Automated River Water Monitoring Buoy

Funded: $1,420
NPO Partnership: CLEAN UP NEPAL
IEEE Technical Society Partner: Instrumentation and Measurement Society

Project Abstract:

Rivers and lakes in Nepal suffer from severe degradation due to poor waste management from land sewage and industries. The current monitoring system for such water bodies relies on manually grabbing the samples and measuring it in labs. This project develops a low-cost, solar-powered telemetry buoy for c**ontinuous monitoring of river health** in Nepal. The system targets the blind spots of manual sampling by providing real-time data on industrial and sewage pollution through an **automated, self-cleaning sensor array.**

The product will be designed to adjust to harsh weather conditions like extreme wind and rain, collision with rocks and will be able to maintain its buoyant and waterproof characteristics. The technical innovation required to create this system is the **problem of biofouling** in any water monitoring system. This is caused due to algae and sediments covering the sensors, rendering them completely useless. To solve this problem, we will design a **custom automated wiper system** to automatically clean the sensors. This project will contain a microcontroller, industrial-grade pH, TDS, Turbidity, DO, and temperature sensors. This will all be contained within a watertight enclosure with a battery. All the data will be transmitted to a centralized cloud dashboard.

Technical Details:

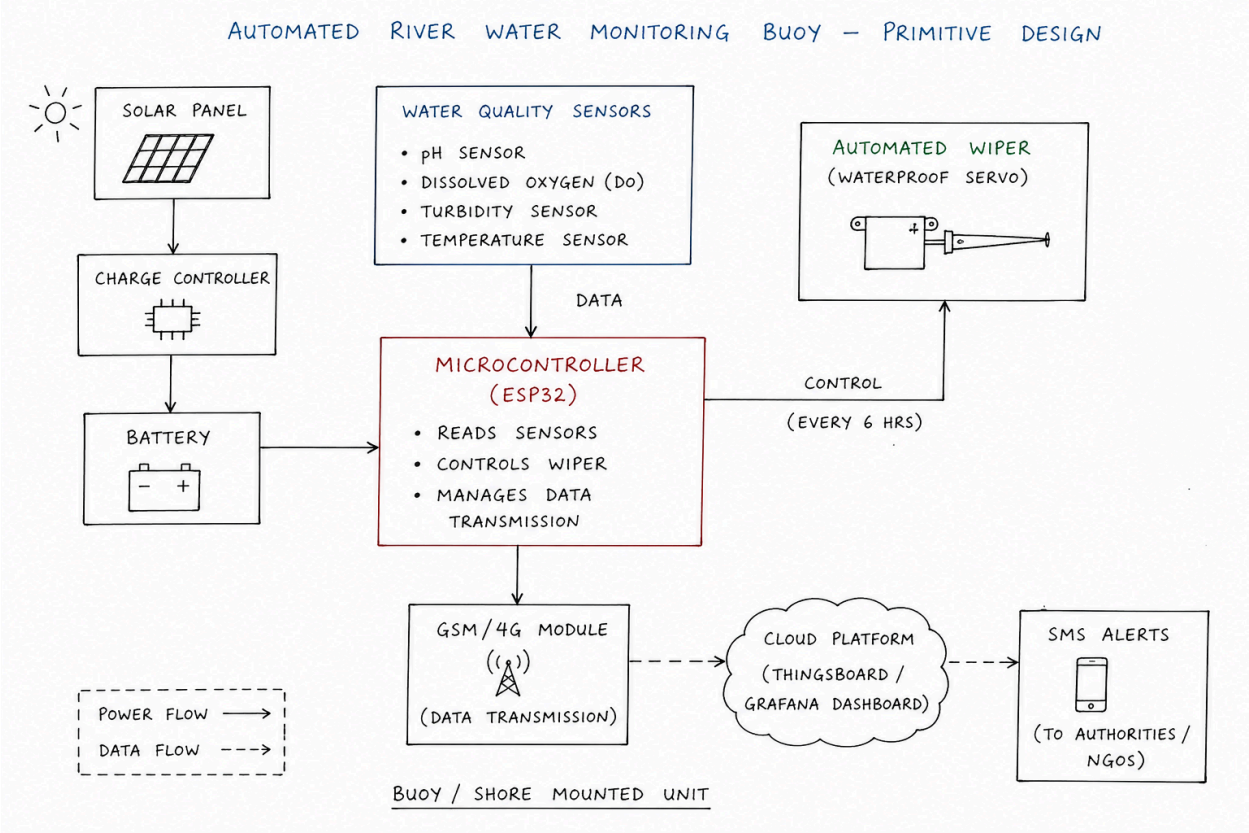
To preserve power, the ESP32 remains in deep sleep, waking every 30 minutes to sample data. Every 6 hours, the system activates the servo motor controlling the wiper. The wiper clears the sensor membranes, preventing the accumulation of biofilm and silt which otherwise degrades sensor accuracy in highly turbid environments.

The system is designed for end-to-end data transmission and presentation. The ESP32-S3 Microcontroller handles edge processing, locally filtering the sampled data to remove noise before transmission. Using the 4G/LTE GSM module, this data is transmitted to a centralized cloud system. This system is provisioned for 12-month cloud hosting, managing the collected logs and feeding a frontend dashboard. This public dashboard, intended to function as a public map of river health, ensures transparency and encourages accountability by displaying real-time data on industrial and sewage pollution.

Several technical approaches contribute to the buoy's reliability and self-sufficiency. The structural components, notably the wiper assembly for mechanical cleaning, are

precisely manufactured using 3D printing. Power management is achieved through a 20W Solar Panel and a charge controller, which ensures efficient charging of the 7Ah LiFePO4 battery. To preserve power, the ESP32-S3 remains in deep sleep, waking only every 30 minutes to sample data. The system is protected by a UV-resistant PVC buoy housing with internal stabilization ballast, and its modular design allows for scalability, enabling the future addition of sensors like Nitrate or Turbidity probes.

Subsystem	Description
Sensor Suite	Industrial-grade pH, Turbidity, TDS, Dissolved Oxygen (DO), and Temperature probes with signal conditioners.
Mechanical Cleaning	IP67 Waterproof high-torque servo motors, 3D-printed wiper assembly, and mounting hardware.
Power & Control	ESP32-S3 Microcontroller, 20W Solar Panel, 7Ah LiFePO4 battery, and MPPT charge controller.
Telemetry & Housing	4G/LTE GSM module, UV-resistant PVC buoy housing, and internal stabilization ballast.
Deployment & Data	Anchor systems, field testing in Kathmandu/Bagmati river, and 12-month cloud hosting.



Deadlines:

Phase 1: Scope and requirements (0.5 months)

This step will include both the students and the non-profit partner. It includes a meeting with the non-profit partner to discuss the scope and the project requirements we have created and ask for feedback from the NGO. This step is crucial as it ensures both the student party and non-profit partner are satisfied with the decision and that the project can move forward. This process will also include any readjustments to the timeline, dates for testing, and regular meetings to update on the project.

Phase 2: Designing the enclosure (2.5 months)
In this step, the students will work solely from the engineering perspective. Here, students will design the watertight buoyant enclosure and test it in water. This part also consists of designing anti-biofouling system. It will initially be designed in CAD software with spaces for sensors and electronics; adjusting for their respective weights. The design will also be 3D printed and prototyped before the final product. The final design of the enclosure will be completed by this phase. Choosing and ordering proper sensors will also be included in this part parallelly since many items are not found in local market, and amazon is not available in Nepal.

Phase 3: Designing the electronics (2 months)
The electronics will all be ordered and received by the end of phase 2. In phase 3, the electronics will be prototyped to make sure it works appropriately. The data from the sensor will also be tested with lab values with the help of non-profit partner. After the prototype is complete and calibrated accurately, it will be fabricated in a PCB to ensure it is safe from any dust and water.

Phase 4: Deploying the backend (1 month)
This part will consist of working in the cloud for the backend. All the data will be sent to this backend and presented in the frontend. The credentials for this web server will be provided to the non-profit. Input from non-profit partners will be taken into account when designing the frontend.

Phase 5: Integrating and Testing (2.5 months)
All the parts from Phase 2 to Phase 4 will be integrated together and polished to be a final product. Any final design iterations will be done in this phase. Finally, the product will be taken in a river to test its accuracy and capabilities. Any bugs will also be ironed out in this phase. Phases 4 and 5 will work simultaneously.

Phase 6: Handoff, Training and Documentation (0.5 months)
The project concludes with transitioning the operational use of the system to the NGO. The student team will compile open-source documentation and conduct a training workshop for the NGO staff on how to read the dashboard, replace batteries, and perform minor maintenance.

Deliverables:

1. Working system of the monitoring buoy or shore station
2. Automated sensor-cleaning mechanism
3. Real-time data dashboard and alert system
4. Test and deployment report
5. Final design documentation for replication

Maintenance and Sustainability:

To ensure that our system is reliable and to maintain the accuracy of our sensor, we will deploy our system in a controlled lab before the field deployment. Initially, we will submerge our entire system in a water tank containing samples from Bagmati river to simulate the environment. This will allow us to test our system for two weeks in a nutrient-rich water in order to verify the wiper's efficiency, any micro leaks and confirm the firmware and telemetry system.

After the lab validation, we will deploy the system in a Bagmati river for a three-month trial period and try to achieve our short-term goal in the given period. We will measure the sensor's accuracy with our partnership with CLEANUP NEPAL. Every two weeks, their team will collect manual samples and compare it with our system using professional laboratory equipment. From this, we can guarantee our systems' sensor and maintain the promised accuracy. We will also diagnose any practical problems with the system during this phase so that the project can handle long-term deployment of up to a year.

Lastly, to guarantee long-term deployment, we will specifically design the system for its physical and electrical reliability in Nepal's dynamic river. Our system is built around worst-case environmental scenarios. From our calculations, the system will last up to 12-15 days without any solar panel. With the 20W marine-grade solar panel and 7Ah LiFePO4 battery, our system is expected to last indefinitely. We will rigorously test the power usage and physical capabilities of our system using the university's lab to ensure that we can deliver the promised results.

Project Impact and Implementation

We will measure the success of the project in two parts – Short term and long term.

Short term success:

- **Anti Biofouling –** The automated wiper mechanism in the sensor should be working accurately and maintain the accuracy compared to the control samples. The system will be checked every week for 1 month to ensure that the wiper mechanism is doing its work as intended.

- **System Uptime –** The system must have more than 90% uptime (disregarding any cloud service outage). It should rarely fail to send data to the centralized system, and provide clear error message for backtracking if there is any problem.

Long term success:

- **Adoption of the system –** The project must be adopted by the NGO in their daily activity and must be actively being utilized for more than 3 months.

- **No human intervention –** After the short term success, there should be no human intervention and the project should function as expected.

- **Accurate alert system –** During monsoon season, the alert system should work as expected due to more pollution from flood and landslides.

When the project becomes a success, it will be targeted first towards the Bagmati river area due to it's extreme pollution and also ongoing activities to clean the river.

Core Members:

Avignya Gautam (Team Leader, PI)
Amir Bhattarai
Samiksha Dhakal
Kripa Timalsena
Agrima Shahi