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AQUATIC ROVER: AN AUTONOMOUS VEHICLE FOR WATER QUALITY: A LOW-COST PORTABLE TOOL

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ABSTRACT

This study proposes an aquatic rover, an autonomous vehicle for water, and low-cost, to measure physical-chemical parameters in freshwater parameters, aiming to identify distortions in the quality of analyzed water. Considering the importance of water for life and the planet Earth, the project seeks to assist in data analysis of the WQI (water quality index) related to water pollution such as turbidity, pH, dissolved oxygen, and temperature. The prototype consists of a low-cost aquatic device that has two available models depending on the needs of each environment. Both models have a set of sensors that enable water quality data gauges and subsequently send the data to a server where they will be assessed on a computer or a mobile device. Furthermore, the main goal of the project is to minimize the necessity for technicians to monitor water quality, thereby reducing human exposure to contaminated areas and increasing body water analyses. Since one of the main problems observed is the time it takes environmental agencies responsible for environmental inspection to identify contamination, the equipment, being autonomous, would reduce the time needed for it and would help these agencies in their work. After designing and testing the equipment, the aim was achieved, because it was possible to measure the required water quality parameters and then analyze them to identify any current contaminants.

Keywords: WQI, Lower cost, aquatic rover.

Summary

1. INTRODUCTION

The city Teresina, in the state of Piauí, Brazil is surrounded by two rivers, Parnaíba and Poti. They are the target of irregular discharge of effluents especially wastewater discarded directly on the rivers without previous treatment, most notably the Poti river. Facing the current scenarios with high levels of pollution in our water bodies in our region, it is possible to observe a drastic change alteration in the river.

According to Damasceno et al (2008, p.1):

> "Impacts are observed in the water sources such as waste accumulation on the river banks, sand banks, exposed soils. degradation of riparian forests, low waters, mineral dredging, erosion, and silting in several sections. Values out of the recommended range by CONAMA (National Environment Council) were observed for DO, NH3 and FC, causing concerns about the aquatic balance due to the intense discharge of domestic effluents in the region".

Not only the waters of the Poti River are polluted but of the whole Northeast, according to Silva (2019), the carried-out surveys make the anthropic influence evident in the water quality in the assessed rivers and reservoirs and they provide input for the development of research of the hydric ecosystems of the Brazilian Northeast. The presented facts motivated the development of this project, a device/equipment able to carry out physical and chemical at different spots from the water. The pH (Potential of Hydrogen), turbidity, DO (Dissolved Oxygen,) and temperature are parameters of paramount importance to ascertain whether the water is safe for human consumption, these variables also compose the calculation of the WQI (Water Quality Index). The WQI is a methodology to evaluate water quality, based on measuring its physical, chemical, and biological characteristics, rating it using established quality parameters (Semil, 2021).

Considering the variables proposed by the project, it is defined that the pH "Consists of the concentration measurement of H+ ions in water, being in practice being gauged through colorimetric kits or digital pH meter. Its scale goes from 0 to 14, and pH equal to 7 corresponds to neutral"(Santos, 2018, p.2).

Regarding dissolved oxygen, "The oxygen in water, the unit of which is mg/L, it may come from two sources: endogenous and exogenous." (Vieira, 2019, p.1).

Besides reducing the necessity of monitoring teams, as the prototype carries this task autonomously, affordably, and with 24/7 monitoring, it also enables faster identification of contaminations. This more efficient monitoring was not possible since there was the need to use trained technicians to monitor a small section of the water.

The Aquatic Rover possesses a communication system via satellite that identifies the position and speed of the robot and with this information we are able to trace contamination focuses. It is also possible to recover or add a route that allows the device to return to the source of the journey (which is usually the riverbank) and the analyses be carried out both of the water collected and data stored during the operation.

1.1 General Goal

The study aims to build a low-cost, electric aquatic rover, equipped with a measurement system of water parameters and it also has renewable energy generation, data storage, geopositioning GPS (*Global Positioning System*), GSM (*Global System for Mobile*) and LoRa (*Long Range*) data transmission. This prototype seeks to assist water treatment, measuring important variables for the lives present in the ecosystem and those that need this resource.

1.2 Specific Goal

To achieve the general goal of this project, the specific listed objectives are highlighted:

- Build equipment capable of mapping and monitoring physical-chemical parameters of water resources;
- Develop an integrated system capable of providing real-time information regarding water quality;
- Simplify and reduce the costs of water quality monitoring using effective sensors and a communication system;
- Elaborate an assembly tutorial to allow its reproduction.

2. METHODOLOGY

The idea for a low-cost piece of equipment came up from an initiative that intended just to measure some water parameters, locate the equipment, and store the data in a memory card. Then, the project was conceived C++ programming language on the platform Arduino IDE (Integrated Development Environment).

Components such as the ESP32 (*Espressif Systems*) microcontroller were used along with a GPS module with the function of identifying the geographic position of the equipment, a memory card module to store all the data, two lithium batteries recycled from old laptops, plus pH, turbidity and tension sensors to measure all the data.

The second stage of the project had as a main goal the modeling of a device that would be more resistant and stable than the first prototype. In the third stage, a piece of equipment was developed that sought to solve problems faced in the model built in the second stage, such problems were solved using communication systems that enabled data transmission and storage directly in the computer or the cell phone connected via LoRa to the equipment.

It must be pointed out that the modeling and creation of the parts were made with the Fusion 360 and later these parts were printed in PLA using a 3D printer. Hence, the Aquatic Rover was built that has two floaters made of recycled PVC (Polyvinyl chloride) pipes, and a 10W-photovoltaic panel. A second model uses an 1100-gallon-per-hour (GpH) engine and 10W-photovoltaic panels, both models use recycled photovoltaic panels and batteries seeking to reduce environmental damages during the production and functioning of the equipment. Figure 1 presents the second built model.

Figure 1 - Assembled final model.

The parts were printed at the first moment using PLA (Polylactic acid Biopolymer) and later with PETG (Polyethylene Terephthalate Glycol). It is worth highlighting measurements of DO (dissolved oxygen) were carried out, using a color sensor model Tcs230 and DO kits with reagents which, by mixing with water, undergo a color alteration. This strategy was used to achieve a low cost as DO sensors have higher prices and in Figure 2, it is possible to observe the image of the assembled system.

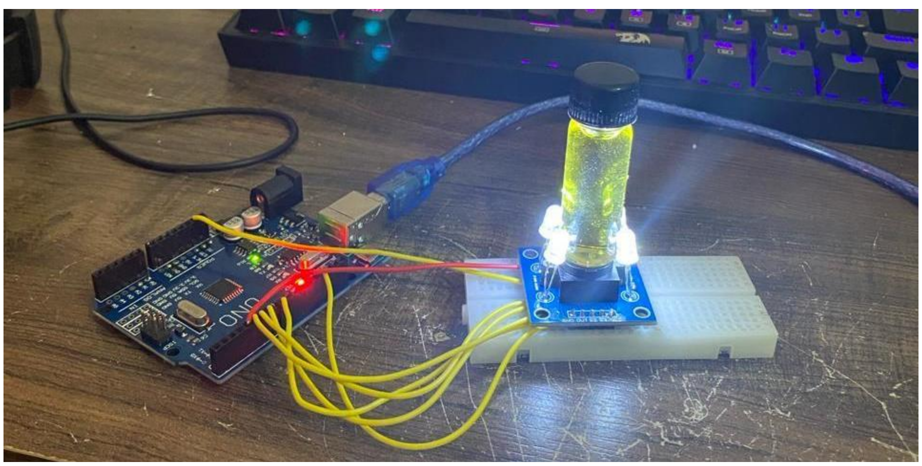

Figure 2 - Dissolved oxygen verification system.

3. RESULTS

In the tests carried out in rivers and lakes, it was observed that the initial models presented problems in moving and analyzing an extensive area. To solve this issue, model two was equipped with an autonomous navigation system allowing the measurement of a larger area. Regarding the 3D parts made of PLA, they became brittle with cracks and fractures in the structure due to low thermal and mechanical resistance, besides the high moisture absorption.

Seeking to solve the issue of parts degradation and gain more durability for the equipment, the printed parts were made of PETG which has higher thermal and mechanical resistance than PLA.

After the production of the parts, the assembly of the circuit was done, and the method found to save space was the creation of stacked modules with different functions. Before the assembly of all the components, simulations were made using the software EasyEDA. The figure 3 shows the circuit after the assembly.

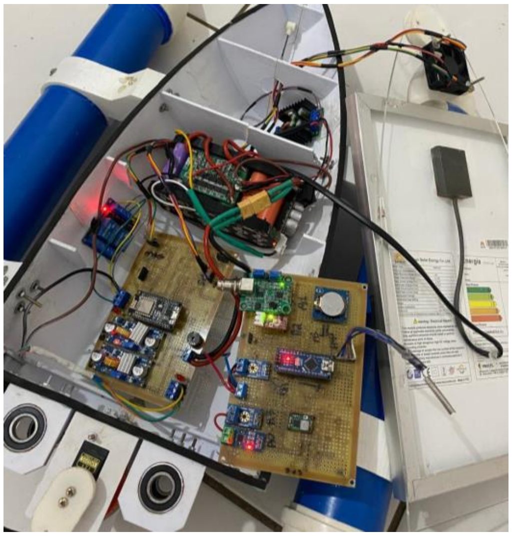

Figure 3 - Assembled circuit.

The third challenge was to develop a protection system to prevent the main circuits from possibly short-circuiting, since during the tests many parts were lost due to electrical overload. To do this, 4A fuses were used, which set a current limit to prevent incidents.

Based on the project goal, all the tests were done in uncontrolled environments (rivers), and tests were carried out in a river and later in a reservoir. Right after that, the SD card was withdrawn for data analysis on a computer or cell phone. Through Fig.4a and Fig.4b, it is possible to observe the results of analyses of the water parameters and location sent by SMS, respectively.

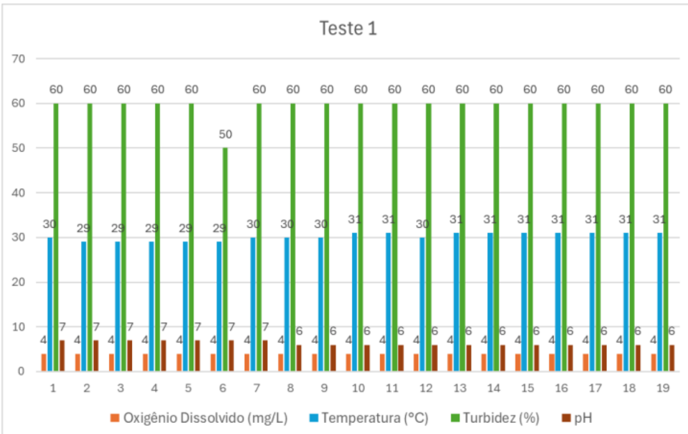

Figure 4a – Result of the analyzed data of Poty River

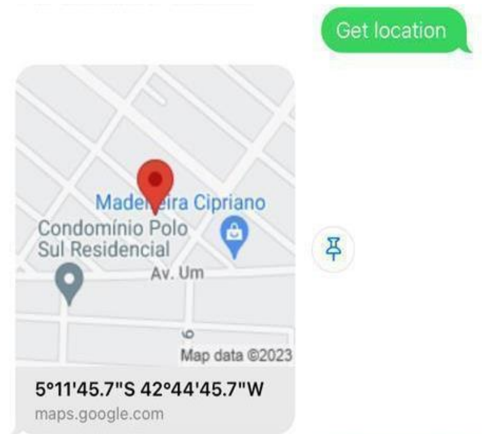

Figure 4b –Location sent by the project via SMS.

According to the results obtained during the monitoring of the Poty River, in Teresina-PI, we can conclude that it presents a great risk both for fish and people that use the water for consumption. The pH is acidic and dissolved oxygen levels make it impossible for fish to survive in the analyzed area.

Regarding this hurdle, we can point out that an excellent performance of the equipment was achieved, as it was possible to obtain six-hour autonomy of operation without the assistance of the photovoltaic panel.

In reference to send messages, when we send “get location” the device sends its current location and “get speed” its current speed.

In the second test, the equipment was subjected to a practical test in the water body in our region located in the city of Timon, in the state of Maranhão, in the Gameleira village, to assess its performance and autonomy under real conditions.

Additionally, the stream water parameters were analyzed, considering its characteristics, such as higher turbidity due to the presence of sediments, lower temperature, and more alkaline pH compared to the water used in the preliminary tests. Fig.5 and Fig.6 show the route taken and the data obtained from the water analysis, respectively.

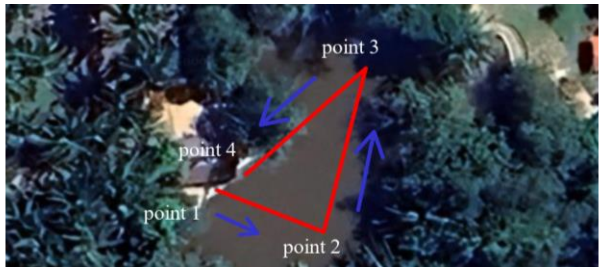

Figure 5 – Test route taken 02.

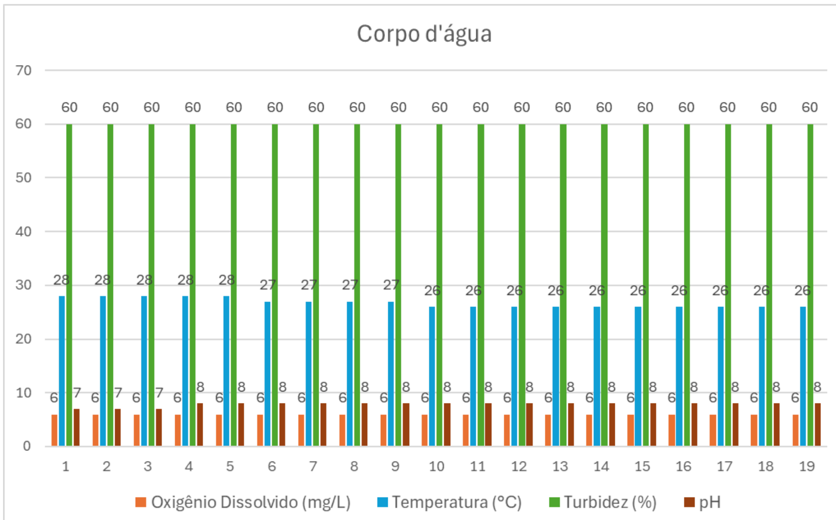

Figure 6 – Data obtained from the analysis of water in the water body of Gameleira

This procedure gives us a qualitative indication of the DO concentration in the water. In both tests, the measurement result was a “good” level classification, which is between 5-6 mg/L. Regarding costs, the prototype was assembled using commercial components and reused materials, in total around US$ 285,64[1] was spent on purchasing parts and components for the project. Compared to commercial meters, such as the HANNA HI9829 portable meter, which costs around US$ 1080.00, the prototype has a lower price, validating its low cost when compared to existing meters.

[1] Amount referring to the average conversion of the Real (Brazilian currency) to the US Dollar, conversion made on June 6, 2024, where 1 US dollar is equivalent to approximately 5.26 reals.

4. CONCLUSIONS

The aim of the project was to develop an aquatic rover with an autonomous system for monitoring water characteristics to contribute to the treatment and preservation of this essential resource. The equipment was designed to measure physical-chemical parameters crucial to determining water quality: pH (hydrogen potential), turbidity index in NTU (Nephelometric Turbidity Unit), dissolved oxygen (DO), and temperature. Based on the measurements of these parameters, the system aims to alert about problems related to water resources and provide relevant information to the user, maintaining low costs to provide greater accessibility to the population. In summary, the water monitoring project represents a significant step towards improving the management and preservation of water resources. The solutions found will contribute to future research and development initiatives. However, it is essential to remember that scientific research is a continuous process, subject to improvements and refinements. It should be noted that the project can contribute to the environmental field. By sharing the results and experiences, it aims to provide more effective solutions to water-related challenges.

5. REFERENCES

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ANNEX A - QUESTIONS ABOUT THE PROJECT

1. What are the major contributions expected from the implementation of this project considering society, the economy, the environment, and especially water resources?

With the implementation of this project, it is hoped to significantly reduce deaths and illnesses caused by heavy metal contamination or leaching, especially in riverside communities, through continuous monitoring that allows for faster and more effective interventions. In addition, the equipment promises large-scale applications for companies and industries, providing savings and greater efficiency than conventional water quality analysis methods. The daily use of the equipment should make the management and preservation of water resources more efficient and economical.

2. What is the innovation being proposed? How does it relate to existing solutions?

The project proposes an autonomous, low-cost device for monitoring water quality, as opposed to current devices that require manual technical management, making the monitoring process costly and laborious. This equipment combines efficiency, with response times and precision comparable to those of a chemical laboratory (as it has the best sensors available on the market), with a more accessible, practical, and modular implementation. Also, the advantage of this aquatic rover is that the information (sensor readings) can be sent in real-time to a database.

3. What region or situation does the project apply to? Can it be replicated? Does it serve developing and developed countries?

The project applies to regions that have water (rivers, lakes, seas) and encompasses two models of equipment, adaptable to different contexts and needs. Model 01, fixed and simpler, is ideal for monitoring bodies of water with smaller areas and without currents, while model 02, more advanced and with mobility capabilities, is recommended for comprehensive monitoring of large water areas. Both models are replicable and applicable in both developing and developed countries, considering their flexible use and cost-benefit.

4. What is the cost of implementing the project?

The cost estimate for implementing the models was based on materials and working hours using the Ender 3S1 printer. Model 01 costs US$ 285.17[2], while model 02, which has additional features, costs US$ 570.34. These values could be reduced with large-scale production. It is worth noting that for the optimized functioning of the prototype, it is recommended to purchase an internet plan for the chip inserted in the GSM module. This module allows data traffic via the 3G mobile network, so the aquatic rover sends data reading the physical-chemical parameters of the water from any location within the 3G coverage area. The estimated value of this mobile internet plan is US$ 5.70 per month.

5. What would you say were the biggest difficulties in developing and implementing the project?

The main challenges include the production cost (which was financed with personal resources), the assembly and testing time (which exceeded the schedule), assembly errors (due to failures in the structure's insulation and undersizing), the difficulty in finding educational material that guides how to assemble and program the modules and the microcontroller (the programming of the ESP and sensors was based on their official documentation), the import of parts (foreign websites with many fees and lengthy delivery deadlines) and designing complex circuits (difficulty in finding free, intuitive software for designing printed circuits), given the artisanal nature of the equipment. However, companies are expected to overcome these barriers with the adoption of the equipment, facilitating its implementation and dissemination as a non-polluting and chemical-free solution for monitoring water quality.

[2] Amount referring to the average conversion of the Real (Brazilian currency) to the US Dollar, conversion made on June 6, 2024, where 1 US dollar is equivalent to approximately 5.26 reals.

6. Which Sustainable Development Goals (SDGs) and targets does your work most relate to?

This work contributes directly to eight SDGs, including health and well-being, clean water and sanitation, affordable and clean energy, industry, innovation and infrastructure, sustainable cities and communities, action on global climate change, and aquatic life. It emphasizes the importance of sustainable management and access to clean water, in addition to promoting technological innovation aimed at sustainability. Within this context, we can highlight the SDGs that are met through the project, such as SDG 6, SDG 9, SDG 14 and SDG 6, the project in question contributes to solving this problem, as a tool for detecting the physical-chemical parameters of water It can be used to identify points where untreated sewage is dumped or even contamination of water bodies. In SDG 9, which deals with innovation and infrastructure, we see that tools for measuring environmental impact are necessary to achieve inclusive and sustainable industrialization. It is possible to verify that a tool for measuring the physical-chemical parameters of water becomes essential for industry sectors that use water from rivers and lakes, as well as infrastructure works that are installed close to these environments. Analyzing SDG 14 Life Below Water it is possible to observe that the project in question directly contributes to this objective. Since, through water analysis, it is possible to determine whether it is conducive to the proliferation of aquatic life, considering that fish and algae are sensitive to variations in these parameters. Additionally, it ensures that the water is suitable for consumption.

7. How the does work relate to the annual theme of World Water Week promoted by SIWI in 2024?

By focusing on the innovative autonomy and low-cost aspects of our project, we highlight its unique ability to transform water quality analysis. By implementing autonomous technologies, the project eliminates the need for continuous operation by specialists, allowing intelligent systems to perform accurate and reliable measurements of essential water parameters. This feature not only streamlines the monitoring process but also makes it accessible to communities that previously might not have had the means for such surveillance. The low-cost aspect is fundamental in ensuring that the implementation of these innovative solutions is not an exclusive privilege of regions with abundant resources, but a viable reality for everyone. Together, these elements highlight the annual World Water Week theme of "Innovative Solutions for a Water Smart World." It is also worth highlighting that this robot can be used by companies in the industrial and sanitation sectors, environmental agencies, and even NGOs, optimizing the process of acquiring information and measuring environmental impacts, thus improving the veESG (Environment Social Governance) characteristics of these companies. Therefore, this research is related to the annual theme of World Water Week 2023 in terms of innovation criteria, as it is an innovative project with real applicability, and governance, as it can help companies improve their corporate governance, their data, as it is characterized as equipment for remotely acquiring data and providing information and developing capabilities, coronsidering that the design and construction process developed these abilities.

8. What moved you to choose this theme?

The motivation came from personal experience of living in a city surrounded by highly contaminated rivers due to government mismanagement and harmful social practices. Frequent contamination disasters inspired the creation of equipment that could significantly improve the management and conservation of water resources, being a low-cost and easy-to-implement solution in any aquatic scenario.