SafeWater Monitor
Phase VI Report

Ester Ear
Geraldine Dos Santos
Kaitlyn Jandrucko
Melanie Dietrich
Moyosola Omole

Advisor: Zahra Pournorouz

We pledge our honor that we have abided by the Stevens Honor System.

Abstract

Water quality in a household is important when it comes to tracing undetectable impurities. Most traditional water quality tests require sending samples to a laboratory which can take days or even weeks to get the results of the water quality. Other options include expensive single use test strips that will only test for one impurity at a time. This device will aim to be easily installed in a household sink pipe system and will be equipped with sensors that will monitor the water quality based on the user’s preference. It also includes an app that will connect via bluetooth and will provide real time information of the water quality in the tank. This addresses the limitations of traditional water quality testing methods which usually require manual testing and being sent to an off site lab for analysis which could take weeks. By using sensors and optimizing the device for easy integration into a sink pipe system, this system provides an accessible solution to test household water quality.

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Introduction

1.1 Problem statement

The SafeWater MonitorSystem will provide an accessible solution for testing household water quality through the implementation of a sensor-based system with bluetooth capabilities. The system will use an ion selective sensor to read the ionic concentration of Calcium present within a home water source; allowing the user to run tests through an app system. This monitoring system will be connected to the outlet pipe underneath the sink. This addresses the limitations of traditional water quality testing methods, which usually require manual testing and being sent to an off-site lab for analysis, which could take weeks. By using sensors and optimizing the device for easy integration into a sink pipe system, this system provides an accessible solution to test household water quality.

Methodology

2.1 Beta Prototype

2.1.1 Technical Contents

The SafeWater Monitor uses a Vernier calcium ion-selective sensor to measure calcium levels in water, which is a key indicator of water hardness. Due to the sensor needing still water to give accurate readings, a servo motor is used to stop the water flow during testing. The motor opens and closes based on user input from the app, allowing the sensor to take measurements at the right time. For testing, the team built a pipe simulation using a PVC t-joint and a stable stand, which lets water flow realistically through the system. At the heart of the system is an Arduino Uno, which connects to both the sensor and the servo motor. An interface shield makes it easy to gather sensor data, while an Arduino R4 acts as a bridge between the Arduino Uno and the mobile app, sending sensor readings over Wi-Fi.

The original version of the app was built in Android Studio, but due to compatibility and stability issues, the team switched to Tkinter, a Python-based interface with a compiler called Pycharm. This change allowed for faster development and easier updates. The app includes features like “Start Measurement” controls, real-time data display, and trend tracking, with future plans for alerts and additional sensor integrations.

All of the electronics are housed in a small, protective box that fits under a sink. It keeps the components safe from moisture and clutter, and the system runs on batteries, which makes installation flexible and outlet-free. The overall design is compact, user-friendly, and built with room to grow as more sensors are added in future versions.

2.1.2 Shortcomings

Throughout the development of the SafeWater Monitor, the team encountered several challenges that required creative problem-solving and design adjustments. One of the first major issues came from the calcium ion-selective sensor itself. While effective in measuring calcium levels, it only produced accurate readings in still water. This made real-time monitoring in a flowing pipe impractical, forcing the team to design a solution that temporarily stops water flow during testing. Implementing a servo motor to control this added complexity to the hardware and required careful coordination with the sensor and app interface. Additionally, our initial plan to use a more advanced sensor for detecting heavy metals like lead was scrapped due to budget limitations. The calcium sensor, while useful, limited the system's range of water quality data and reduced the impact we had hoped to make with our original concept.

Software development also brought its share of setbacks. The app was first built in Android Studio, but technical problems, like build failures and compatibility issues, slowed progress. To keep the project moving forward, we switched to Tkinter, a simpler Python-based platform. While this change made development easier, it also meant we had to scale back some features originally planned for a more advanced mobile app. Hardware integration was another obstacle, as syncing the Arduino Uno Arduino R4, sensor, and servo motor required a lot of troubleshooting. Communication between components, especially transmitting data from the Arduino to the app, was more challenging than expected. On top of this, shipping delays and limited testing time made it difficult to fully optimize the system. Despite these shortcomings, the team adapted and created a functional prototype that laid the groundwork for future improvements and expansion.

2.1.3 Final Prototype

Hardware

Our final prototype design features a stand to hold the t-joint piping and the servo motor for the stopper mechanism. The stand features an extended platform that is used to help support the rubber stopper. This was implemented due to the weight of the water being too heavy for the servo arm causing it to bend and let the water leak out. The t-joint pipe is fitted with an adapter allowing for the sensor to be stabilized and inserted into the pipe with a watertight seal. Setup can be seen displayed in a SolidWorks exploded view model in *Figure 1*.

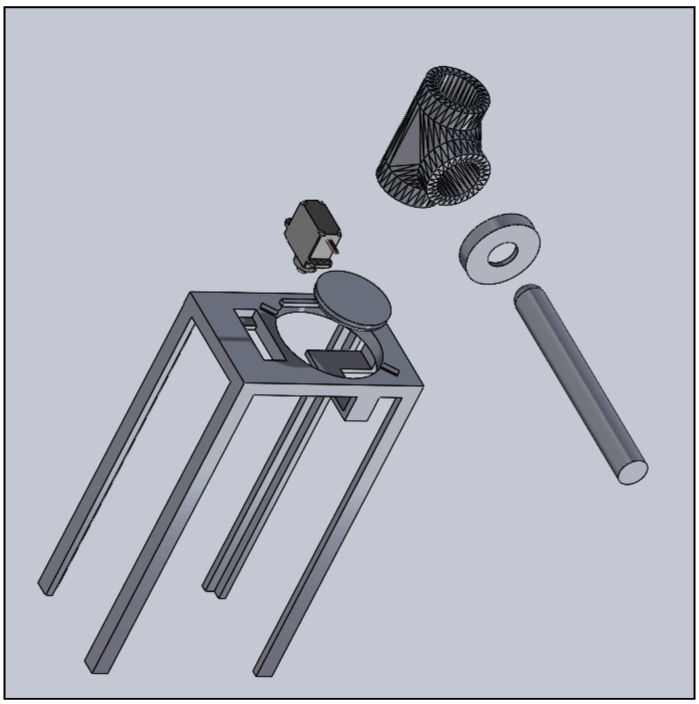


Figure 1. Exploded View of Product in SolidWorks

Another aspect of our design is our electronics box, seen in *Figure 2.* This box is designed to compactly store all of the electronic components in an easily accessible box. This box features a sliding lid for easy access and a wire output hole that will allow all the required wiring to come out of the box without preventing it from sealing. The top of the box is also engraved with our logo to keep a simple minimalist branding to our device. Our final prototype fully assembled can be seen in *Figure 3.*

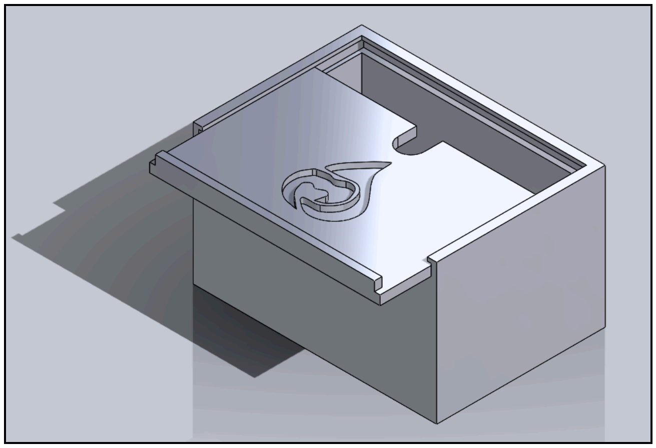


Figure 2. SolidWorks of Electronics Box

Figure 3. Final Product Assembled

The device leaves room for future improvements to be made. This design iteration does not properly simulate the piping under the sink as you would not be able to fully seal off the bottom like we demonstrated in our prototype. An alternative solution would be to improve upon the prototype and add an addition of piping that would connect the outlet sink pipe to the device, making it a separate testing chamber. This would allow for a more realistic testing setup to be created. Another future improvement is an ion selective sensor that has the ability to detect more contaminants can be implemented, replacing the current sensor. This would allow for the device to be more practical and functional for users.

Software

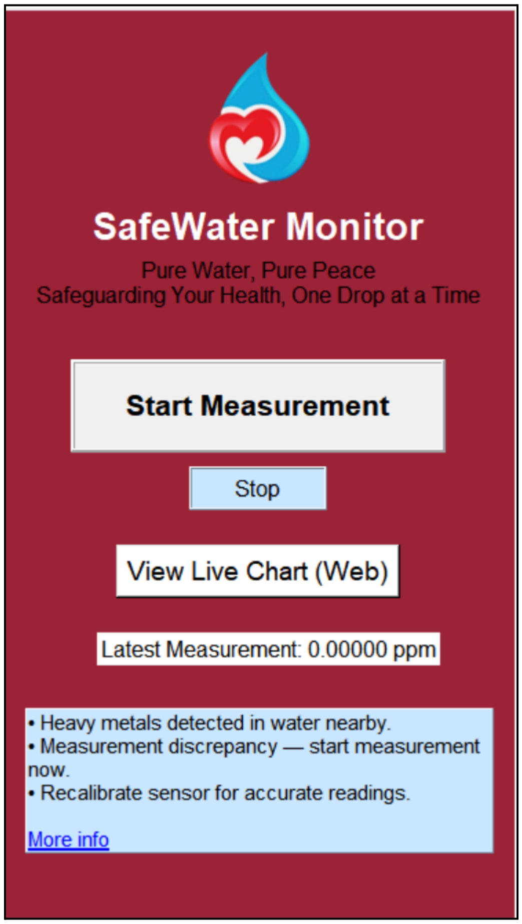


Figure 4. Software UI

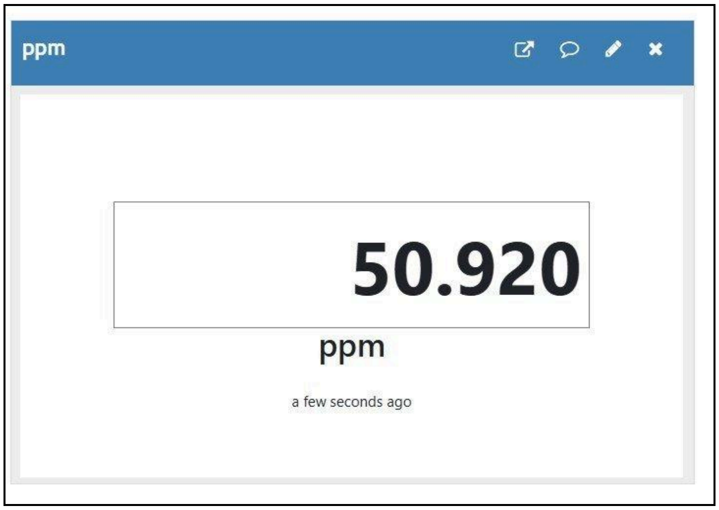


Figure 5. Data From Sensor

Figure 6. Live Graph of Data From Sensor

The final prototype for the SafeWater Monitor GUI utilizes the Tkinter library in Python for full Wifi integration with the Arduino Uno. Easily-navigable properties on the dashboard include a large "Start Measurement" button, alerts section with system and water quality notifications, and embedded box with latest sensor measurement. Upon pressing "Start Measurement", the Vernier sensor begins wirelessly sending data over to be processed and turned into a real-time, continuously-updating plot. Once the user has collected enough data, they can seize the process through the "Stop" button, saving energy. Measurement data from all readings is stored in a ThingSpeak channel, where users can use the "View Live Chart (Web)" button to open a browser window and review how readings have changed over any specific period of time.

The combination of these features results in a functional, straightforward app for monitoring water quality.

As for future improvements, different pages would be added for better organization. These pages would include a “Settings” section for a customizable experience, “Trends” section with an embedded version of the ThingSpeak graph, and homepage with the latest sensor measurement and “Start Measurement” button. The “Alerts” section would also provide accurate notifications based on the analyzation of water quality data nearby, compare user measurements to safe levels of contamination, and troubleshoot exact issues affecting both software and hardware performance. In addition, a user account feature would enable the syncing of data across multiple devices and subscription management. The implementation of these additional features would prioritize user experience to create a more visually-pleasing and functional SafeWater app.

2.1.4 Functionality

The final prototype successfully integrated mechanical and software components to detect calcium ion concentration in still water samples. To start a measurement the button “Start Measurement” on the app that is on the Tkinter app. When the user initiates the test, the servo motor closes the bottom of the t-joint. This stops water flow, ensuring a still water environment for accurate testing. Water from the pipe enters the chamber by gravity and is held for a new sensor for the chamber to fill up. The sensor is mounted in the t-joint where it can begin the data collection. The Arduino Uno reads the analog signal in mV from the sensor. To make the data understandable, it is converted to ppm. The processed readings are displayed through Tkinter showing real-time calcium levels. The app provides the user with visual feedback and plans to add trend history in future versions. After the measurement is complete, the servo motor reopens the chamber, allowing water to flow freely again and resets the system for the next test.

2.2 Bill of Materials and Budget

We managed our project budget with careful planning and strategic decision-making. Our total expenditures amounted to $488 out of the allocated $700, keeping us well within our financial limits. The most significant expense was the Vernier Calcium Ion-Selective Electrode, priced at $299, which accounted for approximately two-thirds of our total spending . By prioritizing this essential component, we ensured the core functionality of our water monitoring system.

To maintain cost efficiency, we utilized existing resources and opted for cost-effective alternatives where possible. For instance, we repurposed materials such as a PVC T-joint and stand to simulate household plumbing, avoiding the need for expensive testing setups. Additionally, we leveraged open-source software and hardware platforms like Arduino, which we already had access to, thereby eliminating additional expenses. This disciplined approach to budgeting allowed us to develop a functional prototype without exceeding our financial constraints.

Variable	**Cost**
Arduino Uno	$26
Arduino Nano	$25
9V Batteries	$9
Breadboard and Wires	$6
Piping	$10
Calcium Ion Selective Sensor	$299
Arduino Interface Shield	$29
Arduino R4	$30
Tax and Shipping	$51
Total Cost	$488

Table 1: Bill of Materials

Conclusion

3.1 Results and Discussion

In this final phase of development, the SafeWater Monitor prototype demonstrated significant progress in both accuracy and functionality. The redesigned testing chamber which features a servo motor-controlled stopper, successfully addressed the sensor's need for still water. By stopping the flow before measurement, the system consistently produced accurate calcium readings in a controlled flow environment, an improvement from earlier inconsistent results. The modified stand with an extended platform was critical in supporting the rubber stopper, preventing leaks caused by water pressure that had previously bent the servo arm. These mechanical refinements ensured a more stable and leak-free system, allowing for reliable, repeatable tests.

On the software side, the switch to Tkinter and Python significantly improved user interaction and system responsiveness. The new app allowed for real-time monitoring, clear display of results, and intuitive user control via the "Start Measurement" button. While Tkinter lacks some of the polish of a mobile-native app, it proved effective for prototyping, reducing build issues and speeding up development. Data transmission between the Arduino Uno, Arduino R4, and the app became more reliable through Wi-Fi communication, although thai still required extensive troubleshooting and calibration.

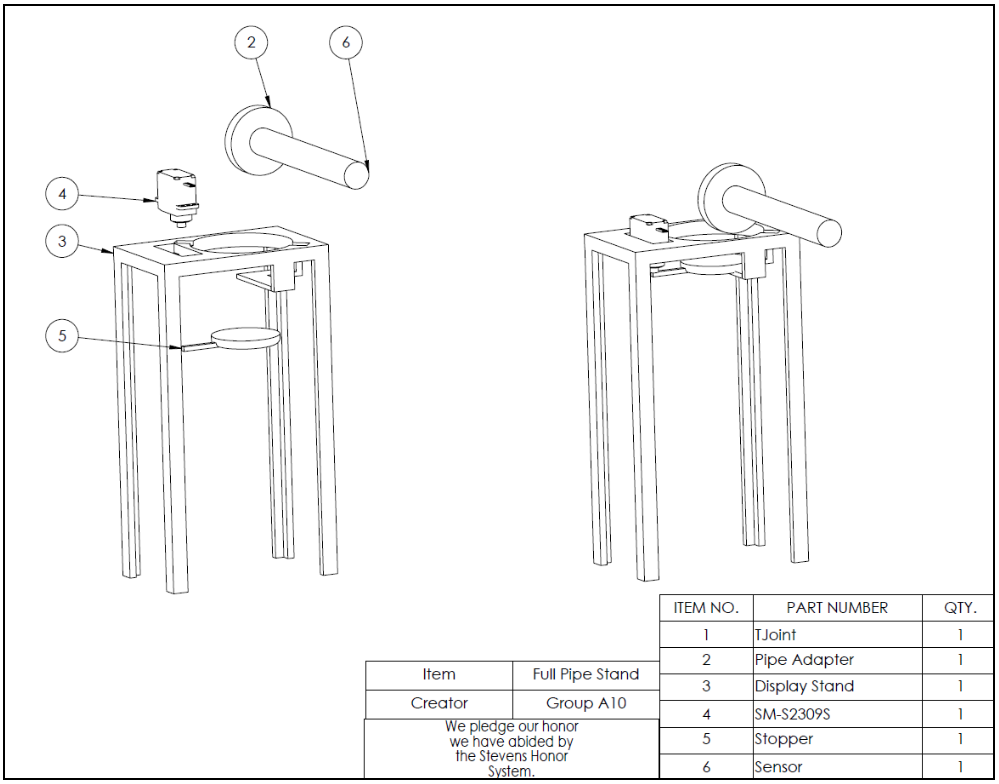
Calibration of the calcium ion-selective sensor was conducted using standard high and low concentration samples. The readings in these tests aligned well with expected values, confirming the system's measurement accuracy in a lab-like environment. However, like earlier versions, minor inconsistencies still occurred during testing with regular tap water. These inconsistencies likely stem from variations in flow rate, slight leaks, or environmental interference, pointing to areas for future refinement in waterproofing and flow control. While the system remains limited to calcium detection due to budget constraints, it was built with expandability in mind. The protective electronics box design under the sink and battery-powered setup provide flexibility for future integration of additional sensors, including those for lead or other heavy metals. Trend-tracking and alert features, while not yet implemented, are planned as part of the app's growth.

The final prototype validates our concept of an automated, user-friendly water quality monitoring system for home use. Continued improvements in water chamber design, app development, and sensor integration will enhance the systems's real-world usability.

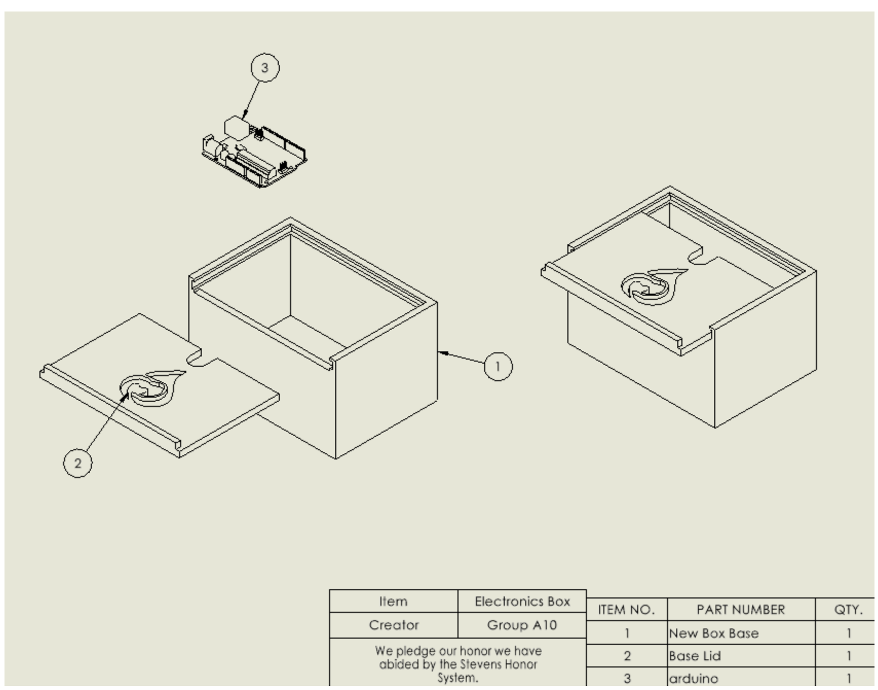
3.2 Lessons Learned

This phase of the SafeWater Monitor project taught us important lessons about precision and user-centered design. We learned that accurate sensor calibration is essential for trustworthy data, as even small variances can misrepresent water quality and mislead users. Additionally, we discovered that temperature plays a significant role in calibration accuracy, specifically if calibration and testing occur under different temperature conditions, results may be skewed. Our simulated sink setup proved valuable for controlled testing, allowing us to fine-tune sensor placement and detect issues in a stable environment. However, it also made clear that lab conditions don't fully reflect the challenges of real household water systems, such as fluctuating flow and inconsistent user behavior. From a usability perspective, designing a simple interface with clear visual cues and a one-button measurement process greatly improved user experience, making the system more accessible for non-technical users. These experiences deepened our understanding of how technical precision and thoughtful design must work hand-in-hand to create a product that is both effective and easy to use.

Appendix



Drawing of Device in Solidworks



Drawing of Electronics Box in Solidworks