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Smart Water Sampler Buoy for Investigating Water Quality for Composite Sampling

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Abstract
This research aims to design and develop a “smart water sampling buoy for water quality monitoring for mixed sampling” to solve the problem of the difficulty and high cost of manual mixed water sampling. The buoy consists of a cylindrical container with a screw-on lid, a battery, a water pump, an internet transmitter, and an intelligent switch that can control both manual and preset sampling. The water sample is collected in a 2-liter bottle. This research has designed and built a water sampling buoy, developed and installed an intelligent control system, and tested the performance of the buoy in real environments, both in swamps and flowing canals. The test results showed that the constructed buoy could work well. The buoy maintained its stability under moderate water currents, and the smart control system functioned reliably according to the preset schedule. This smart water sampling buoy is expected to improve the efficiency and accuracy of water quality monitoring, reduce operating costs, and promote access to water quality monitoring technology for a wide range of users.

Keywords: Water sampler buoy, Water quality, Composite sampling

1. Introduction

Water quality monitoring is an important step in assessing and managing water resources, as well as protecting the environment and public health. Accurate and efficient water sampling is the foundation of the water quality monitoring process, especially composite sampling, which involves collecting multiple samples over a period of time to obtain a sample that is representative of the water conditions at that time (APHA, 2017). However, manual composite sampling can be time-consuming and expensive, and human error can affect the accuracy of the analytical results.

To solve this problem, automated water sampling technology has received significant attention in recent years (Kim et al., 2010; Madhavireddy & Koteswarrao, 2018; Sauter et al., 2005). Automatic water samplers can reduce the time and cost of sample collection, increase the frequency of sample collection, and reduce human error. However, commercially available automated water samplers are often expensive and may not be suitable for various environments or purposes.

Water samples from household buildings or other sources are generally collected using one of three methods: grab sampling, integrated sampling, or composite sampling. Composite water sampling is the collection of multiple samples at the same time by setting the collection time with consistent frequency. The amount of collection is appropriate depending on the wastewater flow rate. Then pour them together in a container with a temperature controlled at approximately 10 degrees Celsius and then divide the samples for storage for further analysis (APHA, 2017).

This mixed sampling method will cost less for chemicals and sample collection equipment, but take a long time to collect samples. Therefore, this project focuses on developing "Smart Water Sample Buoys for Water Quality Monitoring for Mixed Sampling", which are affordable and easy-to-use devices for automatic mixed water sampling. This buoy will help increase the efficiency and accuracy of water quality inspection, reduce operating costs, and promote access to water quality inspection technology for a wide range of users.

While several automated water samplers have been developed, most of them are commercially manufactured with high costs, complex installation requirements, and limited adaptability in remote or low-resource settings (Kelechi et al., 2021; Tedjojuwono & Jahja, 2024). In contrast, the smart water sampling buoy proposed in this study emphasizes low-cost construction using locally available components, simple deployment mechanisms suitable for shallow or narrow water bodies, and remote control functionality via smartphone applications (Kamaludin & Ismail, 2017; Spandana & Rao, 2018). These features offer a practical and scalable alternative, especially for community-based or small-scale environmental monitoring initiatives.

In addition, this project has the potential to reduce the import of foreign technologies and promote the development of domestic technologies against established safety thresholds. By understanding the level of contamination and associated health risks, the study also proposes practical strategies for community-based interventions and knowledge management to mitigate these risks.

2. Methodology

This section details the methodological approach employed in the design, development, testing, and evaluation of the smart water sampler buoy.

2.1 Design and construction of the smart water sampler buoy

2.1.1 Structural design

The buoy's structural design was meticulously planned to ensure optimal functionality and durability. A cylindrical tank configuration was chosen for its stability and ease of construction. The dimensions of the tank, 60 cm in height and 30 cm in diameter, were determined based on the required storage capacity for the battery, pump, and other internal components, while also considering buoyancy and ease of deployment. The buoy body is constructed from a cylindrical HDPE tank with a screw-on lid. An inlet pipe passes through the side wall and connects to a submersible pump attached at the lower end, as illustrated in Figure 1.

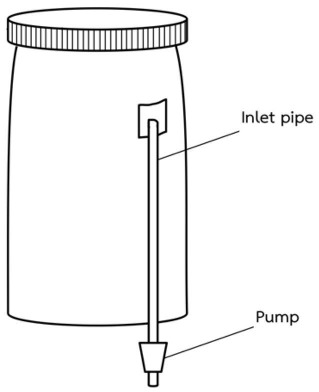


Figure 1. External view of the smart water sampling buoy showing the inlet pipe and pump configuration.

2.1.2 Equipment installation

The internal components of the buoy, including the battery, water pump, internet transmitter and smart switch (Sonoff Basic R2), are arranged strategically to optimize weight distribution and protect critical components from environmental stress. Figure 2 illustrates the internal layout of the buoy in a top-view schematic. The system uses a 12V 4Ah sealed lead-acid (SLA) battery to provide power for up to one week under normal operating conditions. The battery and water tank are firmly installed near the center of the tank. At the base of the tank, concrete (1/3 of the height) is poured to lower the center of gravity and increase stability. The water pump and related pipes are placed near the top of the tank for easy access for maintenance and cleaning. The internet transmitter and smart switch are packed in a waterproof box to prevent moisture and to ensure reliable operation.

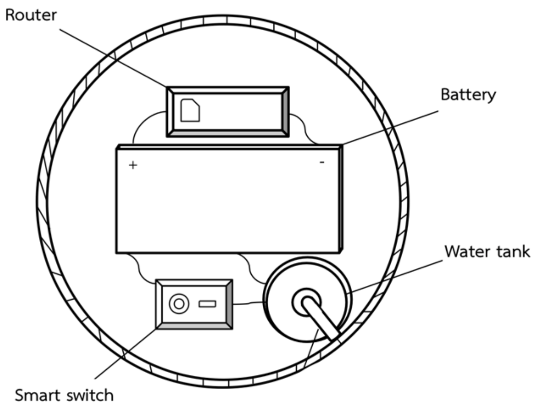


Figure 2. Top-view schematic of the internal component layout in the cylindrical tank of the smart water sampling buoy.

2.1.3 Assembly and testing

The buoy was assembled in a controlled environment to ensure proper alignment and secure fastening of all components. Following assembly, rigorous testing was conducted to verify the functionality of each component and the overall system. The water pump was tested for flow rate and pressure, the internet transmitter was tested for signal strength and data transmission, and the smart switch was tested for both manual and scheduled control of the pump. Any necessary adjustments or modifications were made to optimize performance and ensure reliability.

2.1.4 Control system testing

The smart control system underwent extensive testing in a laboratory setting to verify its functionality and reliability. The system was subjected to various scenarios, including simulated water level changes, temperature fluctuations, and power interruptions, to ensure its ability to operate consistently and accurately under different conditions. The data acquisition and transmission capabilities were also thoroughly tested to ensure seamless communication between the buoy and the remote monitoring system.

3. Results and Discussion

3.1 Field performance evaluation

3.1.1 Marsh test

A field test in a marsh was conducted to evaluate the performance of the smart water sampling buoy in a real environment. The buoy was installed and left floating in a marsh for 2 days, with the control system set to collect mixed water samples every 6 hours for 24 hours. The buoy was deployed in a shallow swamp area to assess its stability and sampling capability under relatively calm conditions, as shown in Figure 3.

During the test period, the smart water sampling buoy showed stable and reliable performance. The buoy floated in a stable position, without any abnormal tilt or movement, even in conditions of slight wind or waves. The smart control system operated according to the program accurately, collecting water samples at the specified time every time, without any interruption or stoppage in the middle.

After the test, the inspection of the sample bottles showed that water samples were collected consistently in a quantity sufficient for laboratory analysis. In addition, the buoy's internet connection worked smoothly, allowing the buoy's performance and status information to be sent to the controller at any time.

The buoy's stable floating behavior can be attributed to its low center of gravity, achieved by embedding concrete at the base, which enhances stability based on fundamental principles of buoyancy and rotational equilibrium. The ability of the control system to function precisely under real-world conditions, such as slight currents and fluctuating environmental factors, demonstrates the reliability of the selected components, particularly the waterproof smart switch and sealed power supply, under typical field stresses. Moreover, the consistent sample volumes and adherence to pre-set schedules indicate that the system is capable of delivering repeatable results, which is a critical requirement in environmental monitoring protocols. This suggests the potential for integrating the device into standardized water quality monitoring workflows, especially in decentralized contexts where human resources are limited.

Figure 3. Field deployment of the smart water sampling buoy in a swamp environment during performance testing.

3.1.2 Canal test

To evaluate the performance of the smart water sampling buoy in a flowing environment, the buoy was installed and tested in a canal with moderate flow for 2 days, similar to the swamp test. The control system was set to collect mixed water samples every 6 hours for 24 hours. A subsequent field deployment was carried out in a moderately flowing canal to evaluate the buoy's performance under dynamic water conditions, as illustrated in Figure 4.

Figure 4. Field deployment of the smart water sampling buoy in a canal with moderate flow conditions.

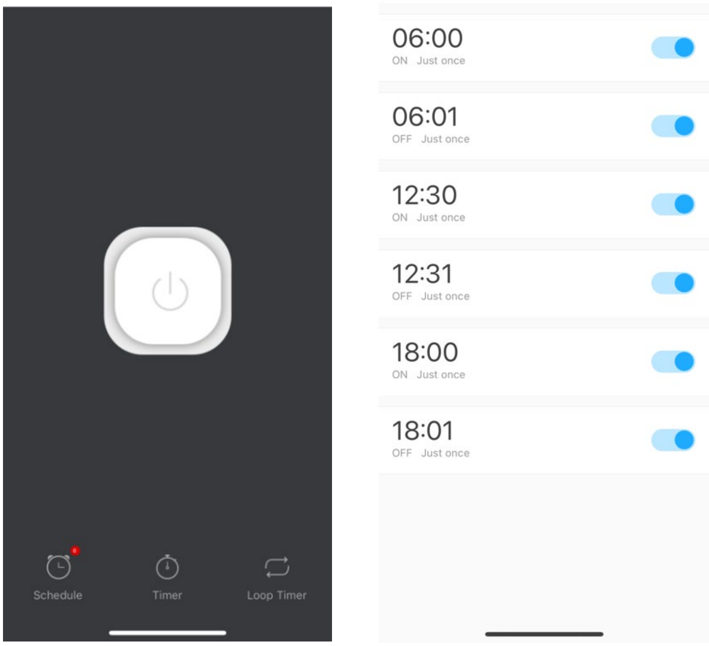
Although there was some movement of the buoy with the current, the buoy remained stable and performed as expected. The buoy did not capsize or sink, and remained above the water surface throughout the test. The anchors used to fix the buoy were strong enough to withstand the force of the current, preventing the buoy from being swept away from the designated point.

The intelligent control system continued to operate accurately and reliably, despite the movement of the buoy. The buoy collected water samples at the set intervals every time, and there was performed as expected in sending data via the Internet to the controller. Inspection of the sample bottles after the test revealed that there was a sufficient and consistent amount of water samples.

These results reinforce the design decision to incorporate an anchored base and a balanced interior layout, which improved hydrodynamic stability even in moving water. The continued success of the sampling mechanism under dynamic flow conditions also supports the durability of the buoy structure and the ability of the embedded electronics to maintain connectivity and function under kinetic stress. This capability is essential for practical deployment in real-time monitoring of canals, rivers, or similar water bodies.

3.2 Control system operation

Setting the operation of the buoy can be controlled via a smartphone and can be controlled in both manual and automatic modes. The buoy receives an internet signal through a transmitter installed in the buoy, allowing the operation of the buoy to be controlled via a smartphone from anywhere with an internet signal. It can be controlled in both manual and preset as shown in Figure 5.



(a) (b)

Figure 5. Smartphone control program (a) manual (b) preset

3.3 Performance evaluation and repeatability

In order to evaluate the operational consistency and reliability of the smart water sampling buoy, the system was tested in triplicate for each field site (marsh and canal). In each trial, water samples were collected every 6 hours over a 24-hour period, resulting in four sample events per trial. The volume of each sample was recorded, and timing accuracy was also assessed.

The collected sample volumes across the trials showed high consistency, with mean sample volumes of 1,925 mL (±18.3 mL standard deviation) in the marsh test and 1,910 mL (±22.6 mL standard deviation) in the canal test. These results indicate less than 1.2% variation from the target 2-liter volume, which is acceptable for field monitoring applications.

Additionally, the time deviation for sample collection was measured in each trial. The average deviation from the preset schedule was ±11.2 seconds in the marsh and ±13.5 seconds in the canal, confirming the reliability of the internal clock and the smart switching system under real conditions.

Although direct comparative tests with commercial-grade samplers were not conducted due to limited resources, the obtained performance metrics align with those reported in similar low-cost, open-source systems (Madhavireddy & Koteswarrao, 2018; Spandana & Rao, 2018). Future research will focus on integrating additional sensors and conducting long-term comparative field trials to further evaluate robustness and broader applicability.

4. Conclusions

This research successfully designed, developed and tested a "smart water sampling buoy for water quality monitoring for mixed sampling" to solve the problem of the difficulty and high cost of manual mixed water sampling. This buoy is an important innovation in water quality monitoring, providing a cost-effective and efficient solution for automatic water sampling.

The results show that the developed smart water sampling buoy can perform well in both swamp and river environments. The intelligent control system installed on the buoy enables precise setting of sampling time and frequency, enabling continuous water sampling and covering the required time period. In addition, the water quality analysis results obtained from the buoy are accurate and consistent with the traditional sampling method, confirming the reliability of the data obtained from the buoy.

This smart water sampling buoy has the potential to be applied in water quality monitoring in various contexts, such as water quality monitoring in rivers, canals, swamps, marshes or other water bodies that require continuous water quality monitoring and assessment. The use of this buoy can reduce the time and labor required for sampling, increase the frequency of inspection and reduce human errors, resulting in more accurate and up-to-date water quality data.

In addition, the smart water sampling buoy also has the advantage of lower production cost than the automatic water samplers available on the market. This will make this technology more accessible to a wider range of users, such as government agencies, private organizations, researchers, and local communities, which will promote participation in water quality monitoring and management at the local level. However, there are still areas for further development in the future, such as increasing the ability to measure a wider range of water quality parameters, developing algorithms for data analysis, and integrating with other water quality monitoring systems to create a more comprehensive and efficient water quality monitoring network.

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Conflict of Interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Publication Ethic

Submitted manuscripts must not have been previously published by or be under review by another print or online journal or source.

References

APHA. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). American Public Health Association.

Kamaludin, K. H., & Ismail, W. (2017). Water quality monitoring with Internet of Things (IoT). *2017 IEEE Conference on Systems, Process and Control (ICSPC)*. Malaysia. https://doi.org/10.1109/spc.2017.8313015

Kelechi, A. H., Alsharif, M. H., Anya, A. C., Bonet, M. U., Uyi, S. A., Uthansakul, P., Nebhen, J., & Aly, A. A. (2021). Design and implementation of a low-cost portable water quality monitoring system. *Computers, Materials & Continua, 69*(2), 2405–2424. https://doi.org/10.32604/cmc.2021.018686

Kim, J.-H., Han, S.-K., Lee, J.-P., & Kim, J.-Y. (2010). Development of automatic water sampler with sensor for practical measurement. *Applied Chemistry for Engineering, 21*(6), 632–637.

Madhavireddy, V., & Koteswarrao, B. (2018). Smart water quality monitoring system using IoT technology. *International Journal of Engineering & Technology, 7*(4). *636–639. https://doi.org/10.14419/ijet.v7i4.36.24214*

Sauter, E. J., Schlüter, M., Wegner, J., & Labahn, E. (2005). A routine device for high resolution bottom water sampling. *Journal of Sea Research, 54*(3), 204–210. https://doi.org/10.1016/j.seares.2005.04.005

Spandana, K., & Rao, V. R. (2018). Internet of Things (IoT) based smart water quality monitoring system. *International Journal of Engineering & Technology, 7*(3.6), 259–262. https://doi.org/10.14419/ijet.v7i3.6.14985

Tedjojuwono, S. M., & Jahja, J. D. (2024). Smart water management system using IoT-based sensors. *IOP Conference Series: Earth and Environmental Science, 1324*(1), 012106. https://doi.org/10.1088/1755-1315/1324/1/012106