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PROMOTING TECHNOLOGY EMPOWERMENT THROUGH THE UTILIZATION OF SOLAR-POWERED COASTAL WATER MONITORING SYSTEM

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ABSTRACT

The Solar-Powered Coastal Water Monitoring System was developed to specifically monitor the level and temperature of coastal water in real-time and generate a report from the collected data. The system is designed using an LM35 temperature sensor, PVC pipe with copper wires calibrated at actual metric measurement, a real-time clock, GSM, and a solar panel. The system was installed in a coastal area to test reliability, accuracy, and response time. The sensor was submerged in the coastal water to measure its level and temperature and transmit these data automatically every 6 hours daily or as specified. Selected fisher folks, IT experts, and a BFAR representative evaluated the system in terms of functionality, aesthetics, workability, durability, economy, and safety. The evaluation reveals that the system is excellent, as indicated by the overall mean of 4.40, which means that the system is beneficial to the residents of the community as well as the government agency that directly handles and monitors such information and reports.

Keywords: monitoring system, solar power, coastal water, technology empowerment, microcontroller, and sensor.

1.0 INTRODUCTION

The rapid growth of technology and infrastructure empowers people to spend time in remarkable ways. Due to various technological changes, new applications produced better ways of doing different tasks. One of these is the application of microcontrollers and sensors to monitor and simultaneously come up with helpful information that can provide accurate reports. As demands on the world's water resources increase, the need for effective water management systems becomes increasingly important. This is essential to collect accurate data such as water level and temperature.

The Philippines is abundantly endowed with water resources. It has 18 major river basins, 421 principal rivers, about 79 natural lakes, and extensive coastlines that stretch 17 460 km. The Environmental Management Bureau (EMB) has classified 62% of the 525 water bodies according to their intended beneficial usage. Only five are Class AA, intended for public water supply. Most water bodies are classified as Class C, intended for fishery recreation and supply for manufacturing processes. EMB, through its regional offices, has monitored 238 water bodies for classification or regular water quality monitoring. Depending on the region's resources, monitoring for these water bodies is manually done monthly or quarterly, or as necessary.

Generally, the methods and tools vary based on the water characteristics or parameters being monitored. Usually, it does not take a single method or tool to simultaneously measure the level and temperature. On the other hand, units like DENR and BFAR conduct an on-site analysis of water level and temperature using meters and probes. These tools are being dropped into the bodies of water to get a manual or digital water quality reading only as necessary or as requested. In addition, these methods are only for monitoring. However, it still uses manual recording or a separate application to make an accurate and updated report. This also requires more significant effort to make a reliable report.

With this, there is a need to develop a monitoring system to be used in various applications related to water resource management, safety, and even emergency services. Measurements of these two parameters are particularly useful in analyzing if the waters could support habitat requirements for fish and other aquatic wildlife. Also, the reports generated through the system can be used as the basis for decision-making, such as whether to institute management interventions to improve water quality or to reclassify a water body. This monitoring system will greatly help the community, particularly the residents living nearby coastal waters. It will provide them with awareness and safety, mainly the fishermen who find their source of living in coastal waters. It is also intended to provide direction for individuals, organizations, and agencies responsible for water management, such as BFAR, DENR, and even PAG-ASA.

The study aimed to:

1. Design a system that:

   a) monitors the coastal water level and temperature; and
   b) Generates reports based on the collected data.

2. Create the system using a sensor, solar panel, copper wires calibrated at actual metric measurement, and a microcontroller.

3. Test the system in terms of accuracy, reliability, and response time.

4. Evaluate the system’s performance using the evaluation instrument for a developed prototype in terms of:

   a) Functionality
   b) Aesthetics
   c) Workability
   d) Durability
   e) Economy
   f) Safety

2.0 METHODOLOGY

Virtual prototyping was used to fine-tune the hardware and software architecture. The software components were designed in two phases, coding and debugging. In the coding phase, Visual Basic 6.0 programming language was used to program the embedded system to display the current water level and temperature released by the system. The coded microcontroller was

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attached to the different components of the system to perform its intended function. In the software debugging phase, compatibility between the hardware and software designs was checked to ensure that there would be no problems during system integration. The materials' quality was considered for the hardware design to ensure the machine's durability. The needed materials were canvassed from the different suppliers considering affordability and quality. Three phases were also used to design the hardware part: debugging, prototyping, and implementation.

The debugging phase ensures compatibility and interoperability between components. These components include a solar panel that charges the battery for the power supply of the system; LM35 was used to monitor the coastal water temperature, PVC pipe with copper wires calibrated at actual metric measurement to measure the level of coastal water; a microcontroller that serves as the brain of the system and used to display the variable results in meter for the water level and degree Celsius for temperature reading in LCD and transmit data in the application installed in a computer system, GSM module used to send and receive the data from the microcontroller; and a metal frame to support all the parts of the system. The application is accessed on a single computer, providing a tabular report that can be printed and the average water temperature and level based on the previously collected data.

The prototyping phase improves the planning and execution of the machine by evaluating the design and functionality. To provide enough space for the different hardware components of the system, such as the solar panel, control unit, and battery, the metal frame was designed with a height of 8.3 inches, length of 23.9 inches, and 23.7 inches at the top and bottom, and a width of 12.8 inches.

3.0 TEST RESULTS

The system was tested at the coastal area where the sensor was submerged in the coastal water. Data on the coastal water temperature and tide level were collected every hour to determine the system's accuracy, reliability, and response time. The data collected were used during the testing and evaluation of the system. These data were collected every 5 minutes within an hour, three times a day, particularly at 6:00 – 7:00 AM, 1:00 – 2:00 PM, and 6:00 – 7:00 PM. Thus, there would be morning, afternoon, and night data monitoring.

3.1 Accuracy Test Results for Monitoring the Coastal Water Level and Temperature

The means of collected tide levels have no significant difference from the actual recorded value, as evident in their t-values of 0.016 and 0.089, respectively. Furthermore, the registered margin of error was ±0.15%. These imply that the data collected from the system were accurate.

Table 1. Accuracy Test Results for Coastal Water Level Monitoring

MEAN	SD	ACTUAL VALUE	T-VALUE	P-VALUE	MARGIN OF ERROR
0.667	0.471	0.715	0.016	0.987	±0.15%
0.436	0.496	0.710	0.089	0.930	

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The collected temperature had no significant difference from the actual recorded value on the said dates, as evident in the t-values of 0.015 and 0.042, respectively. The registered margin of error is ±1.28%, which implies that the data collected from the system were accurate.

Table 2. Accuracy Test Results for Coastal Water Temperature Monitoring

MEAN	SD	ACTUAL VALUE	T-VALUE	P-VALUE	MARGIN OF ERROR
30.13	5.07	30.6	0.015	0.988	±1.28%
29.77	5.02	31.1	0.042	0.966	

3.2 Reliability Test Results for Monitoring the Coastal Water Level and Temperature

The correlation coefficient computed using the Significance Correlation Coefficient was 0.387, having a p-value of 0.015. It means that the data provided by the system were consistent, considering the time and date when the data on tide levels were collected.

Table 3. Reliability Test Result for Coastal Water Level Monitoring

CORRELATION COEFFICIENT	N	P-VALUE
0.387	39	0.015

The correlation coefficient computed using the Significance Correlation Coefficient was 0.975, having a p-value of 0.000. It means that the data provided by the system were consistent considering the time and date when the data on temperature were collected.

Table 4. Reliability Test Result for Coastal Water Temperature Monitoring

CORRELATION COEFFICIENT	N	P-VALUE
0.975	39	0.000

3.3 Response Time for Monitoring the Coastal Water Level and Temperature

In addition, the system's response times were recorded when the data were retrieved, and the recorded response times had a minimum of 5 seconds and a maximum of 20 seconds.

The average response times were 7.15 and 6.74 seconds, respectively, meaning the system can respond quickly.

Furthermore, to test for the accuracy of the average of previously collected data, it was compared to the manual way of solving for the average. It was found to come up with the same result. With this, the average was said to be accurate and reliable.

4.0 EVALUATION RESULTS

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The system was evaluated by 20 evaluators, including IT experts, a BFAR representative, and fisher folks. The system's performance was evaluated through a survey instrument with indicators such as functionality, aesthetics, workability, durability, economy, and safety.

4.1 Functionality of the System

The system's functionality was evaluated in terms of ease of operation, provision for comfort and convenience, and user-friendliness, as shown in Table 5. The highest mean of 4.75, interpreted as excellent, was observed in user-friendliness. This means that most evaluators found the system easy to learn and use with less supervision from the implementer. The overall rating of the system in terms of functionality is 4.62, which is interpreted as excellent. This means the system functions as designed, easy to operate, convenient, and user- friendly.

Table 5. Summary of evaluation results for the functionality of the system

CRITERIA	MEAN	INTERPRETATION
Ease of Operation	4.65	Excellent
Provision of Comfort and Convenience	4.45	Excellent
User-friendliness	4.75	Excellent
Overall Functionality	**4.62**	**Excellent**

4.2 Aesthetics of the System

As shown in Table 6, the system's aesthetics was evaluated in terms of color appeal, design attractiveness, and size appropriateness. The highest means of 4.35, interpreted as excellent, was observed at appropriateness of size. This means that most of the evaluators found the system to have a suitable size. The overall rating of the system in terms of aesthetics is 4.13, which is interpreted as very good. This means that the size of the system is very appropriate, and the design is appealing to the eyes of the evaluators.

Table 6. Summary of evaluation results for the aesthetics of the system

CRITERIA	MEAN	INTERPRETATION
Color Appeal	4.10	Very Good
Attractiveness of the Design	3.95	Very Good
Appropriateness of Size	4.35	Excellent
Overall Aesthetics	**4.13**	**Very Good**

4.3 Workability of the System

Table 7 shows the system's workability was evaluated in terms of availability of materials, technical expertise, tools, and machines. The highest mean of 4.45, interpreted as excellent,

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was observed in the availability of technical expertise. This means that most evaluators found the system developer provides high-end devices to lessen the efforts to monitor coastal water levels and temperature. The overall rating of the system in terms of workability is 4.37, which is interpreted as excellent. This shows that the materials used are locally available, the technical expertise needed to make the project work, and the tools, machines, and devices are all readily available.

Table 7. Summary of evaluation results for the workability of the system

CRITERIA	MEAN	INTERPRETATION
Availability of Materials	4.30	Excellent
Availability of Technical Expertise	4.45	Excellent
Availability of Tools and Machines	4.20	Very Good
Overall Workability	**4.37**	**Excellent**

4.4 Durability of the System

Table 8 shows that the system's durability was evaluated in terms of quality of materials, workmanship, and design. The highest weighted mean of 4.55, interpreted as excellent, was observed in the quality of materials. This means the evaluators found the system skillfully made based on the quality of materials. The overall durability of the system is 4.48, which is interpreted as excellent. This indicates the materials' quality, design, and workmanship were considered.

Table 8. Summary of evaluation results for the durability of the system

CRITERIA	MEAN	INTERPRETATION
Quality of Materials	4.55	Excellent
Quality of Workmanship	4.50	Excellent
Quality of Design	4.40	Excellent
Overall Durability	4.48	Excellent

4.5 Economy of the System

As shown in Table 9, the highest mean of 4.30, interpreted as excellent, was observed at both the materials and the machines required. Most evaluators found the system skillfully made based on the materials' quality. The overall rating of the system in terms of economy is 4.28, which is interpreted as excellent. This indicates that the system is economical in terms of the materials needed, time and labor spent, and the machines required.

Table 9. Summary of evaluation results for the economy of the system

CRITERIA	MEAN	INTERPRETATION
Economy in terms of materials needed	4.30	Excellent
Economy in terms of time/labor spent	4.25	Excellent
Economy in terms of machine/s required	4.30	Excellent
Overall Economy	**4.28**	**Excellent**

4.6 Safety of the System

As shown in Table 10, the system's safety was evaluated in terms of the absence of toxic/hazardous materials and sharp edges and the provision of a protection device. The highest means of 4.55, interpreted as excellent, was observed in the absence of toxic/hazardous materials. This means that most evaluators found the system safe in terms of the absence of toxic/hazardous materials, which is very important in the fisheries sector. The overall rating of the system in terms of safety is 4.53, which is interpreted as excellent. This indicates that the system thoroughly followed the provision to protect the aquatic resources and its nearby residents and community.

Table 10. Summary of evaluation results for the safety of the system

CRITERIA	MEAN	INTERPRETATION
Absence of toxic/hazardous materials	4.55	Excellent
Absence of sharp edges	4.40	Excellent
Provision for the protection device	4.35	Excellent
Overall Safety	**4.28**	**Excellent**

4.7 Overall Evaluation of the System

The overall evaluation of the system revealed that the highest mean of 4.62, which was interpreted as excellent, was observed at functionality, implying that the system functions as expected. The overall rating is the system which is 4.40, which is interpreted as excellent. This means that most evaluators found the system beneficial to the community residents and the government agency that directly handles and monitors such reports and information.

Table 10. Summary of the overall evaluation results and interpretation

INDICATOR	MEAN	INTERPRETATION
Functionality	4.62	Excellent
Aesthetics	4.13	Very Good
Workability	4.37	Excellent

Durability	4.48	Excellent
Economy	4.28	Excellent
Safety	4.53	Excellent
Overall Mean	**4.40**	**Excellent**

5.0 SUMMARY OF FINDINGS

In consideration of the objective of the study and the results of the project evaluation, the following conclusions were derived.

1. The system was designed based on its intended purpose: to monitor the coastal water. These data benefited fisherfolks as they rely on living with the coastal resources. Another purpose of the system is to generate reports providing possible trends on coastal water level and temperature.
2. The system was developed using high-quality components such as an LM35 sensor to monitor the coastal water temperature, PVC pipe calibrated at actual metric measurement to monitor the water level, GSM, real-time clock, LCD, and solar panel.
3. Repeated testing and evaluation were done before finally implementing the system for optimum results and improved performance. After improving its performance, the system was found to retrieve accurate and reliable results and had a short response time.
4. The system was evaluated as excellent in terms of functionality, workability, durability, economy, and safety; and Very Good in terms of aesthetics. Overall, the system was rated excellent, with a grand mean of 4.40, and the functionality was found to be the best among other criteria.

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