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AQUAMAG: Smart Water Quality Monitoring through Internet of Things

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Abstract

One of the most fundamental needs of humanity is water. It is essential to provide clean water for human consumption. This research aims to design and build a functional water monitoring system to guarantee a safe water supply. Using the AQUAMAG device and web-based platform, the water quality is assessed in real time, and the current water status is monitored. There is a webpage for viewing all the recorded data from the database for analytical monitoring purposes. At the same time, the device sends a message notification to the user for the water condition update. The evaluation-based ISO 25010 standards showed end-users remarkably accepted the device attributed to the accurate turbidity and pH sensors. This water monitoring mechanism can help the user visualize if the water source is polluted or contaminated through a water quality test. With its efficient application and practicality, it has excellent potential for the community. Hence, a portable and user-friendly device that can be used within households and establishments as an alternative way of checking water quality before using it can be developed. Relatively, the study can raise awareness on water quality in the community through the developed device, which can also avoid illnesses caused by contaminated water.

Keywords: *Internet of Things, Smart Water Quality Monitoring, Sensors, Arduino*

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1. Introduction

According to the World Health Organization (WHO), drinking contaminated water results in 485,000 deaths from diarrhea per year. Far worse, inadequate water quality monitoring contributes to the development of other water-related diseases like cholera, dysentery, polio, and others that have serious negative effects on human health (World Health Organization, 2022). While it is vital to regularly check the quality of the water, there are several factors limiting the capacity to test water quality.

The current situation in the Philippines shows that 91% of the estimated 100.7 million people have access to at least essential water services. However, regional primary water service access varies from 62% to 100% across the nation, making access extremely uneven (WEPA, 2003). In addition, both urban and rural areas frequently experience water pollution. In fact, the Philippine Clean Water Act of 2004 (also known as Republic Act 9275), which aims to protect the nation's water bodies from contamination caused by land-based industry and commercial companies, is one environmental policy the government is pursuing to combat water pollution (Aquino et al., 2014). For instance, in Manolo Fortich, a municipality in the Northern Philippines, regular testing and water monitoring are being conducted by the Municipal Water District and Municipal Environment and Natural Resources Office to ensure good water quality. According to the critical individuals interviewed, they have no control over other elements that may impact the quality of the water when it enters the pipeline. Aside from the regular water testing, an adequate amount of chlorine is also added on a weekly basis. Therefore, to contribute to the fight against water pollution, water sanitation is vital in domestic and commercial spaces.

The establishments that engage in domestic and commercial usage of water need to have a clean water supply to meet the sanitation standards of the Department of Environment and Natural Resources (DENR). Because contaminated water can spread diseases, this act safeguards people's safety. Hence, the development of a portable and user-friendly device that applies Turbidity, pH, and ultrasonic sensors IoT (Internet of Things) as alternative way of water quality monitoring in the households and commercial establishments can give solutions to water sanitation concerns not only in the municipality of Manolo Fortich but in other rural and urban areas.

2. Literature review

All living creatures depend most heavily on water, so it is crucial to manage and conserve it now for future generations. At the same time, water contamination is a significant cause of diseases worldwide. This should not be ignored because diseases caused by contaminated water may be even more dangerous, as it has been proven that water-related diseases such as diarrhea, cholera, dysentery, polio, and others are caused by a lack of water quality monitoring, resulting to major health problems. Therefore, monitoring water quality is of utmost importance (Mohd Tarik et al., 2021).

The digital age has seen significant improvements in the handling of water. To ensure the containment and elimination of impurities, an Internet of Things (IoT)-based smart water monitoring system helped identify and analyze water quality in real time (Jan et al., 2021). In a similar study, the four distinct types of water were evaluated (river water, tap water, pond water, and lake water) using three different types of sensors (PH sensor, turbidity sensor, and flow sensor). Parameters from the water, such as water quality, water flow, and PH, were obtained using these sensors. Examining various water sources can determine if water is safe to use in various contexts. It is simple to determine if the water source is contaminated or polluted with this (Patil et al., 2015). Similarly, Texas Instruments developed an IoT (Internet of Things) based real-time water monitoring system to avoid water loss in water storage tanks and sump pumps. This system can quickly manipulate and analyze the water level utilizing IoT and cloud computing technologies. Additionally, because Internet of Things-based system is fully automated, it might save time and resources by doing away with manual water level monitoring (Supriya, 2020). A method for monitoring water quality with low-cost IoT sensors was also created using Embedded-C, and the written code is replicated using the Arduino IDE. It collects information on the immediate environment's pH, Turbidity, water level, temperature, and humidity (Pasika & Gandla, 2020).

Another design in the development of an IoT application with Visual Analytics for Water Consumption Monitoring is the assessment of water monitoring using a different method, which is done by tracking water usage with the use of an IoT platform with visual analytics. The researchers employed a visual analytics platform after processing data from a Hall Effect water flow sensor mounted to every faucet using a NodeMCU (Tasong & Abao, 2019). For those residing in Bangladesh's outlying areas, where there is a lack of safe drinking water, a microcontroller-based water quality monitoring system was created. The instrument, which was meticulously designed, is sensitive to a number of water properties, including temperature, Turbidity, and hydrogen potential. The pH was shown on the Liquid Crystal Digital (LCD) panel. Finally, sensor levels and errors are calculated by comparing each attribute value to the equipment (Dey et al., 2018).

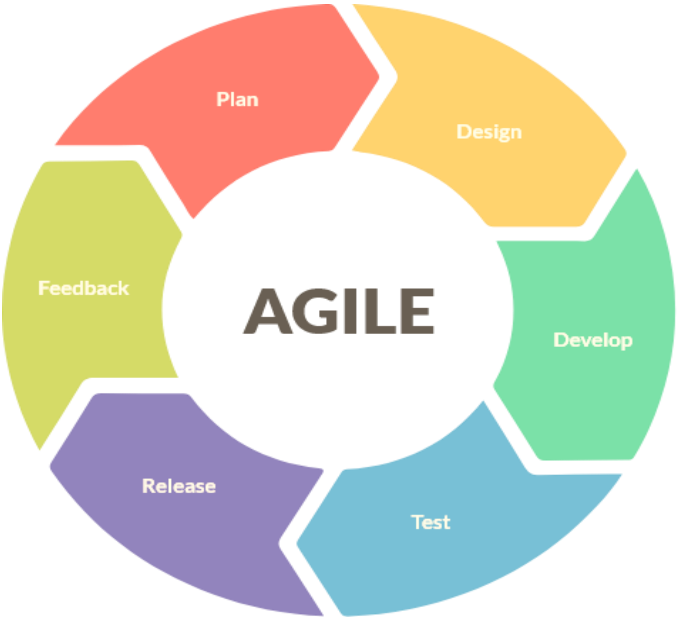
Monitoring dams is highly significant in critical situations such as water overspill and water shortages. Water level monitoring and managing dams are possible using IoT and information technologies that deploy intelligent sensor networks based on existing systems (Akhila, 2018). Approximately 65-70% of water pollution is caused by residential sewage, with the rest originating from industrial sources such as tanneries, textile mills, food processing plants, distilleries, chemical, and metal companies, and solid waste dumped directly into rivers. This harms people's health, leisure time options, and the environment and results to financial consequences. According to the Philippines Environment Monitor, the yearly cost of water pollution's adverse economic effects is projected to be PHP67 billion (more than USD1.3 Billion). The yearly economic cost, according to a World Bank analysis in terms of poor sanitation in the Philippines, is almost USD1.4 billion, which is one of the leading causes of pollution in urban waterbodies (Jalilov, 2018). All of these studies are crucial for laying the theoretical groundwork for creating AQUAMAG, a smart water monitoring device that can assess the water's purity using a turbidity sensor and its acidity or alkalinity using a pH sensor. The data are recorded in a database, and a short message service notification is sent to the end user. Additionally, the result is displayed on the device monitor.

3. Methodology

In this study, an agile development approach builds the project's hardware counterpart and develops the software application that comes with it. Agile methodology is an effective process for teams looking for a flexible product development approach (Eby, 2017). It gives a good overview of how the hardware works and allows the developers to maneuver the project, starting from hardware development to software development and improving both.

Figure 1

Agile Methodology



Source: https://www.zucisystems.com/software-development/agile-methodology

The study used an agile methodology with slight modifications to design the Smart Water Quality Monitoring through the IoT hardware and software. The methods and phases in this study are based on the frame shown in Agile Methodology.

Plan. In the planning phase, the researchers systematically developed the AQUAMAG device through proper planning and meeting to meet the requirements and cascade accomplishments. The development target activities are clearly specified through a Gantt chart.

Design. In this phase, there were two approaches taken in designing the AQUAMAG: one was visual design, and the other was the architectural structure of the application. The project manager convened the rest of the team at the first iteration and presented the requirements created during the prior stage. The team then debated the best strategy for achieving these objectives and suggested the tools required. The project designer also designed the user interface. It is critical to evaluate user interface and experience when they are done correctly and, more importantly, when they are not. The basic design is improved each time to incorporate the new functionality.

Figure 2

System Architecture

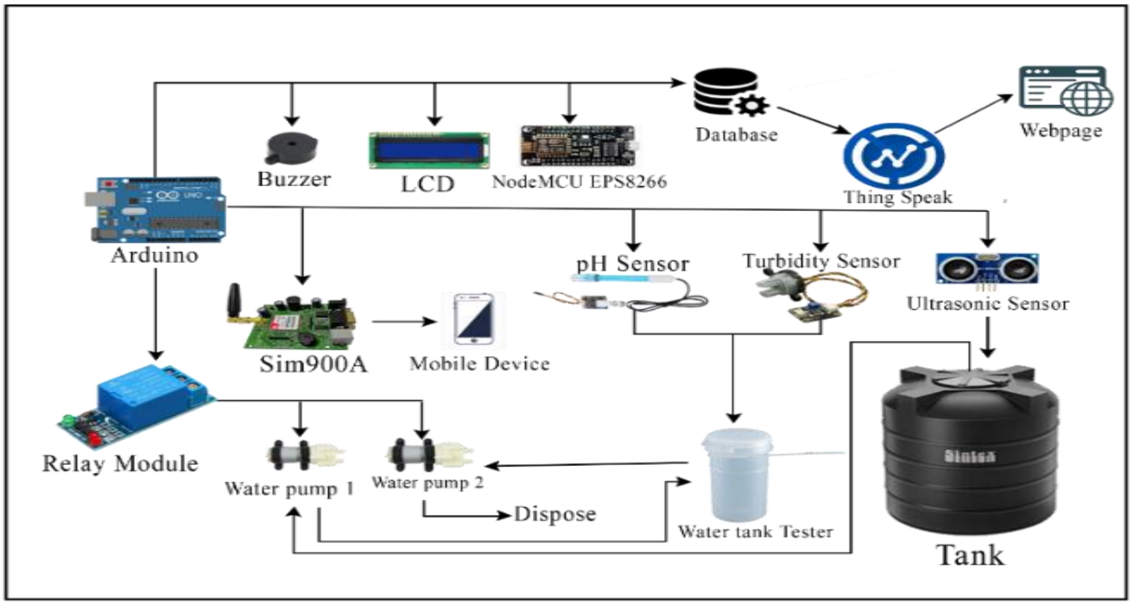


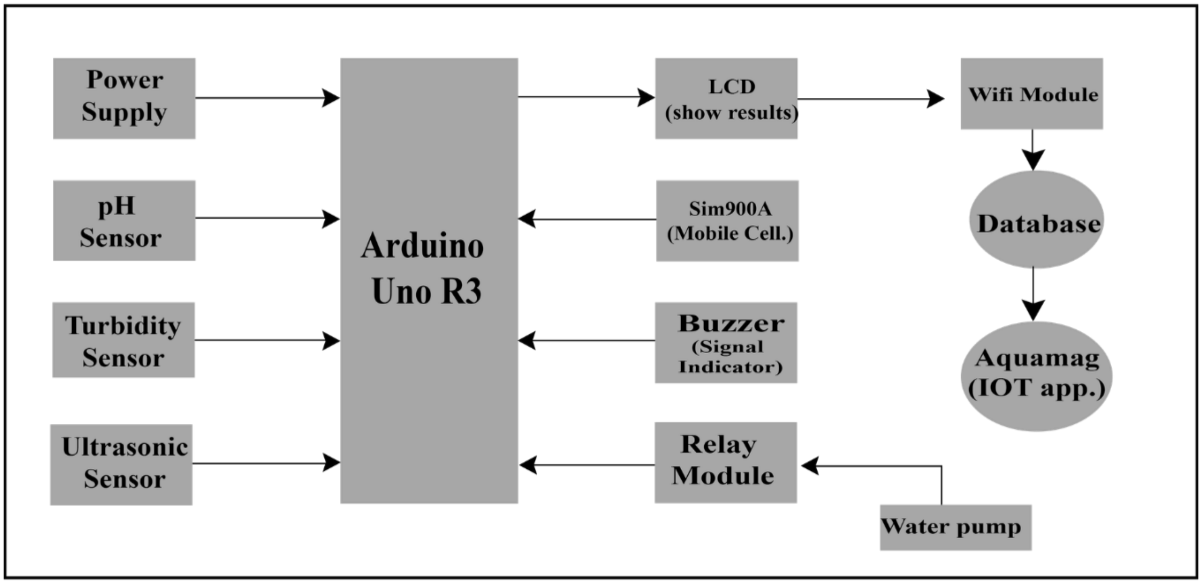
Figure 2 shows the architectural system design of the AQUAMAG device. The diagram shows each system's significant hardware component with their specified connections to make the project work properly. The first water pump brings water into the main tank and into the water tank tester when the switch is turned on. Then, the sample water is tested using the pH and turbidity sensors. The ultrasonic sensor subsequently gets the water level from the main tank. The Ultrasonic, Turbidity, and pH sensors are all attached to the water tank. When the Ultrasonic sensor detects that the water level is low or full, the buzzer warns the users. The Turbidity sensor is triggered if Turbidity is detected. On the LCD, the pH sensor, which gauges the water's acidity or alkalinity, is also shown. If there are alarming outcomes regarding the water condition, Sim900A sends a message to alert the user that the water condition is at high risk. All gathered data are sent to the web page.

Figure 3 shows the block diagram that identifies the flow of information between the systems. The real-time water quality monitoring concept in an internet of things context is described. Numerous sensors (including pH, Turbidity, and ultrasonic) are shown in the schematic connected to the core controller and the relay module, buzzer, and SIM900A. The core controller accesses the sensor values and processes them to transmit data via the internet.

The central controller is an Arduino. Viewing of the sensor data is possible via the LCD and WiFi systems. It can also send message notifications for the update of data results.

Figure 3

Block Diagram



Develop. Through this phase, multiple tests for the hardware, software, alterations, and changeovers are done within the duration of the project. The researchers ultimately decide what concept design they construct and implement by considering the working prototype model used in the previous phase. The developers go through multiple brainstorming and discussions to complete the hardware design constructed. The webpage is also developed in this phase, considering the methods and workflow concluded for the application. The developers used the following sensors and items to build the AQUAMAG device:

Turbidity Sensor SKU: SEN0189- Turbidity is a metric used to assess a liquid's relative clarity. It is a measurement of the amount of light scattered by the components of water when light is shone through a water sample. It is an optical property of water. The Turbidity increases with the intensity of the scattered light. This sensor measures the amount of light dispersed due to the solid particles suspended.

Ultrasonic Sensor HC SR04- It is an electrical tool that uses ultrasonic sound waves to estimate a target object's distance. It then turns the reflected sound into an electrical signal. The tank is measured, and its water content determined.

pH Sensor SEN0161 - The pH scale measures the proportion of free hydrogen and hydroxyl ions in water. Water that contains more free hydrogen ions is acidic, whereas more free hydroxyl ions make water more basic. Since chemicals in the water can alter pH, pH is a crucial sign of a chemical change in the water. This determines the alkalinity and acidity of the water in the tester.

SIM900A – This module provides information by sending warning messages to the user for the water status update.

LCD – The Liquid Crystal Display serves as the primary monitor where users can view the result of the water condition from the three sensors.

Buzzer – This device is used as a warning and alarm sound to signal users when the water tank is full or empty.

Water Tank Tester – This component acts as a tiny water tank in which the two sensors, pH and Turbidity, are placed for easy water monitoring of the water quality. This is a safety measure to protect the sensors from getting wet.

Water Pump – This water control device drains or removes the water that emerge from the water tank tester using pumping or evaporation.

Arduino Uno R3– This microcontroller serves as the device's brain, where all the different sensors' codes are put to command and give signals to determine the water level and condition of the water quality.

ESP8266 D1 Mini – It served as both the voltage reader for the battery and the WiFi module to send information to the web page and database through a localized WiFi network.

The developers interpreted the working design module into codes. They used a detailed software IDE to code the Arduino Uno R3 and the ESP8266 WiFi module and used the trial and error method to find the best suitable values for the limitations inputted to the source code to enable the water monitoring device to work as desired. These coding processes for the microprocessors were done iteratively. The web page has its supporting HTML script encoded in the ESP8266 D1 Mini and is accessible through the localized WiFi by entering the Arduino IDE serial monitor's router IP address. To view the values stored in the database, a PHP script is executed through the use of the web browser on a computer where the localized database is also running.

Figure 4

The Hardware setup of AQUAMAG Device

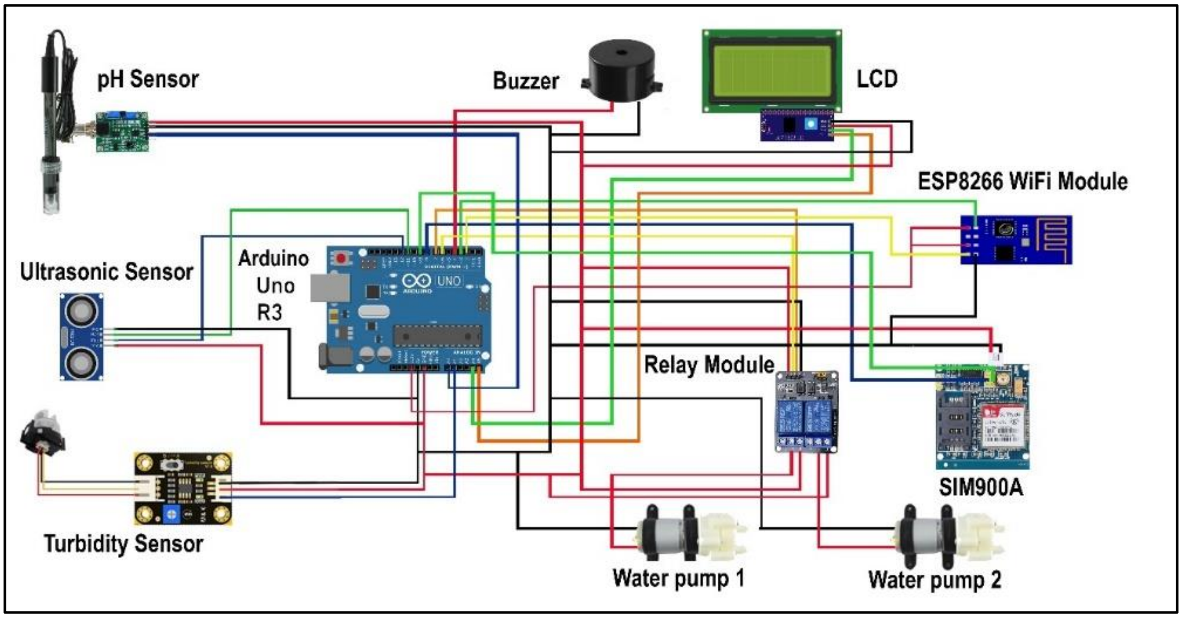


Figure 4 shows the overall hardware circuit connections of the device, starting from the Water pump 1. This is connected to the relay module, which is connected to Arduino Uno. All three sensors, the buzzer, the SIM900A, and the ESP8266 WiFi module are connected to the Arduino Uno. Water pump two disposes the water from the water tester tank. The project needs 12 volts power supply to power up the system.

Test. In testing the system, the study selected 30 respondents, which are composed of 15 workers from the Manolo Fortich Water District and another 15 from City Environment and Natural Resources Office - Department of Environment and Natural Resources (CENRO-DENR), selected through purposive sampling. The ISO/IEC 25010 evaluation, which was broken down into 8 characteristics, was employed to ascertain the quality traits and properties of the software program. *Functional suitability* measures how well a system or product satisfies all necessary requirements when used under certain circumstances. *Performance Efficiency* measures a system's performance concerning the number of resources it consumes when operating in a given environment. The degree to which a product, design, or element may share data with other goods, systems, or components and carry out its functions in the same software or hardware environment is referred to as *Compatibility*. *Usability* is the degree to which particular users can utilize a system or product to accomplish certain goals with productivity, usefulness, and satisfaction for a specific setting. Reliability is the extent to which a system, product, or component performs given functions for a particular duration under certain circumstances. *Security* is the degree to which a system or product secures data so that users, other systems, and products have the appropriate data access for their authorization levels and types. *Maintainability* means the effectiveness and efficiency with which a system or product may be fixed, enhanced, or modified to meet new needs and conditions. *Portability* is how easily and effectively a system, product, or component can be transferred from one operational or usage context to another, depending on its Portability (ISO 25000, 2021).

Figure 5

The scale of pH Sensor

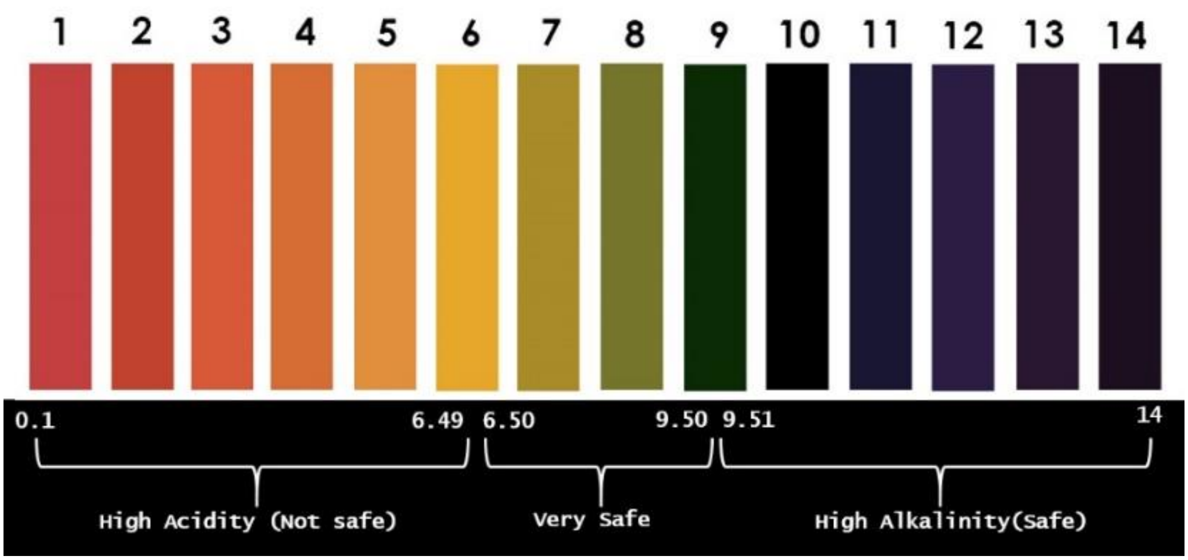


Figure 5 shows the scale measurement of the acidity or alkalinity of the water with a value between 0-14. The calculation is an acidity balancing test or the alkaline content of the hydrogen ions in the water (Cloete et al., 2016). The source of pH natural for water is about 7. pH ranges from 6.5 to 9.5 can be considered safe water for drinking (Bande, 2016). The source of pH is low (0) for acidic and high (14) for alkaline solutions. Water begins to turn more acidic as the pH value falls below seven. Any value over seven indicates a higher alkaline level. Different pH sensors operate in various ways to gauge the water's quality. Measurements of the water's Turbidity are used to determine the intensity of infrared light reflected at a 90-degree traversing beam (ISO 7027 technique).

Figure 6

Testing of Water Sample

Figure 7

Displaying of Result

Figure 6 shows the interface of getting a water sample when the researchers conducted the testing while Figure 7 shows the actual reading of water status, getting the data to result using the pH, ultrasonic, and Turbidity sensors. Meanwhile, Figure 8 shows the data results that were sent through SMS after the device tested the water quality. It contains the acidity and turbidity level reading of the water sample. Figure 9 shows the ThingSpeak application with the actual result in graphical form of the water using the pH sensor from the different buffer solutions. ThingSpeak is an open data analytics platform for the internet of things devices to communicate with a programming application interface to keep and analyze the collected data.

Figure 8

Short Message Service Notification

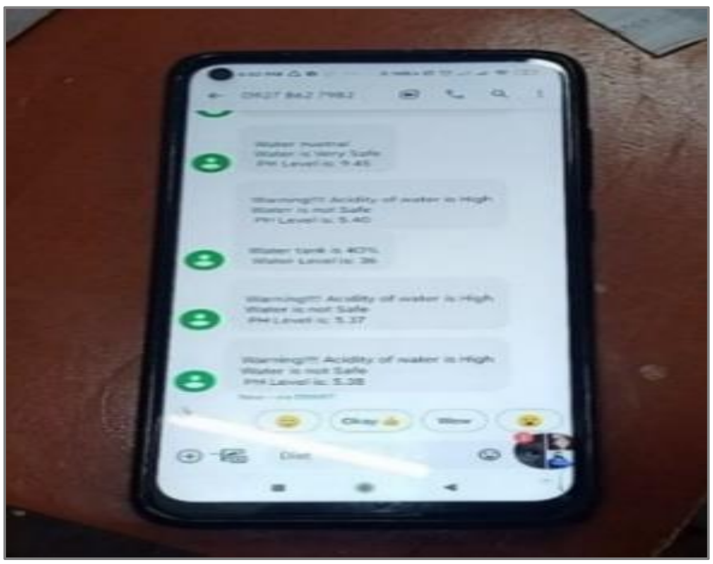
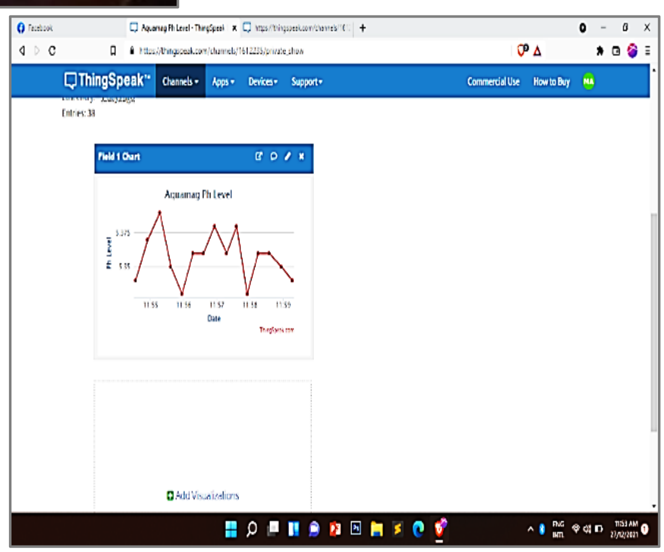


Figure 9

ThingSpeak Application Result



Release. In this phase, user training is conducted to make it easier for the users to use the device. This is done by providing a guide or user manual and giving them step-by-step directions on how it works. This Smart Water Quality Monitoring through the Internet of Things provides an alternative way of water quality and water level monitoring to those who need it at their convenience. This can be used primarily in isolated areas where local supply is scarce and water quality is still being determined. For the time being, this is used in the domestic, commercial space, and academic institutions within the Municipality of Manolo Fortich for further efficiency testing and more data analysis. This information can be used to improve the project prototype further if ever used on a more significant measure soon.

Feedback. Based on the comments and testing evaluation of the key persons from the Manolo Fortich Water District and Municipal Environment and Natural Resources Office - Department of Environment and Natural Resources (MENRO-DENR) who are experts in the field of water monitoring and testing, the device performance in testing the Turbidity and acidity level of the sample water is good. In terms of the functionality and usability of the device, it is very good and easy to use. The device is also commended as good in terms of being reliable in testing results. Portability is also commended as good, but further enhancement of the device size must be considered for better portability in transportation, especially in far-flung areas of the municipality.

Figure 10

Testing and Feedback

Figure 10 shows the actual testing and feedback of the system by the Manolo Fortich Water District and MENRO-DENR representatives with years of experience in water monitoring and testing.

4. Findings and Discussion

Table 1

AQUAMAG Water Testing Result

Test	pH	Turbidity	Date
Test 1	6.92 (Very Safe)	3.05 (Very Clear)	November 17, 2021
Test 2	6.86 (Very Safe)	3.13 (Very Clear)	November 24, 2021
Test 3	7.14 (Very Safe)	3.30 (Very Clear)	December 1, 2021
Test 4	7.17 (Very Safe)	3.32 (Very Clear)	December 9, 2021
Overall Mean	**7.02 (Very Safe)**	**3.20 (Very Clear)**	

The water quality testing was conducted on the water sample of the municipality during the 4-week testing using the AQUAMAG device. The municipal water source got a very safe water quality result, with 6.92 as the lowest and 7.17 as the highest. The overall mean for the water acidity testing is 7.02, which is safe for drinking. The Turbidity of the water tested was overall very clear, with results from 3.05 as the lowest and 3.32 as the highest. The overall mean of the water turbidity testing is 3.20 NTU, within the acceptable turbidity level of less than 5 NTU. The device was also tested with an acidic and dirty water sample by putting lime juice and mud in the sample water. It was able to determine that the sample water was acidic and dirty.

Table 2 shows the result of the evaluation-based ISO 25010 standards. There are eight items in the figure, namely: Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability. The Functional Suitability of the device as perceived by the user-respondents got a weighted mean of 3.37, which has a "Strongly Agree" verbal interpretation, given that the device functions well based on its purpose. The respondents highly commended the functionality of the device. The Performance Efficiency of the device got a weighted mean of 3.51 with a "Strongly Agree" verbal interpretation based on its efficiency in producing fast results. The Compatibility of the device gained a weighted mean of 3.60, which is verbally interpreted as "Strongly Agree" based on all the data gathered and processed.

Table 2

AQUAMAG Evaluation System ISO/IEC 25010

Area	Mean	Verbal Interpretation
Functional Suitability	3.37	Strongly Agree
Performance Efficiency	3.51	Strongly Agree
Compatibility	3.60	Strongly Agree
Usability	3.47	Strongly Agree
Reliability	3.21	Agree
Security	3.31	Strongly Agree
Maintainability	3.24	Agree
Portability	3.24	Agree
OVERALL RATING	**3.36**	**Strongly Agree**

Legend: Strongly Disagree (SD) 1:00 – 1.75, Disagree (D) 1.76 – 2.50, Agree (A) 2.51 – 3.25, and Strongly Agree (SA) 3.26 – 4.00

The Usability of the device gained a weighted mean of 3.47, which is interpreted as "Strongly Agree" since it is usable enough for actual implementation. The device's Reliability gained a weighted mean of 3.21 with an "Agree" verbal interpretation. The device is reliable in terms of consistent quality results. The Security of the device gained a weighted mean of 3.31, which is interpreted as "Strongly Agree." The Maintainability of the device gained a weighted mean of 3.24, which is verbally interpreted as "Agree" since it is easy to maintain. The Portability of the device gained a weighted mean of 3.24 and an "Agree" verbal interpretation for not requiring additional rework.

Among the eight items, the Compatibility component garnered the highest mean value of 3.60, representing a verbal interpretation of "Strongly Agree." This indicates that the device is compatible because it meets the desired functional requirements, while the Reliability, among all indicators, obtained the lowest mean of 3.21. But in general, the device achieved a grand mean of 3.36, with the verbal interpretation of "Strongly Agree." This indicates that the device is deployable and highly acceptable.

5. Conclusion

Based on the result from the table representation of AQUAMAG device readings, testing, system evaluation, and numerous testing by the researchers, the system is commended and accepted by the representatives of Manolo Fortich Water District and Manolo Fortich CENRO-DENR. During the testing and system evaluation, it received high ratings from the user-respondents. This shows that the developed device could provide an alternative way of water testing and monitoring where the end-users can conveniently and efficiently do the testing through this portable device. The gathered information is substantial for the study to conclude that the AQUAMAG device is significant, accessible, and convenient for monitoring the water level and its quality. With its accessibility, users can view the data offline and online through LCD and SMS. In addition, the application interprets the data into simple words for the user to understand the details quickly. One of the possible additional features to the project for future research is the water level indicator using LED for the user to see if the water level is full or empty. Furthermore, adding a flow sensor to determine the user's water consumption is recommended. Users can also add an uninterruptible power supply (UPS), back up of a power supply and helps prevent system failure despite a power outage.

6. Acknowledgement

This study is part of a capstone project as a requirement for the course. As such, the researchers are truly indebted to their instructors, family, and friends for their support, commendable ideas, uplifting correction, and hands-on aid during this study.

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Fabrication of Battery-Operated Roof Paint Sprayer with Automatic Charging Off System

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Abstract

The study was conducted at Barangay San Juan, Aborlan, Palawan, and was evaluated from April to December 2021. Fabrication of the device was based on the needs of roof painters to lessen their exposure to sunlight during roof painting. The roof paint sprayer was divided into three major parts. First, the container served as overall part with hand carry at the top, which weighs 6 kilograms when empty but approximately 11 kilograms when full. Second, the direct current motor is rated 60 W, 12 V nominal, maximum flow of 5 liters per minute, and a maximum pressure of 116 psi. The base of the motor was fitted at the bottom while the hole of the first container is connected to the inflow of the motor, and a hose with an adjustable nozzle is connected to the outflow. Third, the power source consisted of a connector cord, female socket, 12V transformer, circuit board, green LED, $12V_{dc}$ battery, battery indicator, and switch. The performance evaluation of the device revealed during testing showed that at the start the roof paint sprayer works smoothly and sprayed almost 1/3 area of the target area (10×3 meters) for almost 2 minutes but suddenly as it sprayed, the dc motor starts difficult to run until it stopped. The major benefit of the device, if studied further, will spray faster on roofs and smooth output.

Keywords: *Roof paint sprayer, Paint, Motor, Battery, Container*

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1. Introduction

The looks of the building depend on the appearance of the roof. Nowadays, there are different types and designs of roofs, especially in urban areas. However, not only the types and designs of roof give the beauteous of the building, added to it is the paint of the roof that extends the life of the roof and adds to its aesthetics.

A roof coating is a monolithic, fully adhered, fluid-applied roofing membrane. The most common roof coatings in the market today are elastomeric. This means coating has elastic properties that allow it to stretch and return to the original shape without damage. Roof coatings are particularly important in climate zones that experience dramatic weather conditions. This roof coating is considered the top layer of a composite roof membrane and underlying system. It acts as the first line of defense against the impact of sunlight (both infrared and ultraviolet (UV)), rain, hail, and physical damage. The process of installation is referred to as cold-process (Thiesen, 2021).

Even in shelters, roofs are painted using a broom. Even though lot of time spent on painting the roof and enduring the heat of the sun for a very long time, the output is not entirely smooth. The mostly available in the market today are airless sprayers. According to the National Coating Corporation (2020), airless spray units are powered by either an electric motor or gasoline engine. While the electric motor may be less prone to the complexities associated with a gasoline engine, it may require a very long extension cord. There is an appreciable electrical current drop when the long extension cords are used. This can adversely affect the motor’s efficiency. By contrast, the gasoline airless sprayer is fully self-contained. However, portable machine roof paint sprayer can give a smooth finish because the paint will atomize. In addition, the painting time is also less. It is portable with no extension cord needed that is used freely on the perimeter of the rooftop.

The long exposure to sunlight is unhealthy; thus spraying too long on the roof under the sunlight is risky. Some sunlight can be good as long as there is proper protection from overexposure. However, too much UV exposure can cause sunburn. The UV rays penetrate outer skin layers and hit the deeper layers of the skin, where they can damage or kill skin cells. People who do not have much melanin and sunburn easily should protect themselves. People can protect themselves by covering sensitive areas, wearing sunblock, limiting total exposure time, and avoiding the sun between 10am and 2pm. Frequent exposure to ultraviolet rays over many years is the chief cause of skin cancer, which should not be taken lightly (National Library of Medicine, 2022).

Lifting heavy items is one of the leading causes of injury in the workplace. In 2001, the Bureau of Labor Statistics reported that over 36 percent of injuries involving missed workdays were the result of shoulder and back injuries. Overexertion and cumulative trauma were the biggest factors in these injuries. Bending, followed by twisting and turning, was the more commonly cited movement that caused back injuries. Strains and sprains from lifting loads improperly or from carrying loads that are either too large or too heavy are common hazards associated with manually moving materials. When employees use smart lifting practices, they are less likely to suffer from back sprains, muscle pulls, wrist injuries, elbow injuries, spinal injuries, and other injuries caused by lifting heavy objects (UNC, 2022).

Figure 1 shows the battery-operated roof paint sprayer with automatic charging off system that could be a solution to speed up a roof painting. It is made of plastic that uses only a direct current motor. The lightweight construction of this portable roof sprayer gives an advantage during working or spraying on the rooftop because the painter can freely walk on the roof without prioritizing the cable or extension wire.

Figure 1

The Battery-Operated Roof Paint Sprayer

Given the benefits and requirements for an ideal roof paint sprayer, this study was formulated to design and fabricate a battery-operated roof paint sprayer, conduct cost estimates of the battery-operated roof paint sprayer, test the time to empty the tank, and determine the power consumption of the machine.

2. Literature review

2.1. Spray Paint in a Can

Edward Seymour invented the first canned spray paint in 1949 in aluminum color. Edward Seymour's wife Bonnie suggested the use of an aerosol filled with paint. Afterwards, Edward Seymour founded Seymour of Sycamore, Inc. of Chicago, USA, to manufacture his spray paints (ThoughtCo., 2022).

According to Ortiz (2022), while modern spray paint did not exist until the middle of the twentieth century, its earliest uses date back to that decade. Joseph Binks, a decorating director for a retail business at the time, created a hand pump that could quickly whitewash the walls of his establishment. In search of a more effective technique to wax his skis, Norwegian inventor Erik Rotheim created this useful piece of technology in 1927. Meanwhile, the first person to apply paint quickly using a pressurized aerosol bottle was Edward Seymore of Sycamore, Illinois, in 1949.

According to Mag (2018), spray painting first appeared in early 1887. The hand-pump device that sprays paint with the aid of cold water was created by Joseph Binks. Accordingly, Francis Davis Millet, who served as the decoration director for the World's Columbian Exposition in Chicago, made use of his creation six years later, in 1893. Binks assisted Millet in using the equipment to spray whitewash on the Exposition's structures. The invention of aerosol paint, which is launched through a compressed aerosol in a can, belongs to Edward Seymour. When Seymour and his wife had the wonderful idea to combine paint and aerosol in a can and add a spray head, they were the owners of a paint company called Sycamore III.

2.2. Spray Paint using Spray Gun

According to Paint Spray Pro (2022), from the 1920s until the 1960s, paint sprayers on the market had some unusual evolution. Users may easily switch up paint sprayers to easily spray different colors. Smaller versions for the kitchen were created once it was discovered that food colors could be used in paint sprayers. Fire retardants and other safeguards were applied by fabric manufacturers using spray guns. Additionally, the Second World War gave rise to a novel future industry: vehicle paint sprayers.

According to Clark (2000), it was in 888 in Toledo, Ohio, when a croaker, Dr. Allen DeVilbiss, specializing in treatment for observance, nose, and throat diseases, was frustrated with his sweat to rehabilitate his cases' sore throats. However, it snappily passed over their throats and was swallowed if he gave them the drug in liquid form. To palliate this, DeVilbiss combined the rubber bulb, some tubing, and the base of an oil painting to construct the first atomizer. By squeezing the bulb, the air was propelled over the top of the tubing, lowering the atmospheric pressure and causing the drug to rush overhead to fill the partial vacuum. In 1907, DeVilbiss' son Thomas expanded on his father's invention and created the first hand-held, air-powered spray gun. By blowing compressed air across the top of a volley tube submerged in liquid, he created a controllable pattern of atomized material. In 1919, Binks introduced his first-hand spray gun using compressed air and vended it to a manufacturer to apply carpet color.

In the 1930's it became possible to change colors easily through the Binks Model 7 as well as the DeVillbiss Model MBC. Both models had flexible spray heads. It was in the 1930s that the High Volume of Low-Pressure spray guns became known while the 1940s saw an increase in the sale and manufacture of spray guns as people found various areas of application for this device. In the 1960s, electric spray guns became a thing. Electric spray guns only needed high voltage and they formed the basis for powder painting that gained prominence in the 80s. In the 90s, spray guns blew up and they became extremely popular. (Smithequipment, 2020).

According to How to Paint Info (2018), airless spraying (figure 2) is the fastest way to paint any roof. Spray in the direction of the iron's flutes in a section that is approximately one-meter wide to move down the sheet. The joins in the iron can serve as a guide.

Figure 2

The Airless Paint Sprayer

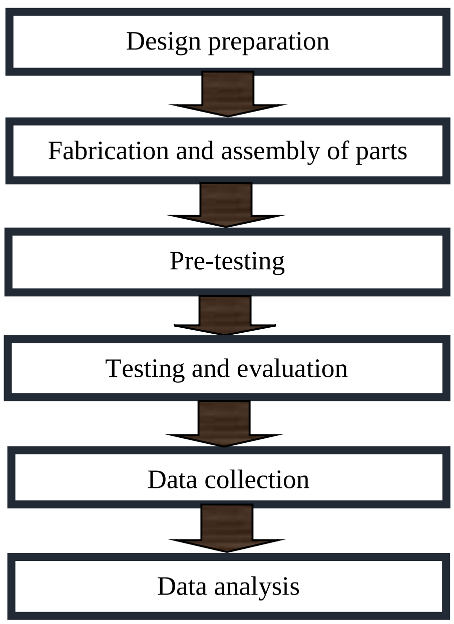
Source: Excerpt from Bunnings Warehouse

3. Methodology

Figure 3 shows the research paradigm that enumerates the activities on the preparation of the device including design preparation, fabrication and assembly parts, pre-testing, testing and evaluation, data collection and data analysis.

Figure 3

Paradigm of activities



Design Preparation. Using the electrical, electronics, and mechanical theories, the analysis of the design to fabricate the battery-operated roof paint sprayer was introduced. This step used experimental research design.

Fabrication and Assembly of Parts. This starts from drawing the layout, physical layout and the smallest detail of fabrication that include: (1) prepare two blue containers by removing the faucet of the first tank then cut the second tank by one inch from the base to at least six inches to the bottom cover; (2) prepare the assembly of a container; the first container on the top then make a hole at the base for linking a hose while cut the second at the bottom for the compartment of electrical means and the first cut for cover; (3) unite two containers by bolts and nuts with washers; (4) secure direct current motor and 12 volts battery; electrical components and transformers were bolted and nutted at the side then position mini digital voltmeter, switches, terminal block, led, and fuse holder at the side; (5) use male adaptor for connecting 220 volts of power supply; (6) rectify 220 volts to charge the

12 volts battery; (7) serve the light-emitting diode (LED) as the charging indicator, while a mini digital voltmeter as battery monitoring; and lastly (8) clip hose in the inflow and outflow of the motor going to an adjustable spray nozzle.

Pre-Testing. Pre-testing of the device determines if the device functions as expected and also to anticipate other problems that may occur during testing.

Testing and Evaluation. The battery-operated roof paint sprayer was tested twice for primer paints and twice for water base paints, and then the output was evaluated. The four trials need 4 gallons of paints and 4 liters of paint thinner. The area or roof for testing was conducted at the researcher's place.

Data Collection. Every test was filled with 6 liters of paint in the container (1 gallon of paint plus water or thinner).

Data Analysis. Data gathered were tabulated, summarized, and analyzed using mean and theoretical electrical, electronics, and mechanical engineering know-how.

4. Findings and Discussion

4.1. Machine description

Figure 4

Battery-operated Roof Paint

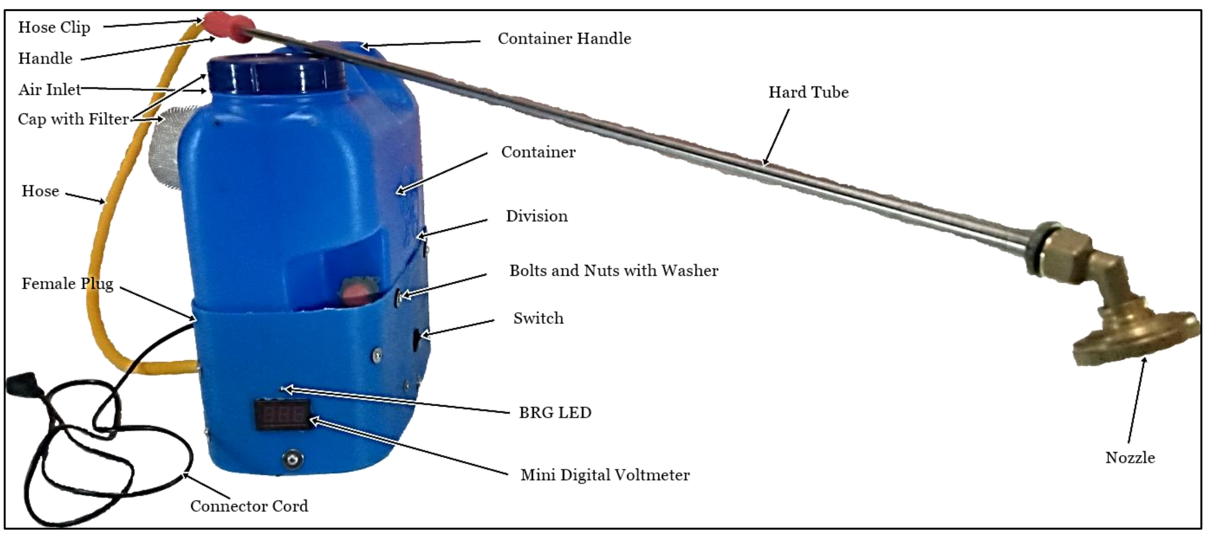
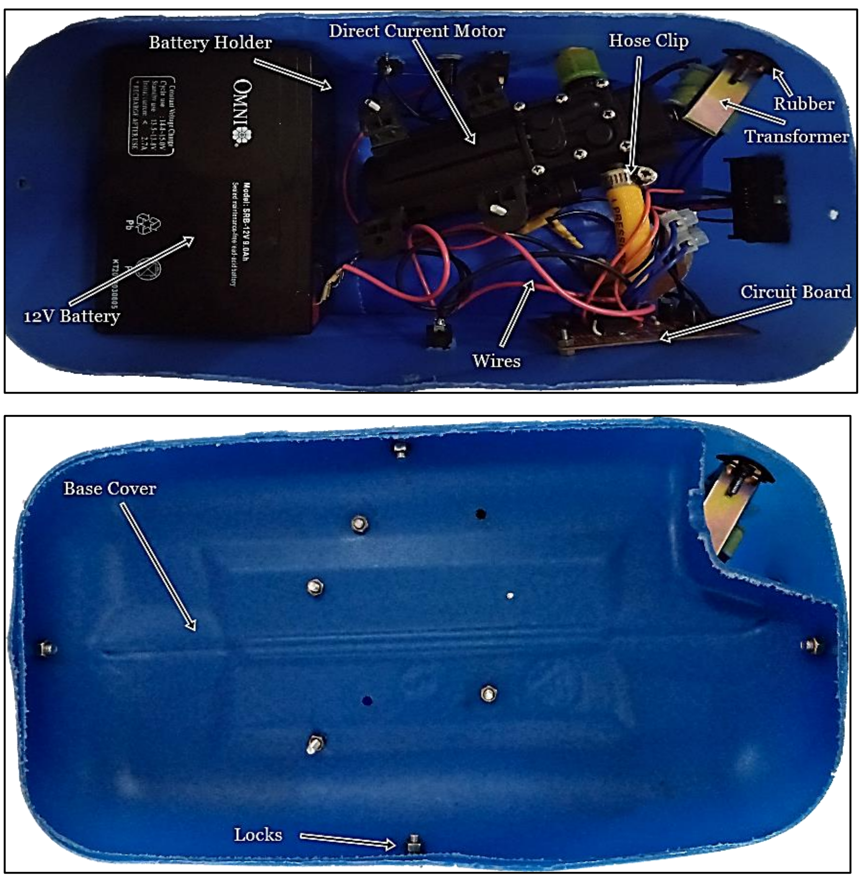


Figure 4 shows the battery-operated roof paint sprayer made handy. It is divided into three major parts: the container, the direct current motor, and the power source. The container served as the overall parts of the sprayer with a hand carry at the top for easy holding. It weighs approximately six (6) kilograms when empty but approximately eleven (11) kilograms when full with 5 liters of paint. The shape of the top and bottom are identical, with a width of eighteen (18) cm and twenty-five (25) cm in length. The overall height of the container is approximately thirty-eight (38) cm. The direct current motor is rated 60 W, 12 V nominal, maximum flow of 5 liters per minute, and a maximum pressure of 116 psi. The base of the motor fits at the bottom. The hole of the first container is connected to the inflow of the motor, and the hose with an adjustable nozzle is connected to the outflow. The power source consisted of a 12 V direct current battery, a female socket for the connector cord, a connector cord for connecting a 220 V alternating current supply, a 12 V transformer, a circuit board, a green LED which served as a charging indicator, a battery indicator, and a switch which turns ON/OFF the device.

4.2. Machine Parts and Function

Figure 5

The Machine Parts



The main parts of the machine are the following:

1. 12 V Battery – it is the power source of the device. It supplies 12 V direct current to the direct current motor.
2. Air Inlet – it is an air passage to avoid shrinking of the tank.
3. Base Cover – it is a cover to protect the electrical components of the sprayer.
4. Battery Holder – it is a shelf for holding the 12 V battery.
5. Cap with Filter – it is for opening and closing of the tank where mixture fills in and plastic filter for removing small particles from mixtures.
6. Circuit Board – it is a board on which electronic components are mounted and interconnected to provide a connection to the charging and operating of a direct current motor.
7. Container – it is held for fluids storage.
8. Container Handle – it is used to carry the container during operation.
9. Direct Current Motor – it is a motor that operates from a direct current power supply only.
10. Division – it is a division from fluid to the compartment of motor, battery, and circuit board.
11. Female Plug – it is a plug whose contacts are separated by a recess into which the prongs of a mating male plug are inserted.
12. Handle – it is used to pick up the nozzle sprayer.
13. Hard Tube – it is a long hollow cylinder used to transport fluids where the nozzle is installed.
14. Hose – it is a flexible tube made of rubber, through which fluids can flow.
15. Hose Clip – it is a grip that holds the hose firmly to avoid leakage of fluid during the operation of the sprayer.
16. Locks – it is used to fasten the base cover.
17. Nozzle – it is a short-tapered tube that directs or accelerates the flow of a fluid.
18. Switch – it is used to start or stop the direct current motor.
19. Transformer – it is a device that uses electromagnetic induction to transfer electrical energy from one circuit to another (i.e., without a direct connection between them).
20. Wires – it is a strand of metal, usually copper, that is encased in plastic or another insulating material and is used to carry an electric current.

Minor parts of the machine are:

1. Bolts and Nuts with Washer – it is used to tighten the electrical components and the base cover.
2. BRG LED (Blue Red Green LED) – it is a light-emitting diode (LED) that serves indicator during charging from red to green light when it is fully charged.
3. Connector Cord – it is an insulated cable used as an adapter to connect between the outlet and the female plug of a sprayer.
4. Mini Digital Voltmeter – it is an instrument that measures and shows battery strength.
5. Rubbers – it is a solid elastic material made and used as insulator materials in battery terminals, the base of a transformer, and the base of a circuit board.

4.3. Bill of Materials

The item description, quantity, unit cost, the total cost of fabrication of battery-operated roof paint sprayer with automatic charging off the system, with a total cost of ₱10,000.00 is shown in Table 1.

Table 1

Bill of materials

Description	Quantity	Unit	Unit Cost (₱)	Total Cost (₱)
8 Holes Water Sprayer High Pressure Spray Head Nozzle for Garden Agriculture Irrigation Use	1	pc	₱265.00	₱265.00
Auto Wire #18	1	m	₱26.00	₱26.00
Blue Container w/ Faucet	1	pc	₱165.00	₱165.00
Capacitor 35 V, 220 μF	1	pc	₱15.00	₱15.00
Cassette Cord	1	pc	₱100.00	₱100.00
Crimp Charge			₱20.00	₱20.00
Diode IN4007	7	pcs	₱4.00	₱28.00
Extra-Large Stainless-Steel Twist Lock Mesh Tea Ball Tea Infuser with Hook Chain	1	pc	₱233.00	₱233.00
Fuse	5	pcs	₱20.00	₱100.00
Fuse Holder	2	pcs	₱35.00	₱70.00
Hannahay 220 to 12 Volts Transformer	1	pc	₱129.00	₱129.00
Hose Adapter (Brass)	2	pcs	₱60.00	₱120.00
jp Bolt 4 × 15	8	pcs	₱4.00	₱32.00
jp Bolt 5 × 20	9	pcs	₱6.00	₱54.00
LCD Digital DC 4.5 V ~ 30 V Panel Detector Volt Meter Voltmeter Tester Monitor Red	2	pcs	₱139.00	₱278.00

LED Light	2	pcs	₱5.00	₱10.00
M – Cassette Terminal	1	pc	₱65.00	₱65.00
Mini Digital Voltmeter DC 100 V, 10 A Panel Amp Volt Voltage Current Meter Tester 0.56” Blue Red Dual LED Display | Mini Digital Voltmeter Ammeter DC 100 V, 10 A	2	pcs	₱168.56	₱337.12
mm Nut 5 mm	9	pcs	₱1.00	₱9.00
mm Washer 4 mm	12	pcs	₱1.00	₱12.00
Omni Sealed Rechargeable Lead Acid Battery 12 V, 9 Ah	1	pc	₱940.00	₱940.00
PCB	1	pc	₱55.00	₱55.00
Pioneer Elastoseal Pisilito 85 g	1	pc	₱60.00	₱60.00
Pressure Hose	1	m	₱35.00	₱35.00
Relay 12 V, 5 Pins	1	pc	₱95.00	₱95.00
Resistor (1/2 W)	3	pcs	₱2.00	₱6.00
Resistor 1 k (1/2 W)	1	pc	₱2.00	₱2.00
Spray Handle	1	pc	₱395.00	₱395.00
Switch	1	pc	₱50.00	₱50.00
Terminal Block	1	pc	₱75.00	₱75.00
ti-Paint Island Gal Metal Primer 700 Red Oxide	4	pcs	₱449.00	₱1,796.00
ti-Paint Island Gal Roofkote 2437 Fortune Red	2	pcs	₱723.00	₱1,446.00
ti-Paint Thinner Mayon 1 L	4	pcs	₱111.00	₱444.00
Transistor	1	pc	₱38.00	₱38.00
Transistor C 2363	1	pc	₱25.00	₱25.00
Variable Resistor 10 k	2	pcs	₱35.00	₱70.00
Volume 10 k Mono	1	pc	₱25.00	₱25.00
Washer	18	pcs	₱4.00	₱72.00
Water Cntainr Slim 2	1	pc	₱225.00	₱225.00
YOSOO Auto Oil Fluid Liquid Extractor Scavenge Exchange Transfer Pump Kit 12 V, 60 W	1	pc	₱986.90	₱986.90
Sub-total:				₱8,909.02
Contingency:				₱1,090.98
Total:				₱10,000.00

Table 1 shows the initial cost of the first design of the machine without analysis of the cost-effectiveness before and after the device was fabricated. It guides future researchers to improve the design of this machine.

4.4. Procedure of Device Operation

In order to uphold the safe use of the device and avoid injury to the user/s, the following procedural use of the product are observed:

During Spray. In the preparation before and use of the roof paint sprayer, the following were observed: (1) mix two liters of thinner to four liters of red oxide (primer); (2) remove the cap of the container; (3) pour and filter the paint into the hole of a container, clean the filter, and return the cap cover to avoid spillage of paint; (4) check if the air inlet has no clog; (5) use the holder or container to carry the roof paint sprayer; (6) be sure that the nozzle is not pointing to anyone; (7) turn ON the switch to start the direct current motor; (8) spray the nozzle to the desired area; and (9) if the spray starts to weaken, press the switch to OFF and charge the battery.

During Charging. If the nozzle starts fading its spray then stop to avoid discharge of the battery that will affect the performance of the battery for the next use, then (1) locate the outlet and be sure that the area is on average temperature and dry surface floor; (2) connect the male socket of the connector cord to the female socket; (3) plug the connector cord into the outlet; (4) red LED will light, which indicates the charging; and (5) when the battery starts to full charge, the blinking from red to green until it is steady to green indicates that the battery is ready to use.

According to Bitan (2021), applying the paint could follow these steps: (1) cover any vents or skylights. Use plastic sheets to wrap and cover the vents and skylights. Seal the edges of the plastic with painter’s tape so none of the paint can get through. Make sure the painter’s tape is not stuck to any of the roofing material, or else it may not stick as well; (2) work from the top to the bottom of the roof. Place the ladder in the middle of the roof along the bottom edge. Start painting at the peak of the roof on the left side and work across the top to the right side. Keep working down the roof toward the ladder. Once at the bottom, stand on the ladder to paint the final section; (3) apply a coat of primer and let it dry before painting them for a better color. Fill the airless sprayer with a water-based primer to easily apply it to the roof. Coat roof evenly, so there’s a thin coat of primer covering all of the roofing material. Once the primer is applied, let it dry for at least 2 hours before start applying paint; (4) spray the paint onto the roof. Hold the nozzle of the sprayer 1–2 ft (30–61 cm) away from the roof and pull the trigger. Move the sprayer from the peak of the roof to a spot 3–4 ft (0.91–1.22 m) down. Let go of the trigger at the end of your stroke; (5) paint across roof strips that are 3–4 ft (0.91–1.22 m) thick. Step back from the first strip painted and continue working toward the opposite side of the roof. Make sure to overlap the painted area slightly for even coverage. Once reach the opposite side of the roof, go back to the started side to make a new 3–4 in (7.6–10.2 cm) strip. Continue working down the roof until it's entirely coated; (6) wait at least 2 hours before the second coat. Once the first coat on the roof is finished, allow it to dry for at least 2 hours, so it has time to set, and so it's safe to walk on. Go back to where the first painting started and apply a second coat in the same way. Keep working across the roof until it's completely painted, and (7) paint any edges or tight areas with a brush or roller. Once the second coat of paint is dry, get back on the roof and look for any areas missed. Work paint onto any edges or tight corners with the tip of a paintbrush or roller, so the color looks uniform. Wait for the first layer of paint to dry before applying another coat.

4.5. Spray Performance Test

The device was tested at a fully charged 12 V battery. Figure 6 shows that during testing the roof paint sprayer works smoothly with the sprayed area almost 1/3 of the target area (10 × 3 meters) for almost 2 minutes but the dc motor suddenly starts challenging to run. After several tries to run the sprayer, the motor was stuck and unable to run. This indicates that 2 liters of thinner plus 4 liters of paint and 12 V and 60 watts dc motor did not meet each requirement.

Figure 6

The 1/3 Part of the Sprayed Area

If someone lives in a warm climate, light colors are helpful for reflecting heat and keeping things cool. The same principle can work for roof. A white roof, when kept clean, reflects more than 80 percent of the sunlight that falls on it. That, in turn, keeps the whole house cooler. On the other hand, climate where heating is a greater priority than cooling, dark color is better. A dark roof will absorb the sun's warmth in spring and autumn when the surface is not covered with snow (Parker, 2021).

According to Island Premium Paints (2016), the benefits of coating the roof with new paint include reinforcing protective layers that keep roof strong against intense heat and rain and a new, eye-catching color to impress the neighbors with. The roof colors indicate:

White – means heavy maintenance work, and white roof paint can easily stain. Studies show that white paint for roof effectively reflects sunlight and its heat.

Yellow – brighten up the home's exterior with the color of the sun for the roof. This color is bound to make home stand out from a background of dull, damp, and boring.

Orange – a mix of passion and happiness, orange is a sure scene stealer that will showcase fire and spark that the home or neighborhood might just need.

Blue – is the top-of-mind color of brightness and coolness; blue is a refreshing color, especially for a house in a tropical country such as the Philippines. A blue breezy and laid-back aura that helps tame down peak temperatures.

Green – is a favorite when it comes to roof color. It is safe, and it pairs up nicely with earth and warm colors. It is safe but also cohesive to the environment.

4.6. Effectiveness of Machine

Test results showed that the device needs more studies or experimentations, especially on self-priming direct current motor capability in terms of viscosity. In addition, the right mixture of viscosity must be emphasized. Similarly, the roof paint sprayer works but not for long because of paint viscosity.

Because it takes more force to quickly deform higher viscosity fluids, the viscosity of fluid directly affects the power required to operate the pump. For example, trying to stir a bowl of water and trying to stir a bowl of honey. The work necessary to move the spoon in honey is considerably higher. The same is true in pumps. If the gears of an external gear pump have to rotate in higher viscosity fluids, the power loss to simply rotate will be higher. If the motor size of the pump is fixed, this may result to lower speeds and reduced pump capacity (DIENER, 2021).

5. Conclusion

This study was conducted from April 2021 to December 2021 at Barangay San Juan, Aborlan, Palawan. A roof paint sprayer could ease the painting of roof painters. It could be a reliable device for roof painters to lessen the exposure to sunlight during roof painting with good atomization spray. This roof paint sprayer could easily be operated by pressing the switch, putting the back strap at the shoulder's user back, and holding the handle of the nozzle while pointing at the desired target to be sprayed. The 9 Ah, 12 V battery at fully charged can spray. But results revealed that after a few minutes of use, the capacity to spray diminishes as fluid viscosity settle. As an outcome of this design, the battery-operated roof paint sprayer was found to be advantageous, but it needs more study on fluid viscosity or adds agitator inside the tank to avoid the settlement of remains.

The battery-operated of roof paint sprayer with automatic charging off system will be successful if the following are considered: (1) experiment on proper viscosity to be used on 12 V, 60 W self-priming dc motor and (2) install an agitator inside the tank to retain the fluid viscosity.

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