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Integrated Telemetry Platform for Measuring and Transmitting Physical, Chemical, Biological and Other Water Parameters in Rivers

Sasko Milev
Faculty of Mechanical Engineering, GoceDelcev University, Stip, North Macedonia,
Krste Misirkov10A, 2000, Stip

ABSTRACT
A platform has been developed for the measurement, transmission, and real-time data processing of various physical, chemical, biological, and other water quality parameters in river systems. The platform continuously monitors and collects data, comparing measured values against legally defined water quality standards in a unified and integrated manner. It provides real-time information to support natural resource management. Water parameters are monitored using an industrial SCADA (Supervisory Control and Data Acquisition) system. The monitoring system consists of a central station, a local station, and multiple mobile monitoring units. The operation of all instruments and equipment at the local station is coordinated through programmable logic controllers (PLCs). Data collected from the local and mobile stations are transmitted to the central monitoring station. This paper presents a selection of measurement results and draws conclusions regarding the advantages and limitations of this integrated monitoring approach.
Keywords: *Integrated telemetry platform, SCADA operating software, PLC automatic system, water quality control*

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I. INTRODUCTION

One of humanity's primary objectives in ensuring quality and healthy living conditions is the preservation of a clean and sustainable environment. A key component of this goal is the provision of high-quality water suitable for various applications and processes. Depending on its intended use, water must meet specific chemical, physical, and biological criteria. In the case of drinking water, parameters such as toxicity and purity are especially critical. Globally, approximately 20% of river water is utilized by humans, with usage in some regions reaching up to 95% of available freshwater resources.

In today's context of rapid urbanization and industrial development—particularly in the chemical, petrochemical, metallurgical, and nuclear sectors—the task of maintaining clean and healthy river water has become increasingly complex. Major sources of water pollution include municipal wastewater, agricultural runoff (often containing pesticides and fertilizers), waste from livestock farms near rivers, landfill leachates, and thermal discharges from power plants. Nuclear facilities also pose a potential risk of radioactive contamination.

SCADA (Supervisory Control and Data Acquisition) systems are computer-based control systems widely used in industrial and energy sectors. These systems collect, analyze, and process data from field equipment, enabling efficient and reliable plant operation. A typical SCADA system includes a central monitoring station, communication infrastructure, a human-machine interface (HMI), programmable logic controllers (PLCs), remote terminal units (RTUs), and field instruments. PLCs are commonly programmed using ladder logic. SCADA software platforms typically support secure access via user authentication (username and password). For remote measurement and monitoring, access to the system can be achieved locally (via Ethernet or LAN), directly through a central server, or remotely via the Internet [1].

A strictly hierarchical approach is implemented in the codification protocol during system operation. When an authorized user accesses the SCADA software interface, they can select and view the most recent set of transmitted measurement data, including graphical representations. The system also supports the integration and comparison of measurement data from different monitoring stations. The SCADA software is embedded within the main application platform for remote measurement and system management. This software is hosted on a server located at the Main Coordination Center [2].

II. CASE STUDY: INTEGRATED TELEMETRY PLATFORM (IN NORTH MACEDONIA)

The platform presented in this paper is designed for the measurement, transmission, and control of water quality data from the Vardar River in North Macedonia. It comprises the following components: 1. a main coordination and supervision station (located in Skopje), 2. a network of fixed remote monitoring stations, 3. group of mobile monitoring stations, 4. a fully integrated PLC-based automation system, 5. an integrated telecommunications system, 6. a remote control and security system [1].

This platform enables the measurement, analysis, calculation, estimation, and evaluation of physical, physicochemical, chemical, biochemical, and hydraulic parameters of the Vardar River. The system includes instruments capable of monitoring more than 40 water quality parameters, such as electrical conductivity, dissolved oxygen, turbidity, temperature, pH, ammonium (NH_4^+), potassium (K^+), manganese (Mn), toxicity, microbial contamination, chloride (Cl^-), chlorophyll, green algae, water level, nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), cadmium (Cd), nickel (Ni), lead (Pb), iron (Fe), and others [3],[4].

The Main Coordination and Control Center serves as the operational core of the platform. It receives all telemetry data, measurements, alarms, status signals, and system messages transmitted from both fixed and mobile monitoring stations within the monitored region. This central hub is located in Skopje.

The coordination software performs rapid diagnostics of incoming signals while maintaining data integrity and consistency. All information is codified, transferred, and stored on appropriate data storage hardware. Measurement data are saved in organized directories, with each folder representing a single day and labelled according to the corresponding date. Each event is recorded as a separate entry, including a timestamp and a detailed description of the event [5]. Structure of an industrial, automatic and fully integrated telemetry platform is shown in Figure 1.

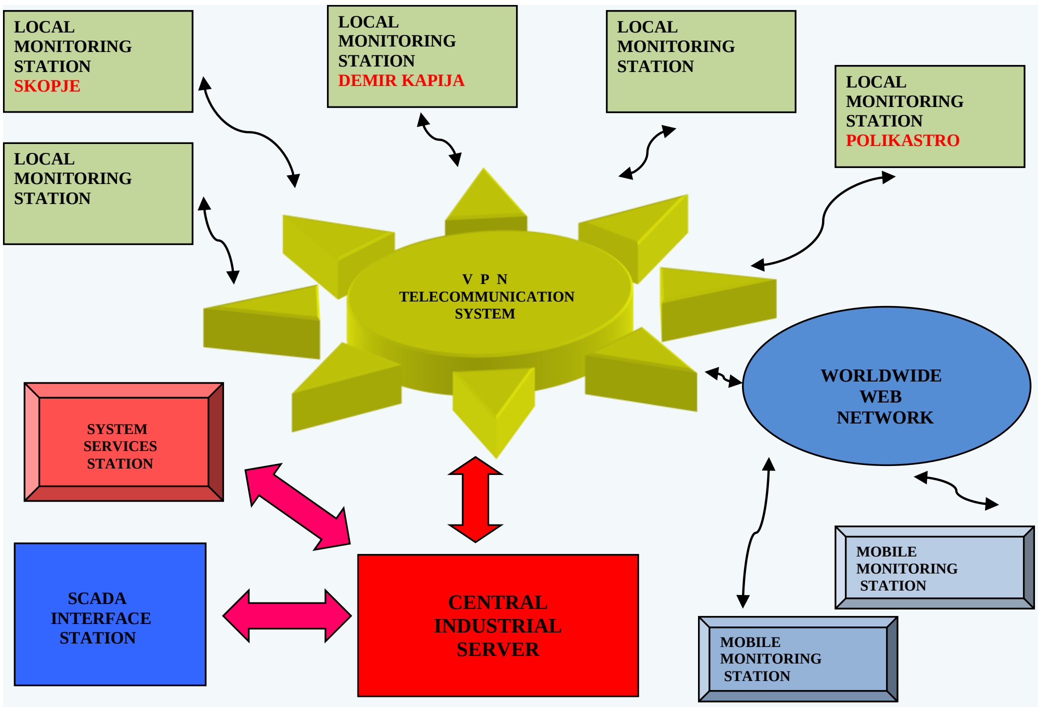

Figure 1:Structure of an industrial, automatic and fully integrated telemetry platform

The unified automatic system used in these tests provides accurate data and allows for simultaneous processing, enabling remote control of the installed elements in the field. Of particular importance is the integration of chemical, physical-chemical, and biological parameters, working together in harmony with accuracy and precision.

The SCADA operating software is embedded in the main application for remote measurement and monitoring. It processes the data collected through remote measurement and monitoring, providing key valuesand diagrams for each parameter being tested. By further processing these qualitative parameters based on the state of each corresponding natural resource, vital information is derived. The platform also provides all necessary warnings and alarms, typically in advance, allowing for the timely initiation of appropriate measures.The data obtained from measurements at local stations are transmitted via a telecommunications system to the central industrial server in Skopje.

The integrated automatic system consists of [1]:

-CPU unit
-MMC-type memory card
-Digital input modules (24V DC)
-Analog input module (for 4 to 20 mA signals)
-Digital output modules
-Communication module (for serial port communication)
-Power supply unit (24V DC)
-Measuring equipment and sensor controllers
-Electronic components
-Main electrical switch
-Accumulators (for electricity)
-Electrical equipment
-Connectors
-Wires and other types of adapters

Figure 2 illustrates the connection method and organizational structure of the PLC-based automatic system, including all analytical instruments, measuring and automation equipment, signal reception equipment, signal analysis and calibration systems, and information about the operational status. It serves as a link between the telecommunication systems and the Main Coordination Center [6].

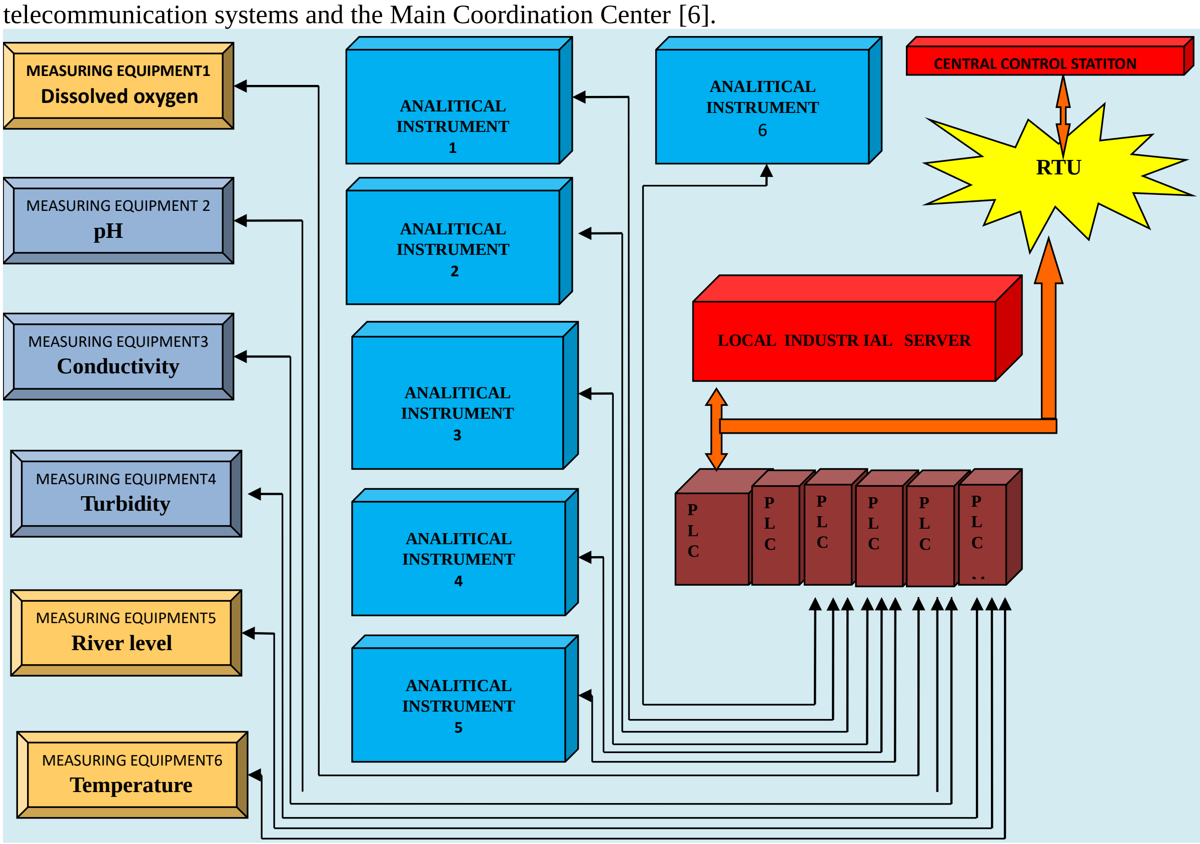

Figure 2: Organizational structure of the PLC based automatic system

2.1 Description of the permanent monitoring station [1]

The local permanent monitoring station consists of a metal structure and a steel container with approximate dimensions of 12 x 2.5 x 2.5 meters. Located outdoors in a variable climate, the station is insulated on both sides, inside and out. The container's interior is divided into two compartments. The first, measuring 3 x 2.5 x 2.5 meters, houses a 25 KVA generator and an air supply system. The second compartment, measuring 9 x 2.5 x 2.5 meters, contains the research equipment and on-line analyzers.

Temperature control systems are installed in both compartments. Access to each compartment is through entrances located on opposite sides of the container. The local remote monitoring station is equipped with an analyzer featuring an automatic spectrometer, as well as measuring instruments and equipment submerged in the river.

The entire system is managed and controlled by an industrial programmable logic controller (PLC) automatic system. The following analytical instruments, measuring instruments, and scientific equipment are used at the local station:

-Measuring equipment submerged in the Vardar River (permanent station)

- Instruments for measuring river water parameters, placed inside the local monitoring station

-Analytical instruments

- Research equipment.

The measuring equipment submerged in the river is equipped with a built-in converter for sensor signals. It is housed in a stainless steel cage, which is fully submerged in the river using a stepped vertical frame made of stainless steel. The equipment includes:

-Dissolved oxygen sensor

-Conductivity sensor

-pH sensor

-Turbidity sensor

-Reduced oxygen sensor

-Temperature sensor

-Ammonium sensor

-Potassium ion sensor.

In Figure 3 are shown submersible sensors and measuring equipment at the permanent measuring station.

Figure 3: Submersible sensors and measuring equipment at the permanent measuring station used for real-time measurements of Vardar River water parameters

Measuringequipmentinstalledatthelocalstationincludes:

-Hydrostaticpressureequipmentformeasuringriverlevel

-Dissolvedoxygenequipment

-pHmeasuringequipment

-Conductivitymeasuringequipment

-Temperaturemeasuringequipment

Analyticalinstrumentsincludeonlinesystemsformeasuringnitrates, nitrites, ammonium, phosphates, totalorganiccarbon, waterconductivity, andtoxicity.

Additionalmeasuringequipmentincludes:

-Equipmentinstalledoutsideformeasuringriverlevel

-Equipment and instrumentsforcollectingriverwatersamples

-Ambienttemperaturesensor

- Temperaturesensorinsidethemeasuringstation

Thesonarlevelmeasuringequipmentisinstalledontopofthesteppedsteelframe.

Thelocalmonitoringstationisequippedwith a programmablelogiccontroller (PLC) samplinginstrumentandhasthecapabilitytoanalyzeandmeasurevariousparameters, includingchemicaloxygendemand, chromium, cadmium, nickel, chlorine, andmanganeseconcentrations, aswellasthepresenceofgreenalgae, chlorophyllconcentration, watervelocityandmicrobialdensity.

Thesereal-timemeasurements, analyses, andevaluationsareuser-friendlyandcanbeautomaticallyactivatedbyadding a suitableinstrumentoranalyzer.

In Figure 4 are shown submersible sensors and measuring equipment at the permanent measuring station.

Figure 4: Submersible sensors and measuring equipment installed individually and in combination submerged in the Vardar River

The PLC system is housed in a 19-inch rack cabinet, along with the telecommunications system, data reader, and signal conversion equipment.It is a fully integrated automatic system that connects to all analytical instruments, measuring equipment, and automation systems. It receives measured signals, performs data analysis and calibration, provides information about system status, and issues signals and alarms. The system amplifies these signals and controls the transmission of control signals to regulate operational and functional status. It stores signals and data in its database for future use, later transmitting them to the computer-integrated logger for logging and backup purposes In Figure 5 is shown local permanent station with integrated PLC-based system.

Figure 5: Local permanent – fixed station with fully integrated industrial PLC-based system

2.2Monitoring of procedures depending on automation time

In the automation functions, three different cycle routines are executed:

- Time-dependent cycle (td-minutes) – for data transmission via VPN.
- Time-dependent cycle (tm-minutes) – for initiating a measurement procedure of the controlled analytical instruments.
- Time-dependent cycle (tc-hours) – for calibrating certain analytical instruments to maintain system accuracy.

The PLC also reads signals that indicate any issues with the measuring equipment. These signals are sent by the devices themselves through Boolean signals from their initially designated outputs. All measuring equipment must be calibrated, and alarm functions should be enabled to alert in case of incorrect measurements or if the measured values exceed permissible limits.

Local Data Reader

The primary purpose of the local data reader is to collect, temporarily store, and process data. It also stores data for security purposes, ensuring that even if data transmission fails, the measured values are not lost. The data is later transmitted to other parts of the management system.

Telecommunication System

The telecommunication system connects the PLC with the Main Server at the coordination center via VPN and the Internet. This is achieved through specific telecommunication commands executed by the telecommunication software integrated with the PLC system. These commands initiate the data transmission cycle. Simultaneously, background data recording is performed to ensure no data is lost during this cycle. This entire procedure takes approximately 10 seconds.

The telecommunications system consists of:

-PLC communication module
-Telecommunication modem
-External antenna
-Frame-holder for the external antenna
-Appropriate telecommunications software
-Connection cables and other equipment

Figure 6. Monitoring site with a permanent measuring station, installed telecommunications system, external antenna, and stainless steel equipment

Mobile Telemonitoring Stations

Mobile stations are similarly composed of modules with a unified structure for multi-parameter, fully automated telemonitoring and remote data implementation. These stations enable easy data collection, identification, sorting, and transmission.The multisensor probes used in mobile stations contain advanced probes used primarily in research centers, functioning with analytical instruments based on spectrometric principles.

Hydras 3LT Software

Hydras 3LT is the software used to connect Hydrolab probes to a personal computer. It automatically scans connected probes and recognizes previously loaded data stored in memory. Up to 32 probes can be connected simultaneously, and all data can be loaded at once.

2.3 Key Functions of Hydras 3LT Software:

System, Online Monitoring, Log Files, Parameter Setup, Calibration, Settings and Software.

System: Allows the user to set basic probe identification information. Access to all four levels of the system can be restricted with passwords for data protection.

Online Monitoring: Provides real-time data viewing, either as a time-series graph or a vertical profile graph. Up to six parameters can be displayed on one graph, and data can be exported in Excel or text format.

Log Files: Allows easy configuration of input quantities via a graphical user interface (GUI). Users can select start and end times, loading intervals, sensor warm-up times, and sort parameters. Once configured, all files are loaded at once.

Parameter Setup: Enables the arrangement of available parameters.

Calibration: Allows calibration of individual sensors, selection of calibration standards, and displays current values and temperature readings for temperature-sensitive calibrations.

Settings: Configures telecommunication settings between Hydras 3LT and the probes.

Software: Loads and sends probe software and removes software drivers.

Hydras 3LT is also used to connect Hydrolab mobile monitoring units to a personal computer. Upon starting the program, the software scans and recognizes connected probes and previously logged files stored in memory. Up to 32 sensors can be connected simultaneously, and all logged files can be loaded at once. Multiple parameters can be measured and analyzed during this process.

III. RESULTS

The measurement results are obtained in electronic form, primarily as data tables, but can also be displayed as diagrams. The following figures and tables present the data on dissolved oxygen concentrations in water.

Surface waters are classified into four categories based on dissolved oxygen levels: Class 1: Concentration greater than 8 mg/L, Class 2: Concentration greater than 6 mg/L, Class 3: Concentration greater than 4 mg/L, Class 4: Concentration greater than 3 mg/L.

By analyzing the dissolved oxygen concentration data, the following results were obtained:

From January to May 2010, the water consistently contained more than 9 mg/L of dissolved oxygen. This indicates that the water remained slightly above the boundary between the first and second categories.

Table 1: Measured values of dissolved oxygen in the period from January to May

Time	02.01	12.01	23.01	09.02	13.02	15-21. 21.02	01.03 15.03	09.05 15.05	24.05 31.05
mg./L	10.5	11.7	11.4	12.2	10.9	11-12	11-12	09-10	09-12

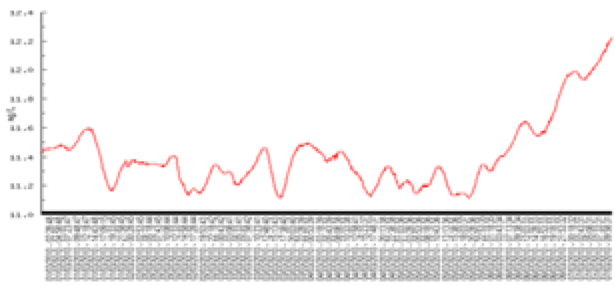

Figure 7: Change in dissolved oxygen levels from March 1st to March 7th

In December, the dissolved oxygen level in the water remained consistently above 8 mg/L. From December 1st to 5th, it ranged between 9-11 mg/L. From December 11th to 21st, it ranged between 10-12 mg/L, and from December 21st to 31st, it ranged between 9-12 mg/L.

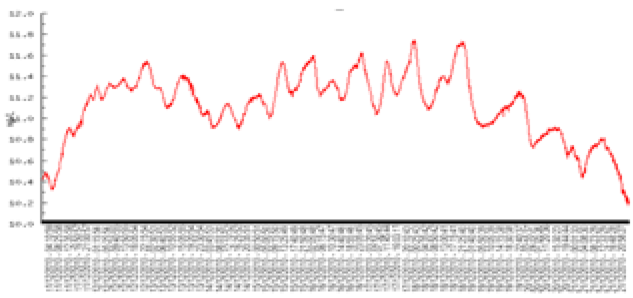

Figure 8. Measured dissolved oxygen values in water from December 11th to December 21st.

During the summer, when the river's water level is lowest, dissolved oxygen levels are significantly lower. The lowest measured value of the year, 3.2 mg/L, was recorded on September 15th.

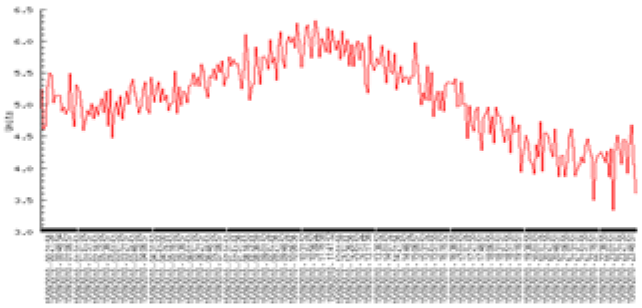

Figure 9: The lowest dissolved oxygen levelwas measured on September 15th

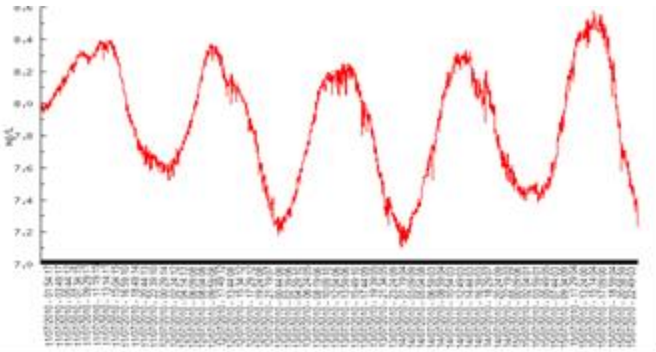

Fig.10 Cyclical changes in dissolved oxygen levels from July 11th to 15th.

This approach allows for the collection of data over both short and long periods throughout the year. The data can be presented as numerical values, or graphs can be generated based on the measured values. With the installed platform, operating software, SCADA software, and PLC system, measurements and testing of all 41 other water parameters can be conducted.

IV. DISCUSSION AND CONCLUSION

Based on the presented information, it can be concluded that the platform, as installed, offers the following advantages:

Automated, Continuous Measurements: Measurements are performed automatically and continuously at all times.

High Frequency of Measurements: The time intervals between measurements are very small, resulting in a larger volume of data for each parameter over a given time period compared to manual sampling.

Lower Error Probability: The likelihood of error during automatic measurements is significantly lower than during manual measurements.

Real-Time Data Management: Transmission, recording, and storage of measured values occur in real-time, with all data being stored in electronic form.

Ease of Data Processing: Data collected and stored directly in electronic form is more convenient for processing and analysis.

Uninterrupted Measurements: Regardless of weather conditions at the measuring point, measurements can be performed without interruption, something not possible if water samples were manually collected by a trained person.

Quick Detection of Pollution: In the event of a significant increase in a specific parameter, indicating the presence of pollutants, the system allows for quick detection and rapid response to prevent further contamination.

Simultaneous Data Collection: The platform enables the simultaneous collection of data from multiple measuring points, whether they are permanent or mobile.

Disadvantages:

Power Outage Risks: Data reading may be interrupted in the event of a prolonged power outage. However, this issue can be mitigated by using a backup power supply unit.

Equipment Lifespan and Maintenance: The installed equipment has a limited lifespan and requires regular maintenance, as well as replenishment of necessary measuring materials.

Conclusion:

The advantages of the presented platform significantly outweigh its disadvantages, making it a highly effective solution for continuous, automated water monitoring.

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