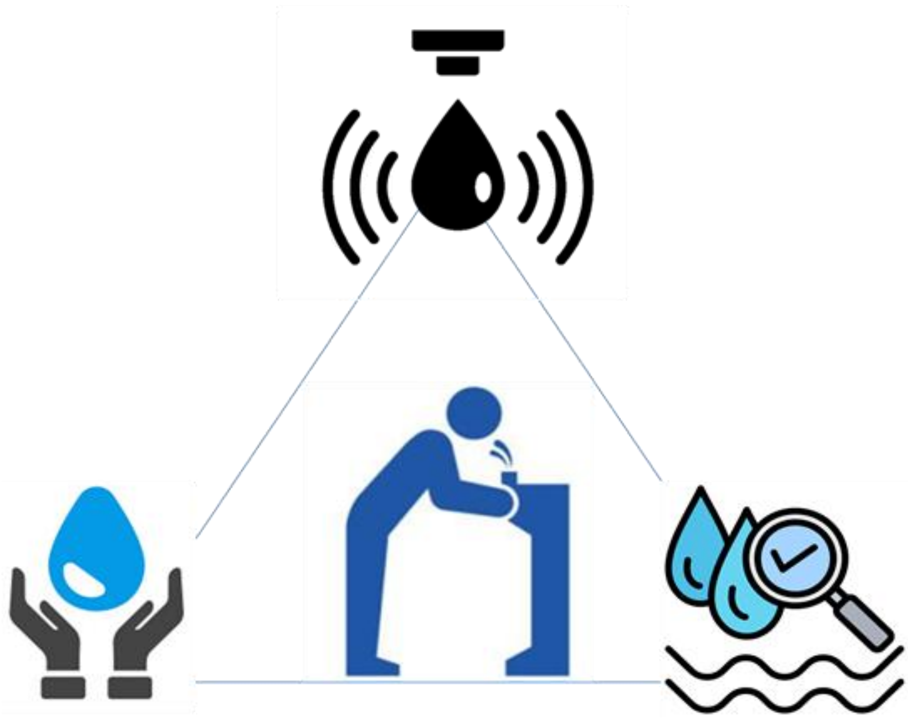
Campus Water Quality Monitoring System



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Abstract

This study employs a TDS sensor and a cloud platform to monitor the water quality of campus water dispenser in real time, aiming to enhance users' trust in drinking water safety and reduce the consumption of bottled water, thereby minimizing plastic waste. The research methodology encompasses multiple aspects, including surveys, TDS water quality testing, the development and installation of monitoring devices, and data analysis. These steps are taken to identify the key factors contributing to the low usage of campus drinking fountains while ensuring water safety and data transparency. The expected outcomes include increasing the usage rate of campus drinking fountains, reducing plastic waste, optimizing the water quality management system of drinking facilities, and assessing the feasibility of expanding this system to other locations. Ultimately, this initiative supports the achievement of Sustainable Development Goals (SDGs), contributing to environmental protection and resource management.

Introduction

Water dispensers are an indispensable part of campus life. However, when using these dispensers, one often notices an odd odor in the drinking water or finds visible impurities. This phenomenon naturally raises concerns about the safety and cleanliness of the water—so much so that some students even opt to purchase bottled water. For example, a survey conducted at Puton University in America found that the choice of drinking water can be influenced by various factors; the greatest barrier is whether people believe the water is clean, tastes good, and is easily accessible.

According to the United Nations Sustainable Development Goal (SDG) No. 6, "Clean Water and Sanitation"—specifically, the target to “achieve universal and equitable access to safe and affordable drinking water for all by 2030”—it is essential that everyone enjoys water, sanitation, and sustainable management. Furthermore, by improving SDG No. 9, “Industry, Innovation and Infrastructure,” water dispenser manufacturers can be provided with creative, innovative designs to build affordable, safe, environmentally friendly, resilient, and sustainable industrial products. In line with SDG No. 12, “Responsible Consumption and Production,” the aim is to promote a green economy and ensure sustainable consumption and production patterns so that natural resources are managed sustainably and used efficiently by 2030.

Our team hopes to contribute by proposing the installation of a water quality monitoring system for campus water dispensers. This system is designed to monitor water quality data in real time, ensuring that users have access to clean drinking water. Moreover, by establishing an online platform, users can manage all campus water dispensers through the monitoring system. The target audience is campus faculty and students, and through this project we aim to promote a healthy and safe drinking water environment.

Research Motivation

Although most people in Taiwan have a positive evaluation of the current drinking water quality, there remain many challenges in maintaining public drinking water equipment and managing water quality. Issues such as insufficient manpower, limited funding, and aging pipelines are common, causing concerns that impurities might have immediate or cumulative adverse effects on health. Trace mineral elements, while present in very small amounts in the human body, play a significant role in metabolism and overall health. Water that contains an appropriate amount of minerals—such as sodium, potassium ions, and silicates—tends to taste good; however, water with excessive residual salts like magnesium and calcium can taste unpleasant. Currently, the maximum allowable total hardness in our country's drinking water quality standards is set at 300 mg/L, primarily to address taste concerns, since overly hard water can leave an astringent and unpalatable sensation.

While there is limited comprehensive research on how water quality management affects risk perception and acceptable risk descriptions, it is clear that many factors and their combinations influence the public's acceptance of drinking water. With this in mind, we have conceived a feasible plan to establish an IoT-based water quality monitoring system. This system uses IoT technology to monitor and manage water quality in a cost-effective manner by collecting water data via sensors and instruments, integrating, analyzing, and processing the data on a cloud platform to enable remote monitoring and early warning of water quality issues.

Cross Disciplinary Collaboration Explanation

This project involves collaboration across three domains:

1. Humanities and Social Sciences

   The high school humanities and social sciences group is responsible for data collection, questionnaire design, survey distribution, and statistical analysis. Their research explores the relationship between participants' knowledge of drinking water and their drinking water behavior intentions. The process includes data collection, questionnaire development, survey administration, data processing, and result analysis.

2. Natural Sciences

   The high school natural sciences group focuses on collecting knowledge related to water purification processes, water quality assessment, Taiwan's drinking water standards, and the relationship between water hardness and human health. They also conduct campus-wide awareness campaigns to enhance students' confidence in drinking water quality. This initiative aims to promote drinking water over bottled water to reduce energy consumption and carbon emissions. Additionally, the project integrates environmental issues such as water conservation, sanitation, and climate change. Experts and scholars are invited to give lectures on Taiwan's water crisis, raising awareness of water resource sustainability and climate change challenges.

3. Information Technology

   The humanities and social sciences group collaborates with the natural sciences group to explore AI-based real-time water quality monitoring. Students learn about IoT devices, smart sensors, and communication technologies used in AI-driven water monitoring systems. Key water quality parameters, such as Total Dissolved Solids (TDS), are measured using sensors and transmitted via IoT gateways to the cloud for remote monitoring. This AIoT (Artificial Intelligence + Internet of Things) system ensures real-time and accurate water quality monitoring for all school water dispenser, enhancing water safety and increasing student trust in the drinking water system.

The goal is to provide clean and safe drinking water, encourage more students to use school drinking fountains, and reduce bottled water consumption for environmental sustainability.

Research Purposes

1. Evaluation of water quality in campus water dispenser through TDS measurement.
2. Development of an automatic water quality monitoring system to ensure drinking water safety.
3. Investigation of students' perceptions of water dispenser water quality through surveys.
4. Comparison of TDS test results with survey data to identify potential correlations.
5. Optimization of campus drinking water management to increase drinking fountain usage and promote sustainability.

Research Content

This study aims to evaluate the water quality of campus water dispensers and establish an automatic monitoring system to ensure that students and faculty have access to safe water. The research will be conducted through TDS measurement, questionnaire surveys, data analysis, and the development of a water quality monitoring device. The specific research content is as follows:

1. Campus Water Dispenser Water Quality Testing

   Measure the TDS (Total Dissolved Solids) value to determine the amount of dissolved solids in the water. A higher TDS value indicates a greater concentration of impurities, which may affect water quality and drinking safety.

2. Survey on Students’ Perceptions of Water Quality

   Design and administer a questionnaire to survey students’ subjective perceptions regarding any unusual odors from the water dispensers, thereby gauging their trust and usage habits.

3. Comparison Analysis of TDS Test Results and Questionnaire Data

   Compare the subjective feedback from students with the TDS measurements to analyze whether there is a significant correlation between them. This comparison will help confirm whether water dispensers with higher TDS values coincide with locations where students report unusual odors, thus identifying influencing factors.

4. Development and Application of a Water Quality Monitoring Device

   Design and produce a first-generation water quality monitoring device that automatically measures the TDS value, thereby detecting the impurity content in the water. The device will upload data in real time to the school website, allowing faculty and students to check water quality information at any time. Additionally, when water is dispensed, the device will display the TDS value and determine if the water quality is abnormal, alerting users accordingly.

Research Methods

School Water Fountain Quality Monitoring and Improvement Plan

1. Questionnaire Survey Method

   To understand students' subjective evaluations of water fountain quality, we will design a questionnaire asking students if they perceive any unusual odors in the water, and investigate the types and intensity of those odors; after collecting the questionnaires, we will perform statistical analysis to identify perceived water quality issues and their hotspot areas.

2. TDS Water Quality Testing Method

   To objectively measure the dissolved impurities content in the water from the water fountains, we will conduct TDS measurements at different water fountain locations throughout the campus, recording TDS values, test locations, times, and other relevant information. By comparing TDS values from different locations, we will determine if there's a correlation between the water's taste and TDS levels.

Fig. 1: Photograph of TDS measurement process.

3. Data Comparison and Analysis

   By integrating the TDS values with the results of the questionnaire survey, we will conduct a comprehensive comparison and analysis to explore the potential correlations between the two. This will allow us to identify any patterns or trends and derive possible underlying causes for the observed relationship.

4. Development and Application of an Automatic Water Quality Monitoring System

   To enhance the transparency and safety of campus drinking water, we will establish a real-time water quality monitoring system. Through TDS sensors, water quality will be monitored, with immediate alerts triggered if values exceed standards. When water is dispensed from the fountains, TDS values will be displayed in real-time, notifying faculty and students of the water quality status. All data will be simultaneously uploaded to the school website for convenient access at any time. This system is expected to increase student confidence in the water fountain quality, reduce the need to purchase bottled water, and ensure that management can promptly intervene in the event of water quality anomalies, safeguarding the drinking water safety of all faculty and students.

Results

1. Questionnaire Survey Method

(1) Survey on High School Students' Primary Factors for Using Water Dispensers and Main Drinking Methods

From Figure 2, it can be observed that students' trust in the water quality of dispensers influences their drinking habits.

Among the 162 high school students surveyed, the majority are concerned about and prioritize water quality safety. However, only 7% of students use the school water dispensers, while as many as 90% bring their own drinking water.

This suggests that most students have greater trust in the drinking water from home and have lower confidence in school water dispensers, possibly due to concerns about water quality or taste. This indicates that improving the transparency of water quality monitoring and enhancing the taste of drinking water may help increase students' trust in school water dispensers. In turn, this could reduce the use of bottled water, achieving both environmental and health benefits.

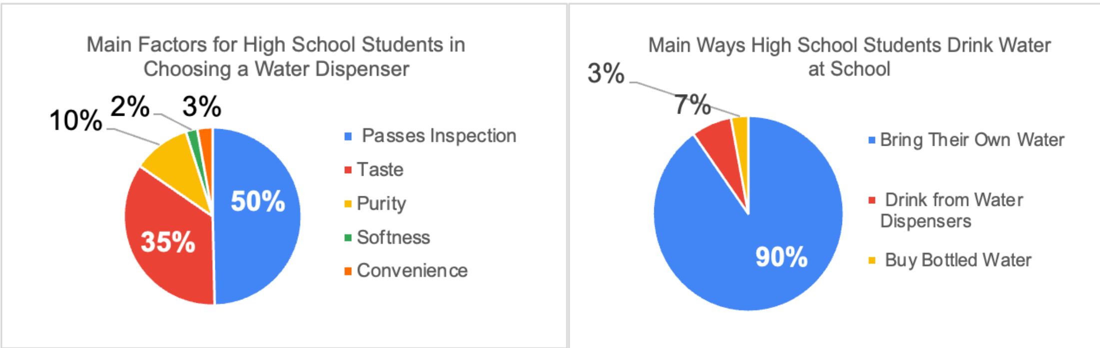


Fig. 2: Survey on High School Students' Primary Factors for Using Water Dispensers and Main Drinking Methods, Questionnaire survey

(2) Survey on University Students' Primary Factors for Using Water Dispensers and Main Drinking Methods

From Figure 3, it can be observed that among the 38 university students surveyed, meeting inspection standards and taste remain the most important factors. However, compared to high school students (7%), university students (77%) are 11 times more likely to rely on campus water dispensers. In contrast, only 4% of university students bring their own drinking water, which is significantly lower than the 90% of high school students who do so.

We speculate that the possible reasons for this difference are:

a. Differences in lifestyle habits, as using water dispensers may be more convenient.

b. University students may have greater trust in the water from dispensers or less trust in the drinking water from their homes.

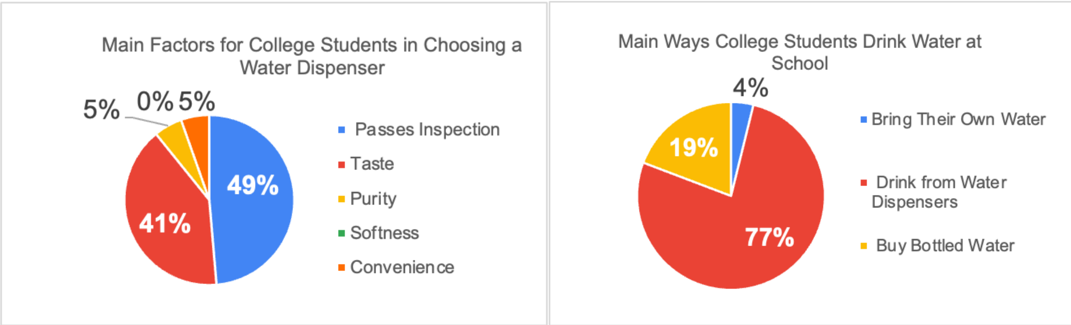


Fig. 3: Survey on University Students' Primary Factors for Using Water Dispensers and Main Drinking Methods, Questionnaire survey

(3) Comparison of High School and University Students' Views on the Good Water Label

a. Introduction to the Good Water Label:

Water dispensers with transparent and publicly accessible water quality information can receive the Good Water Label, issued by a credible organization (currently, no such label exists).

b.Integrated Analysis of High School and University Students' Views:

If there is an opportunity to implement the Good Water Label in the future, Figure 4 shows that both high school and university students have a high level of agreement that such a label could enhance confidence in the drinking water from dispensers.

Additionally, the Good Water Label would signify that the dispenser has met inspection standards. Combining the findings from Figures 2 and 3, it can be inferred

that implementing a similar labeling system may further increase students' acceptance of water dispensers and promote their usage.

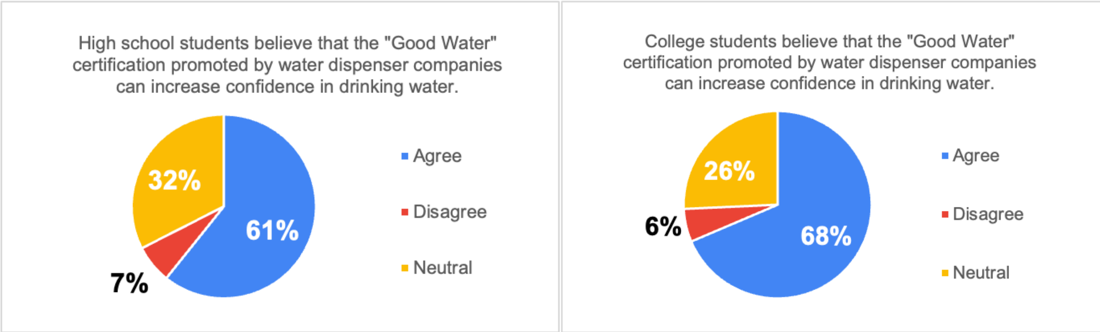


Fig.4: Comparison of High School and University Students' Views on the Good Water Label

2. TDS Water Quality Testing Method

To objectively measure the dissolved impurities content in the water from the water fountains, we will conduct TDS measurements at different water fountain locations throughout the campus, recording TDS values, test locations, times, and other relevant information. By comparing TDS values from different locations, we will determine if there's a correlation between the water's taste and TDS levels.

(1) Introduction to TDS:

Total Dissolved Solids (TDS) indicates the amount of dissolved solids in a liter of water, measured in milligrams per liter (mg/L) or parts per million (ppm).

In Taiwan, the drinking water quality standard is that TDS should be below 500 ppm per liter.

(2) TDS Change Analysis:

From Figure 5, it can be observed that the TDS values on Friday and Monday show little difference, and the overall values are very low, meeting Taiwan's drinking water quality standard. This indicates that the filtration system of the campus water dispensers is very effective.

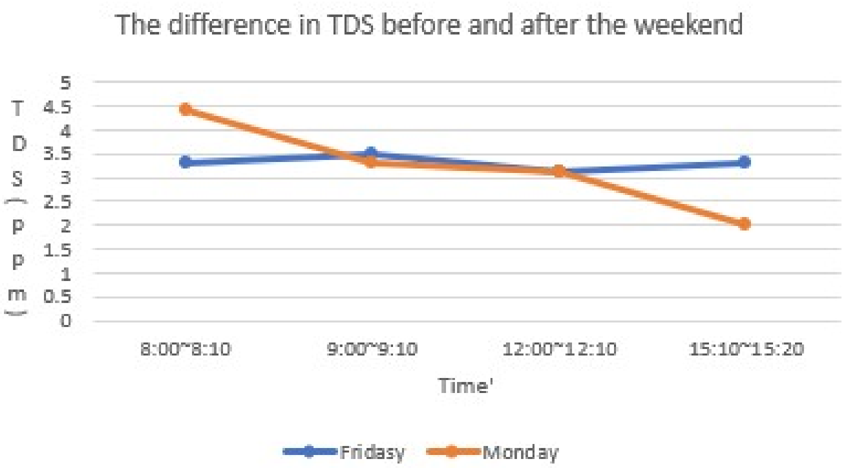


Fig.5: Changes in "TDS Value of Water Dispensers" Between the Weekend and Monday

3. Data Comparison and Analysis

Although the TDS value is low, students still do not trust the water dispensers, highlighting the importance of transparent water quality information.

From the analysis of TDS values, it can be observed that the TDS value of the water dispensers is very low, indicating that the water quality meets safety standards. However, the questionnaire survey shows that students' trust in the dispensers remains relatively low, revealing a gap between "water quality information" and "student trust." Combining the TDS data and questionnaire results, even with low TDS values, if transparent water quality monitoring information is lacking, students may still choose to buy bottled water or avoid using the dispensers. We speculate that students' distrust largely stems from the lack of water quality information or the absence of a system like the "Good Water Label" to enhance their confidence. Therefore, making water quality data public and implementing a system like the "Good Water Label" is necessary.

4. Development and Application of an Automatic Water Quality Monitoring System

To enhance the transparency and safety of campus drinking water, we will establish a real-time water quality monitoring system. Through TDS sensors, water quality will be monitored, with immediate alerts triggered if values exceed standards. When water is dispensed from the fountains, TDS values will be displayed in real-time, notifying faculty and students of the water quality status. All data will be simultaneously uploaded to the school website for convenient access at any time. This system is expected to increase student confidence in the water fountain quality, reduce the need to purchase bottled water, and ensure that management can promptly intervene in the event of water quality anomalies, safeguarding the drinking water safety of all faculty and students.

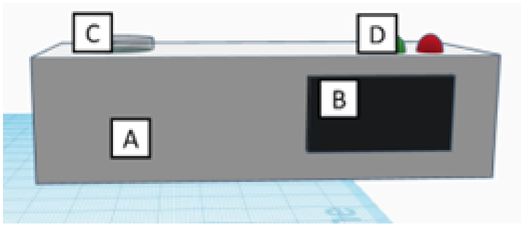
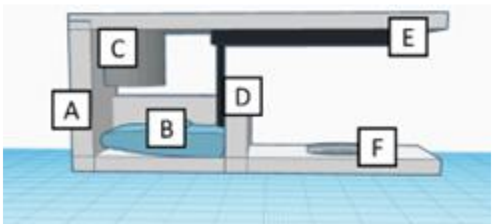
(1) Introduction to the Design of the Water Quality Testing Device

The device is developed using an ESP32 main board as its core. It primarily utilizes the Gravity TDS sensor to measure the total dissolved solids in water, and the measured data is displayed on an onboard screen. When connected to a network, the device uploads the data to a backend database and sharing platform for further academic research.

To simplify usage, the device employs an automatic control method along with corresponding indicator lights. It operates in two modes: offline mode and network transmission mode. Upon powering on, the device enters AP Mode, allowing the user to input local Wi-Fi credentials (during which the red indicator light flashes continuously). Once connected, it switches to “network transmission mode” (the indicator light turns green), performs the first measurement, displays the data and current mode on the screen, and transmits the data to the database. If the network connection fails or no action is taken, the device will automatically switch to offline mode after three minutes, in which the measured data is only displayed on the screen without any transmission.

Below is a table describing the device's design diagrams. The enclosure is 3D-printed to protect the circuitry from liquid exposure and potential malfunctions. Inside the enclosure is a small reservoir for collecting the incoming solution; this reservoir can be replaced when new liquid flows in to ensure that only fresh liquid is measured.

Table 1: Design Diagram of the Water Quality Testing Device

name	Illustration	Description	
Device Appearance Diagram		A	3D-printed enclosure
		B	Display screen
		C	Inlet
		D	Indicator LED
Device Analysis Diagram		A	3D-printed enclosure
		B	Containing the measured solution
		C	Inlet
		D	TDS sensor
		E	ESP32 main board
		F	Outlet

Discussion

1.Water Quality Testing Scope and Technical Challenges

This study primarily uses TDS (Total Dissolved Solids) to assess water quality, but other factors affecting water quality include chemical, physical, and biological indicators such as pH levels, conductivity, and microorganisms. Due to limitations in experimental equipment and operational difficulty, we have not yet been able to comprehensively test these values. In the future, we hope to improve the automation and accuracy of data by seeking more suitable sensors, such as multifunctional water quality monitoring instruments.

2.Funding and Platform Maintenance Issues

The cost of the device itself is relatively low, and if applied in campuses, it could be supported by school funding. However, establishing an online water quality monitoring platform would require additional funding, including costs for server setup, data storage, and platform maintenance. Therefore, to expand the scope, external sponsorships, government subsidies, or corporate partnerships may be needed to ensure the long-term operation and maintenance of the system.

3. Future Development Directions

In the future, water quality monitoring technology can be further optimized to expand the scope of monitoring. Additionally, we aim to integrate AI data analysis to predict water quality changes. Furthermore, if we can successfully integrate an LED light indicator system, it could further increase users' trust in drinking water safety and be promoted to more public areas, thus advancing the SDGs (Sustainable Development Goals).

Conclusion

This study used TDS sensors and surveys to analyze the water quality of campus drinking fountains and students' trust in them. The findings show that although TDS levels meet safety standards, most students still prefer to bring their own drinking water, indicating a lack of trust. This distrust is likely due to the lack of transparent water quality information and the absence of a certification system, such as a "Good Water Label."

To increase the use of drinking fountains and reduce bottled water consumption, this study suggests establishing a real-time water quality monitoring and information-sharing system. By making water quality data accessible and introducing a certification system, students' confidence in drinking fountains may improve. In the future, water quality monitoring technology can be further enhanced, the monitoring scope expanded, and AI data analysis integrated to support sustainable development goals (SDGs).

Appendices

1.the following table shows the production cost of the Water Quality Testing Device:

Based on the above, a single device costs approximately 615 NTD. Compared to commercial water quality testing equipment available on the market, this device is much more affordable. Furthermore, the components are readily available, making it highly feasible for DIY teaching and practical applications.

Table 2: Materials and Cost for the Water Quality Testing Device

Material Name	Function Description	Required Price (NTD)
ESP32 Development Board	Main control core for data processing and transmission	165
TDS Sensor	Measures total dissolved solids (TDS) in water	220
2C OLED Display	Displays device information and TDS values	70
Wiring Components	Hardware connections	10
Power Supply Module	Provides power to the device	50
3D Printed Enclosure	Protects the device and improves aesthetics	100

2.Real-Time Water Resource Sharing Platform

Using the values collected from various “Water Quality Testing Devices” installed at different locations, IoT technology is used to share the data to establish this platform. The platform aims to promote transparent management and sharing of water resources. It collects real-time water quality data (such as TDS values) from multiple measurement stations and presents the information to users via a visual map interface.

Whether you are a community resident, a student, or a water resource manager, you can access the water quality conditions at various locations at any time.

The platform consists of three parts: the measurement station, the backend database, and the front-end display. At the measurement station, the "Water Quality Testing Device" (when connected to Wi-Fi) transmits each measurement to the backend server. The backend database is built using MySQL; once the device obtains the data, it sends the information here, and any user can retrieve the water quality data from the platform. The front-end is a web platform designed to graphically display the water quality data of each measurement station. The diagram below shows the overall system architecture.

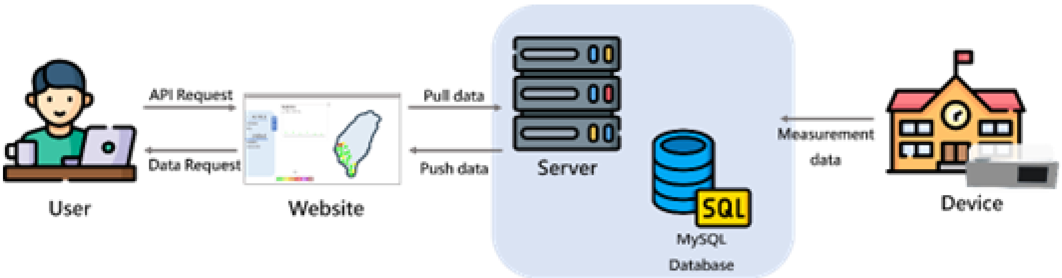


Fig.6: Overall System Platform Architecture Diagram

The web interface is designed using React for the front end and Python Flask for backend processing of user information. The following table shows the initial design of the web interface.

Table 3: Web Interface Design Diagram

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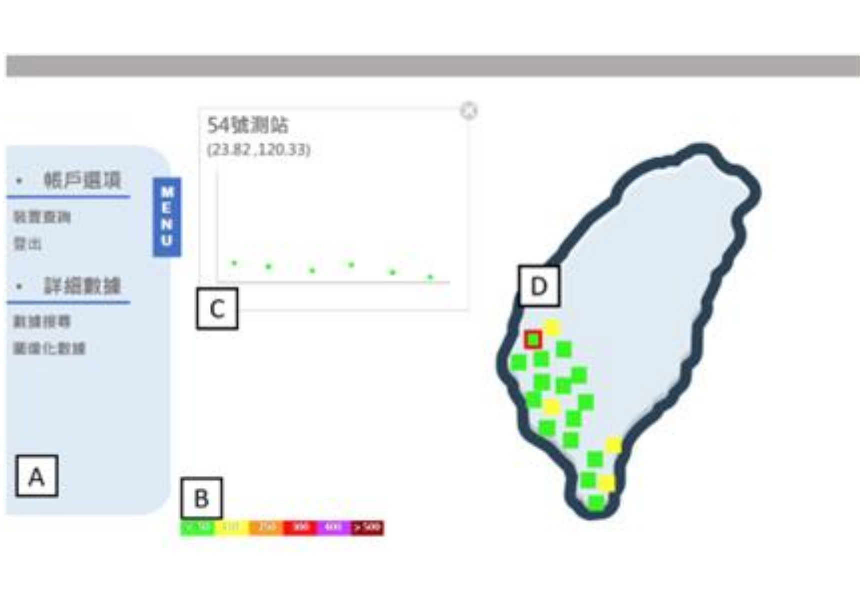
<tr><th>Illustration</th><th colspan="2">Description</th></tr>
<tr><td rowspan="4">
</td><td>A</td><td>User operation menu</td></tr>
<tr><td>B</td><td>Water quality alert bar</td></tr>
<tr><td>C</td><td>Detailed information of a single measurement station</td></tr>
<tr><td>D</td><td>Distribution and values of all measurement stations in Taiwan</td></tr>
</table>

References

Wu-Qizhi (2021). A Study on Drinking Water Behavior Intentions and Related Factors Among Students at a National University in Taipei. Master's Program in Health Promotion and Hygiene Education for In-service Teachers, National Taiwan Normal University, Taipei.

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