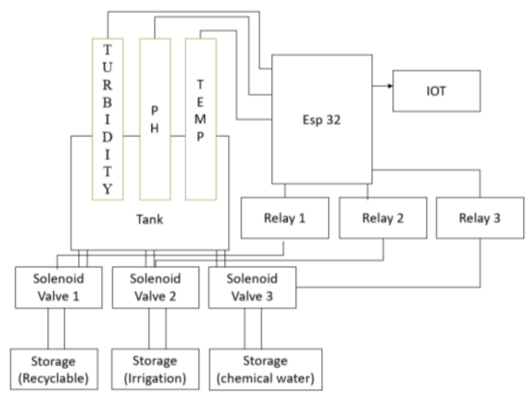

Fig.2 schematic diagram

4.1 C. Circuit Operation for Real Time Water Segregation

The electrical circuit diagram fig.3 The circuit diagram of the Real-Time Water Quality Monitoring and Automated Disposal System shows the integration of sensors, the ESP32 microcontroller, relays, solenoid valves, and an IoT platform to automate water management. The pH, TDS, turbidity, and COD sensors are placed in the water tank to measure key water quality parameters. These sensors provide data to the ESP32, which processes it to determine the appropriate categorization of water—whether it is suitable for reuse, irrigation, or needs chemical treatment.Based on the sensor readings, the ESP32 sends signals to relays connected to three solenoid valves, each controlling the flow of water to different storage tanks or treatment systems. Solenoid Valve 1 directs reusable water, Solenoid Valve 2 handles irrigation water, and Solenoid Valve 3 sends chemically contaminated water for further treatment. Relay modules act as switches to control the solenoid valves.The system is connected to the Blynk IoT platform, enabling users to remotely monitor real-time sensor data and valve statuses. The app also offers a manual mode for user-controlled valve operations. This setup allows for efficient, automated water management and disposal, based on real-time quality analysis.

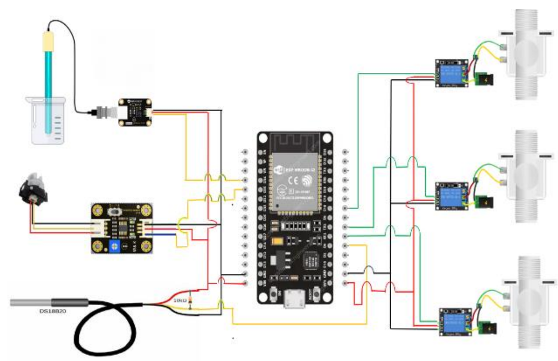

Fig.3 Electrical Circuit Diagram

D. Flow Chart Automation In Water Segregation

The flow chart fig.4 illustrates the coordination of real-time sensor data, control logic, and a manual override through the Blynk application in the operation of a wastewater management system. The process begins with input from sensors measuring pH, TDS, turbidity, and temperature of the wastewater. These sensor readings are transmitted to the ESP32 microcontroller, which is responsible for processing the information and executing control measures based on predefined operational parameters for desired water quality. All collected sensor data is sent to the Blynk application for presentation to the user, as real-time monitoring of water quality is essential for effective wastewater management. The ESP32 leverages this coarse-grained sensor data to determine the opening and closing of solenoid valves, ensuring that the consensus among sensor readings prevails in decision-making.

The system primarily operates in automatic mode, where different solenoid valves activate based on the water quality conditions. For instance, if the water is heavily polluted, a clean-out valve opens. If the water is reasonably polluted and suitable for recycling or reuse, a recycle valve is activated. Conversely, if the water is clean enough for irrigation, an irrigation valve is engaged. Additionally, the app allows users to override the automated control logic, enabling manual valve operation through the Blynk app if desired. This combination of manual and automated control enhances the system's versatility and efficiency in managing wastewater.

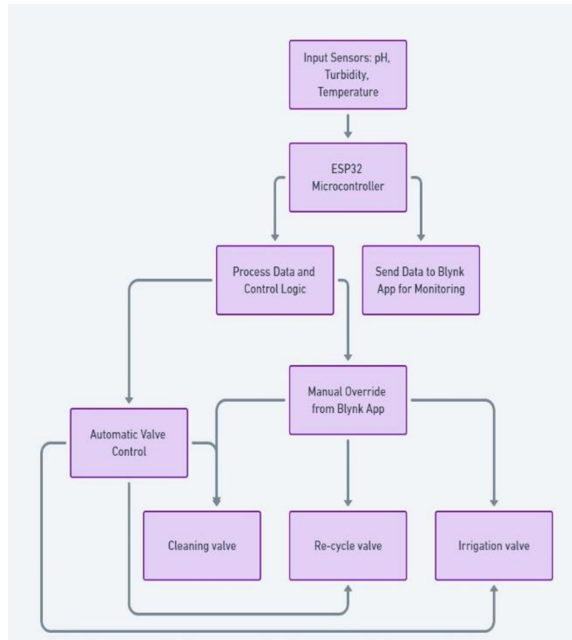

Fig.4 flow chart

VI. Results and Discussion

The table 5.1 data of water samples measured in pH, turbidity and temperature for the determination of the valve condition for water categorization is given in this table. The water is then categorized into three categories by the system, defined by concentration ranges such as reuse, irrigation and a receipt of chemical treatment. Water samples of pH 6.5–8.5 and below 5 NTU turbidity (S1, S3, S6) were suitable for reuse due to the optimal tolerance range. The samples which have seen a pH level from 6.0 to 7.5 and turbidity between 5-10 NTU were considered satisfactory for irrigation use, included Sample No. Turbidity values in samples 4,5,7 and 9 are beyond the spec limits as is pH, since they do not meet a set of criteria for discharge without chemical treatment. This data demonstrate how sensor-driven automation can help to provide real time water management and improved classification in the process industry.

Table 5.1. Different samples of water from dyeing industry is Recorded

No of Samples	PH	Turbidity	Temperature	Valve Condition
1	7.2	4.3	28	Reuse
2	6.8	7.5	30	Irrigation
3	7.4	3.2	26	Reuse
4	8.2	10.2	34	Chemical
5	8.8	12.5	33	Chemical
6	7.7	1.3	29	Reuse
7	8.4	13.5	35	Chemical
8	7.4	8.6	27	Irrigation
9	9	14.2	32	Chemical

DESIGN OF BLYNK :

The Blynk development for the project, illustrated in Fig 5, establishes a real-time interface for effectively monitoring and controlling the wastewater quality management system. This interface dynamically displays critical sensor data, including pH, turbidity, and temperature, providing users with live insights into current water quality conditions. Additionally, the Blynk app features control buttons (switches) for operating various solenoid valves responsible for managing water disposal. These valves include an agricultural valve for directing water suitable for irrigation, a cleaning valve for handling water that requires immediate removal from the system, and a treatment valve for managing water needing further chemical treatment. Each valve can be manually toggled on or off through its corresponding switch, allowing users direct control over the system.

The Blynk platform supports both automatic and manual control options. When the system detects unsafe pH, turbidity, or temperature levels, the valves automatically activate based on predefined thresholds, enhancing the efficiency of wastewater management by ensuring timely responses to changing water quality conditions. However, users retain the flexibility to override this automatic mode and manually operate the valves as needed, allowing for personalized decision-making in various situations. Furthermore, the interface continuously displays the operational status of the system, indicating whether the switches are on or off, and logs data for future reference. This functionality streamlines the management of the wastewater treatment process, reducing the need for manual intervention while enhancing operational accuracy through remote access and real-time feedback. Overall, the integration of the Blynk app ensures a comprehensive and user-friendly approach to wastewater quality management.

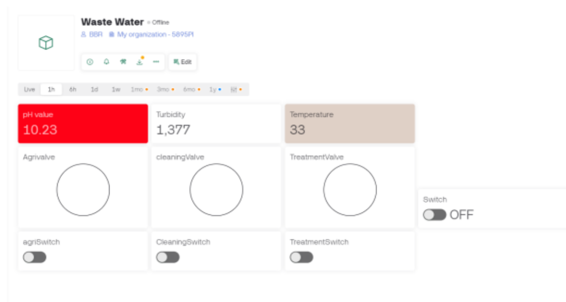

Fig.5 Blynk dash board

VII. Conclusion

In conclusion, the proposed Real-Time Water Quality Monitoring and Automated Disposal System presents a comprehensive solution to the pressing challenges of wastewater management within the textile dyeing industry. By leveraging IoT-enabled sensors for pH, temperature, and turbidity, the system accurately classifies wastewater into three categories: reusable, suitable for irrigation, or requiring chemical treatment. The integration of automated solenoid valves facilitates efficient water disposal with minimal human intervention, while the Blynk platform enhances user experience through real-time data visualization and remote control options.The inclusion of a manual mode empowers users to customize operations according to specific requirements, ensuring flexibility in managing diverse wastewater conditions. Overall, this project not only improves water management practices but also promotes sustainability and minimizes environmental impact associated with textile dyeing processes.

VIII. Future Scope

The future scope of the Real-Time Water Quality Monitoring and Automated Disposal System includes several enhancements aimed at improving its efficiency and expanding its applications. Integrating advanced sensors for dissolved oxygen, conductivity, and ammonia will enable a more comprehensive evaluation of water quality. Additionally, implementing machine learning algorithms will enhance predictive capabilities, allowing for proactive responses to water quality fluctuations. Introducing automated chemical dosing systems based on real-time sensor data will optimize the treatment of chemically contaminated water. Developing a dedicated mobile application will facilitate easier remote monitoring and provide real-time notifications about water quality conditions. Collaborating with local environmental agencies for data sharing can support broader water management initiatives. Furthermore, the system's design can be adapted for use in sectors like food processing and pharmaceuticals, which face similar wastewater challenges. Incorporating automated reporting features will help industries efficiently meet regulatory requirements, while exploring resource recovery methods such as nutrient extraction or waste-to-energy conversion will promote sustainability.

IX. References

[1] Alnouri, S.Y., Linke, P., El-Halwagi, M., 2015. A synthesis approach for industrial city water reuse networks considering central and distributed treatment systems. J. Clean. Prod. 89, 231–250.
[2] Chen, C.L., Hung, S.W., Lee, J.Y., 2010. Design of inter-plant water network with central and decentralized water mains. Comput. Chem. Eng. 34, 1522–1531.
[3] Ramos, M.A., Boix, M., Aussel, D., Montastruc, L., 2016. Water integration in eco- industrialparks using a multi-leader-follower approach. Comput. Chem. Eng. 87, 190–20
[4] Taskhiri, M.S., Tan, R.R., Chiu, A.S.F., 2011. Emergy-based fuzzy optimization ap- proach for water reuse in an eco-industrial park. Resour. Conserv. Recycl. 55, 730–737.
[5] K. S. Adu-Manu, C. Tapparello, W. Heinzelman, F. A. Katsriku, and J.-D. Abdulai, "Water quality monitoring using wireless sensor networks: Current trends and future research directions," ACM Transactions on Sensor Networks (TOSN), vol. 13, p. 4, 2017.
[6] H. R. Maier and G. C. Dandy, "The use of artificial neural networks for the prediction of water quality parameters," Water resources Research, vol. 32, pp. 1013-1022, 1996.
[7] M. Z. Abedin, A. S. Chowdhury, M. S. Hossain, K. Andersson, and R. Karim, "An Interoperable IP based WSN for Smart Irrigation Systems", presented at the 14th Annual IEEE Consumer Communications & Networking Conference, Las Vegas, 8-11 January 2017, 2017.
[8] H. R. Maier and G. C. Dandy, "The use of artificial neural networks for the prediction of water quality parameters," Water resources Research, vol. 32, pp. 1013-1022, 1996.
[9] B. Paul, "Sensor based water quality monitoring system," BRAC University, 2018
[10] SubhasiniDwivedi, Michael Fernandes, RohitD'souza, “A Review on PLC based Automatic Waste Segregator”, IJARCET, Volume 5, Issue 2, February 2016.
[11] Angulo, C., Cabestany, J., Rodríguez, P., Batlle, M., González, A., de Campos, S., 2012. Fuzzy ex pert system for the detection of episodes of poor water quality through continuous mea surement. Expert Syst. Appl. 39, 1011–1020
[12] Behmel, S., Damour, M., Ludwig, R., Rodriguez, M., 2016. Water quality monitoring strat egies- a review and future perspectives. Sci. Total Environ. 571, 1312–1329.
[13] Blaen, P.J., Khamis, K., Lloyd, C.E.M., Bradles, C., Hannah, D., Krause, S., 2016. Real-time monitoring of nutrients and dissolved organic matter in rivers. Sci. Total Environ. 569–570, 647–660.
[14] Boënne, W., Desmet, N., Van Looya, S., Seuntjens, P., 2014. Use of online water quality monitoring for assessing the effects of WWTP overflows in rivers. Environ. Sci.: Pro cesses Impacts 16, 1510–1518.
[15] Cassidy, R., Jordan,P., 2011. Limitationsof instantaneouswaterqualitysamplinginsurface water catchments: comparison with near-continuous phosphorus time-series data. J. Hydrol. 405 (1), 182–193.
[16] Fu, G., Butler, D., 2012. Frequency analysis of river water quality using integrated urban wastewater models. Water Sci. Technol. 65 (12), 2112–2117.
[17] Glasgow, H.B., Burkholder, J.M., Reed, R.E., Lewitus, A.J., Kleinman, J.E., 2004. Real-time re mote monitoring of water quality: a review of current applications, and advance ments in sensor, telemetry, and computing technologies. J. Exp. Mar. Biol. Ecol. 300, 409–448.
[18] Jiang, P., Xia, H., He, Z., Wang, Z., 2009. Design of a water environment monitoring system based on Wireless Sensor Networks. Sensors 9, 6411–6434.
[19] Mellander, P.-E., Melland, A.R., Jordan, P., Wall, D.P., Murphy, P.N.C., Shortle, G., 2012. Quantifying nutrient transfer pathways in agricultural catchments using high tempo ral resolution data. Environ Sci Policy 24, 44–57.
[20] Donge He, Li-Xin Zhang, “The Water Quality Monitoring System based on Wireless Sensor Network” Report: Mechanical and Electronic Information Institute, China University of Geo- Science, Wu Hen, China, 2012