Waste Technology (WasTech)
Journal homepage: http://ejournal.undip.ac.id/index.php/wastech
An International Journal

Design of Integrated pH-Water Level Sensors using Arduino Uno-ESP 32 Microcontroller for Integrated Rice-Fish Farming Waste Water Utilization

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Abstract - *Integrated Rice-Fish Farming System (IRRFS), a conventional rice, poultry, and fish farming system which is widely practiced in south asia, facing the serious obstacles amidst its advantageous contemption. The main challenge is inharmonious water uptake management as the side effect of its area arrangement and inappropriate water irrigation system due to the lack of technology application, leading to the chemical contamination and high water consumption. This paper develop an integrated pH and water level sensors using combined arduino uno-esp 32 microcontroller for the newly designed IRRFS (mina padi) concept and the new concept of IRRFS in terms of area arrangement restructuration with 1:500 diminution scale, aiming to overcome the pest and chemical contamination to the system and high water amount necessity. The integrated pH-water level sensor is designed to maintain daily water uptake of fish ponds and paddy fields to prevent harvest failure. The integrated sensor will instruct either 1st pump or 2nd pump to drain in or drain off the water from the system. The working accuracy is tested by both calibration and the prototype experiment, resulting in the simultaneity working ability of integrated sensors with 1st pump and 2nd pump which possess with high accuracy.*

Keywords – *pH Sensor, Water Level Sensor; Arduino Uno; Integrated Rice-Fish Farming System (IRRFS)*
Doi: https://doi.org/10.14710/12.12.52-59
[How to cite this article: Dhiya'ulhaq, S., B. et al. (2024). Design of Integrated pH-Water Level Sensors using Arduino Uno-ESP 32 Microcontroller for Integrated Rice-Fish Farming Waste Water Utilization, 12(2),52-59, doi: https://doi.org/10.14710/12.12.52-59

1. Introduction

Indonesia needs to unleash its agricultural potential. It is sparked by the continuously increasing food needs as the population grows. According to the latest data of the Central Statistical Agency (BPS), with a population growth of 1.3% per year and a population of 278.7 million people. The main challenge is the increasing demand for food as a result of population growth amidst land displacement that threatens the paddy production. An integrated rice–fish farming system (IRFFS), known as well as Mina Padi, is a conventional farming style widely practiced in east and southeast asia, where a fish is kept in the vicinity of fish crops, as an intersection between two seasons of cultivation, or keeping fish as a substitute for the third harvest (palawija) in the ground [1]. The rice fish farming system has proven to provide a number of significant benefits. Empirical studies show an increase in farmers' income economically, diversification of agricultural and fishing products, as well as improved water environmental quality and soil fertility [2]. In addition, this practice also contributes to the sustainability of agricultural land, prevents land displacement, and absorbs labor on a fairly large scale [3] [4].

The increase of paddy production in the Integrated rice–fish farming system (IRFFS), as its practical positive impact, should be valued well because with the paddy system, fish dirt can serve as a soil fertilizer that ultimately affects increased padi production [5]. Fish debris can be potential fishing waste for use in crop cultivation as organic fertilizer when properly managed. It contains nitrogen, phosphorus, and potassium, which is derived from the residues of feed and the dirt contained therein [6]. The content depends on the type of feed, the frequency of feeding and the absence of water replacement. For example, one of these is the waste of catfish dirt that contains catfish elements, the macro content of the water dirt catfish contains nitrogen ranging from 0.98-1,67%, phosphorus

1.89-3,40% and potassium 0.10-1.03%. Contains C-organic 0.28- 0.98 with pH 7-8 [7].

In the IRRFS system, the water irrigation plays an important role in regulating the availability of water and soil temperature to support plant growth and over-irrigation and under-irrigation can cause crop yield to decrease, resulting in production and quality losses [8]. Especially in utilizing fish pond waste that can be processed and used as fertilizer to support the growth of plants such as rice. However, many irrigation systems still use manual methods, so water distribution is often not optimal. Based on the problems, there is a need for the development of technology to optimize the irrigation management system so that there is automation in the opening of the water pipes as well as monitoring the availability of water [9]. The technology that can be used is the pump integration water level sensor. These sensors are designed to monitor the water level in the basin, which is crucial in the setting of irrigation and efficient water management. Research on the use of water level sensors in a wild farm has been presented by Aznar-Sánchez et al. [10], using water levels sensors employ the positive impact towards farmers in case of water levels controlling in a more accurate way, avoid excess or shortage of water, and improve the productivity of peat crops. In addition, the idea of using water height sensors for fisheries as well as agriculture has already been developed and applied in the research carried out by Calone et al. [11], on the application of ultrasonic sensors to water level reading in aquaponic farming systems. However, no one has yet developed a modern IRFFS.

The optimization of IRRFS needs to be done by employing process automation, which allows the use of computerized and digitally connected systems to optimize the various stages of production, ranging from the monitoring of the growth of plants up to the harvest process and the processing of yields [12]. According to research by Karunathilake, et.al [12], automation in agriculture not only helps in improving productivity and yield quality, but also enables more efficient management of resources, such as water, fertilizer, and energy. In addition to the use of water altitude sensors, it is necessary to integrate other sensors. One kind of sensor technology that can be applied is a pH sensor. pH is the degree of acidity used to indicate the acidity or acidity of a solution [13]. Water pH monitoring becomes crucial because a proper water pH is essential for the health and growth of fish. Water pH sensors can be used to monitor and control the level of acidity or depletion in pond or dung water [14]. Research on the design of pH sensor devices in fisheries and agriculture has been done a lot, among them is Shin, et. al [15] which design water pH control devices for hydroponic plants based on the arduino uno microcontroller.

Based on the existing studies related to the application of sensor technology to IRRFFS, there has not been a process automation system with the integration of two sensors simultaneously. Based on the previous reason as well, this research is intended to develop a two-sensor integration system, consisting of a pH sensor and water level sensor which work in a simultaneous way. The energy source for the sensor integration system is utilized by the use of solar panels as alternatives electrical generator aiming to reduce its operational cost. In addition to the use of integrated sensors, there present the use of pumps as well, which is installed to distribute water and maintain the amount remain in allowable value to support optimal growth of the crop. Furthermore, there will be the LCD screen to monitor the amount of water available in farming and fishing system, assisting the farmer to oversee the water in a real time. The innovation is developed to deliver positive contribution to the farming operational efficiency, to reduce the risk of injuries and fatigue in farmers, and to spark the increasing of paddy production. Thus, process automation with the integration of pH sensors with water altitude sensors is a necessity aspect in modernizing and improving the sustainability of farming in this digital age.

2. Materials and Methods

2.1 Materials

The materials and chemicals used in this research are CH_3COOH (acetic acid), NaOH (sodium hydroxide), demineralized water (produced in the laboratory). The tools used in the research are soldering iron, solder wire, multimeter, screwdriver set, wire cutters, wire strippers, heat shrink tubing, electrical tape, pH sensor E-201-C, Arduino Uno-SMD, ESP-32, LCD, bistable relay, step-down converter, water level sensor-V1.0, power supply, water pump, solar charge controller, solar panel, and junction box.

2.2 Preliminary Design of the Integrated Sensor

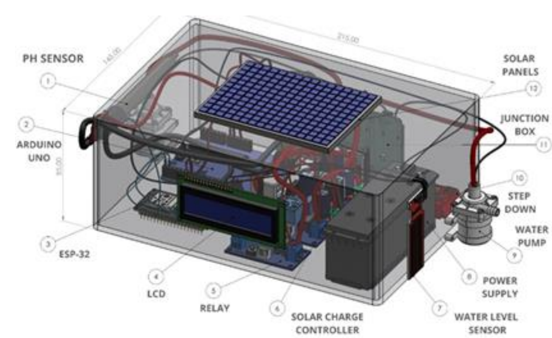

Figure 1. Design of a pH sensor E-201-C device integrated with a Water level sensor-V1.0

In the initial design stage of the integrated sensor, the process begins with the development of an efficient system concept for measuring water pH and water level in fish ponds and rice fields. Figure 1 shows a visualization of the physical design of a pH sensor E-201-C device integrated with a Water level sensor -V1.0. This design is planned to automate the maintenance of water quality within the specified parameters. In this design the block diagram of the water pH sensor E-201-C device integrated with the level sensor-V1.0 depicted in Figure 2 forms the basis for planning the interactions between components. This diagram visualizes how the electric current flows from the solar panel, through the charge controller, and finally to the other components, ensuring the system operates properly using renewable energy.

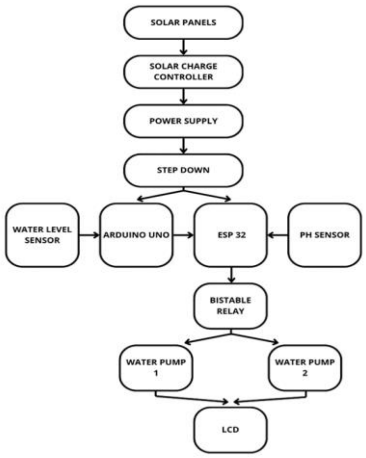

Figure 2. Block Diagram of the Integrated Sensors Working System

2.3 Development of Integrated pH-water level sensor

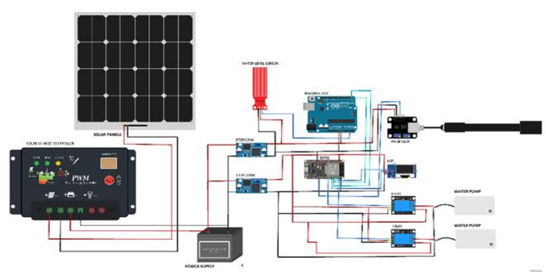

Figure 3. Wiring diagram of the Integrated Sensor System

The development stage of the integrated pH and water level sensor focuses on the physical implementation of the design. Various tests and trial and error processes are carried out at this stage to achieve optimal integration between components. Figure 3 shows the system wiring diagram, which illustrates the connectivity between the solar panel, sensor, and microcontroller. Tests were conducted to ensure that the pH sensor E-201-C provided accurate readings while the water level sensor V1.0 could detect the water level within the set limits. Adjustments were also made to the electronic circuits, including voltage settings for the Arduino Uno-SMD and ESP-32, to avoid damage due to overvoltage. The troubleshooting process is also important to fix technical problems, such as discrepancies between sensor readings and reality in the field, and to ensure that the relay system properly activates the water pump. The connectivity of each component can be seen as follows:

1. The solar panel connects to the solar charge controller and then to the power supply.
2. The power supply connects to step-down converters 1 and 2 as the power source.
3. The Water level sensor-V1.0 connects to the Arduino Uno-SMD.
4. Arduino Uno-SMD connects to the ESP-32.
5. pH sensor E-201-C connects to ESP-32.
6. ESP-32 connects to relays 1 and 2 and the LCD.
7. Relays 1 and 2 connect to pumps 1 and 2.
8. LCD connects to the ESP-32.

2.4 Logical Program Setting of the Sensor

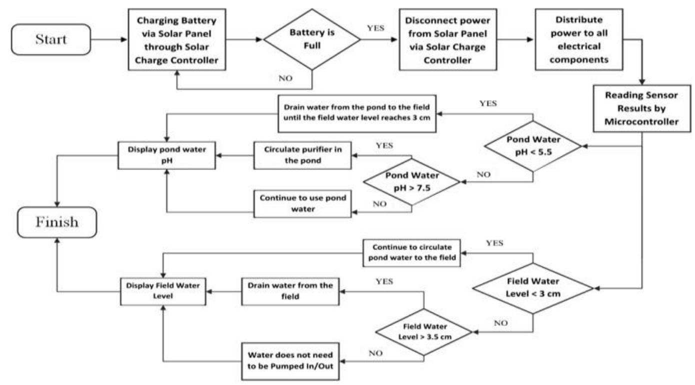

Figure 4. Control algorithm for the pH sensor E-201-C device integrated with a Water level sensor-V1.o

Logical program setup is done using the Arduino IDE platform, as shown in Figure 4, which illustrates the logic flow of the system. The program combines the operations between the Arduino Uno-SMD and ESP-32 in a synchronous manner. The Arduino Uno-SMD is responsible for reading data from the water level sensor and transmitting it to the ESP-32, which then processes the water pH level data. The program is designed to regulate the water flow based on the read value; if the pH value is below 5.5, the system will drain the water from the fish pond to the rice field, while if the pH value exceeds 7.5, the system will perform water purification. In addition, the system automatically drains water from the pond to the paddy field if the water level of the paddy field is less than 3 cm and releases water if it is more than 3.5 cm to prevent flooding. Information on pH and water level is displayed in real-time on the LCD connected to the ESP-32, ensuring efficient monitoring and responsiveness to conditions in the field.

2.5 Accuracy Testing of the Sensor

The sensor accuracy testing is aimed to evaluate its working ability and error possibility. The test was carried out by comparing the detected value of pH sensor with the pH meter obtained value in various pH sample condition testing. Basically, there are 3 conditions of the solution testing, consisting of neutral, acidic, and base conditions. Both acidic and base conditions are set in the range of outspec pH condition where either pump 1 or pump 2 will be ordered to work. In other hand, the water level sensor will be tested by comparing its detected value with the result of actual water height using manual calculation. Output of this test was an error value of each sensor, that able to be obtained by the following formula:

$$Error\ (\%) : \frac{|\,Actual\ value - detected\ value\,|}{Actual\ value}\ x\ 100 \ldots (1)$$

2.6 Integration Working Logic Testing

Analysis of the sensor-pump system logic integration working was carried out by testing both of sensor working with two pumps, where 1st pump if programmed to flow the water from fish pond to the paddy field and 2nd pump is set to flow the water from paddy field to the outside which either be back to the fish pond or be flown to the water drainage, as the pH and water level is changes according to the working logic. The integration working as the paramater is changed was then observed.

2.7 Functional Testing in Prototype System

The measurement is proposed to evaluate integrated working between fish pond pH sensor, 1st pump, water level sensor, and 2nd pump in case of maintaining optimal amount of water in both fish pond and paddy field of integrated rice-fish farming system prototype with 1:500 in diminution scale.

3. Results and Discussion

The integrated pH and water level sensors are planned to be implemented in a new-designed concept of integrated rice-fish farming system (mina padi). The development lies in the restructuring of poultry cage, paddy field, and fishpond with the aim to increase its efficiency in terms of daily water uptake, fertilizer contamination, total land use, and paddy-harvest failure minimization. Actually, conventional Mina Padi, that has been widely practiced for generation in East and South-east Asia including Indonesia, consist of the paddy field which is surrounded by direct fishpond, and there the poultry cage nearby the field, allowing the fish moving freely between rice paddies without any barricade present and the duck cage is placed at the same water pond as the paddy and the fish field. The conventional practice was considered advantageous in terms of land usage and water utilization, especially for limited fertile land area [1]. Hence, the conventional practice faces the serious obstacles in case of chemical contamination to the living fish due to fertilizer excess usage, easier-access of pest (snakes, frogs, and birds) to the field system due to fish presence, and difficult to be implemented in limited water availability area [17]. In other words, the main challenge of rice-fish farming is inharmonious water uptake management as the side effect of its each area arrangement and unappropriate water irrigation system. Thus, the area arrangements need to be restructured.

3.1 Application Concept of Integrated Sensors for Modern IRRFS

New-designed of Mina Padi concept is developed from the conventional mina padi practiced-principle, where paddy farming and fishing with poultry farming are combined, with the addition of two sensors to facilitate and optimize water usage. Catfish farming is chosen because it is relatively easy to breed and fed, short harvest cycle, contain high protein, and require an incapacious pond. Furthermore, peking duck farming is chosen because of lower feed prices, a shorter harvest time of 45 days, and a smaller cage area than other poultry. In this concept, a duck cage is made in the middle of a fish pond, where the pond is bound by a pit. The cellar is built 2 m above the base of the pond, underpinned by a 3 cm stainless steel wire of each, and there is a half-parallel pipe mounted 50 cm below the base with a 10 inclination to facilitate the distribution of duck stools into the fermenter tank mounting near one of the ends of the cage. The 250 L capacity tank as a place of 14-day long fermentation for fish feed, that is made of rice bran, molase, and ducks manure, will be installed 1.75 m above a pond base and there lie a hole at the bottom of the side for direct distribution of fish food to the fish pond.

The application of the new-designed mina padi concept concept is not limited only to the large scales. On the experimental scale, for instance, a duck cage can be made in the size of 4 x 5 m, a 5x6 m fish pond, and an 8 x 8 m paddy field. At this size, the duck cage would ideally be divided into 20 squares of 1 x 1 m, with a capacity of 50-week ducks and 5 adult (six weeks old) ducks. The ducks will be separated according to their age in a week, to prevent the adult ducks from oppressing the little ducks. The duck patch is also deliberately made not too smooth and not too loose, to anticipate that the duck is not stressed or the ducks are not too active running. At the size of that cage, there will be 100 adult ducks to accommodate.

Further schematic design of new-designed IRRFS concept at various point of videw is shown by Figure 5 and Figure 6 below.

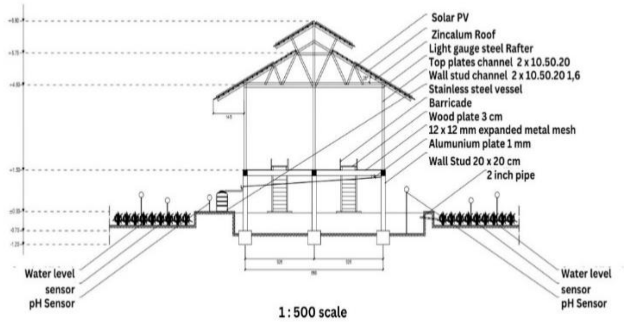

Figure 5. Front-view of new-designed IRRFS concept

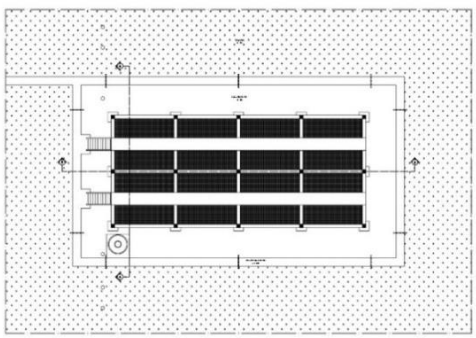

Figure 6. Top-view of new-designed Mina Padi concept

The fish pond will be equipped with a pH sensor, as a nitrate quantity detector (NO_2^-). If the nitrate is high, the water pH will decrease, and it can be directly discharged to the paddy field using a centrifugal pump to supply its nitrogen needs. The required water pH conditions for optimum fish farming around a pH of 5.5 - 7.5. When the pH of the water is too low, there are indications of high amounts of fish farming residue which is degraded by microorganism, producing acidic compounds. When water pH is too acidic, the fish may suffer poisoning due to inappropriate water conditions. On the other hand, the pH of water in the 4-5 range indicates high nitrogen content, which can actually be utilized as water supply for paddy needs. The utilization of used-fishing-water will help to suppress the use of NPK fertilizer, because the nitrogen and phosphorus content can be obtained from fish residue presence. Thus, fish farming waste water can be used to irrigate the surface. In order to determine the right time to flow the fish farming used-water, a water pH sensor is applied to the fish pond.

On the other hand, the paddy field around the fishpond will be equipped with a water level sensor. When the level rises above maximum water level, 4 cm, the water will be drained to the water reservoir outside the paddy field, to avoid a flooding that sparks deterioration of the harvested paddy, leading to paddy harvest failure possibility. Whereas, if the level is decreased below the minimum water for optimum paddy growth, 3 cm, the water will be flown to the paddy field using a centrifugal pump from either fish pond or outside water basin. The water level installation at every corner of the paddy field helps the farmer to maintain optimal daily water uptake of the paddy itself.

Further schematic design of integrated pH and water level sensor for new-designed mina padi concept application is shown by Figure 7 below.

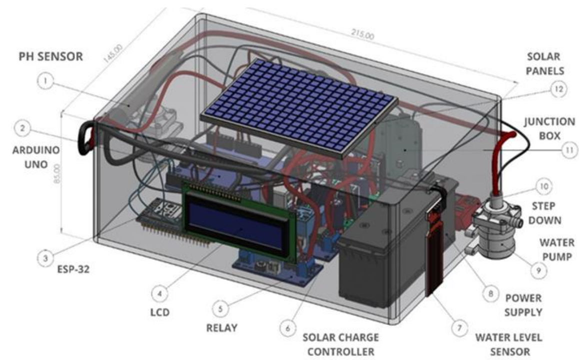

Figure 7. Design of integrated pH-water level sensor for modern IRRFS

3.2 Sensor Accuracy Analysis

The integrated pH-water level sensor is successfully developed. In order to evaluate its working ability and error possibility, there was a series of sensor testing. The measurement is carried out via direct method, where the actual value detected by the sensors will be compared to the detector system programmed to the sensor, to evaluate the generated data.

Table 1. E-201-C pH Sensor Accuracy

Sample	E201C pH sensor	pH meter	Error (%)
Aquadest, 25˚C	6,94	7,00	0,857
Acetic acid 0,25 M diluted in 1L water	5,18	5,38	3,71
Acetic acid 0,5 M diluted in 1L water	4,08	4,26	4,22
Sodium hydroxide 0,01M diluted in 1L water	9,01	8,89	1,34
Sodium hydroxide 0,02M diluted in 1L water	10,22	9,92	3,024
Average error			2,63

Table 2. Water Level Sensor Accuracy Testing

Water-level sensor	Actual value	Error
2,5 cm	2,5 cm	0%
3 cm	3 cm	0%
3,5 cm	3,5 cm	0%
4 cm	4 cm	0%
Average value		0%

Based on Table 2, it is obtained that the water level sensor is working in a stable state, shown by its error reaching 0%. The water level accuracy is greater than E-201-C pH sensor due to its lower sensitivity of electrode as the value detector. The lower sensitivity is affected by its working principle, where a water level sensor electrode detects the height by capturing the water pressure and capacitance [23]. The technology is generally more robust and less prone to drift than pH sensors [15]. On the other hand, a pH sensor works by determining the potential difference between a glass electrode and a reference electrode in a tested solution. The potential difference is equal to the concentration of hydrogen ions present in the solution, which can be further processed to determine the pH value [24]. The working principle sparks the sensitivity of electrodes, which can be affected by temperature, drift, calibration, buffer solution state, and quality itself.

3.3 Integration Working Logic Testing

Table 3. Integrated pump working logic testing result

E-201-C pH Sensor	Water-level Sensor	Pump 1	Pump 2
5,5	3 cm	off	off
6	3 cm	off	off
6,5	3 cm	off	off
7	3 cm	off	off
7,5	3 cm	off	off
5,5	≥ 3,5 cm	off	off
6	≥ 3,5 cm	off	off
6,5	≥ 3,5 cm	off	off
7	≥ 3,5 cm	off	off
7,5	≥ 3,5 cm	off	off
≤ 5	3 cm	on	off
≤ 5	3,5 cm	on	off
≤ 5	≥ 4 cm	on	on

The integration working logic testing was intended to analyze the sensor ability to work simultanously with the system according to the logical program setting. The sensor system consists of the pH-water level sensor itself, two pumps, microcontroller, relay, and LCD screen. There installed 2 integrated pumps, where 1st pump is programmed to flow the water from fish pond to the paddy field, and the 2nd pump is set to flow the water from paddy field to the outside which either be back to the fish pond or be flown to the water drainage. The sensor was tested in various condition of pH and water level, and the result of the test is shown at the Table 3 above.

Based on the Table 3, it it obtained that the entire integrated sensor system is able to work simultanously according to the setted parameter.

3.4 Functional Testing of Integrated Sensor in IRRFS Prototype

The integrated pH-water level sensor was then tested to the newly-designed mina padi concept prototype with 1:500 diminution scale to the real design planning. The size diminution is intended to develop a small scale of the integrated sensors and to analyze its working accuracy at a smaller system before it is applied in a real field. The measurement is proposed to evaluate integrated working between fish pond pH sensor, 1st pump, water level sensor, and 2nd pump in case of maintaining optimal amount of water at both fish pond and paddy field. The detail of the new design of mina padi concept in 1:500 diminution scale with integrated sensor implementation can be seen in the Figure 8 below.

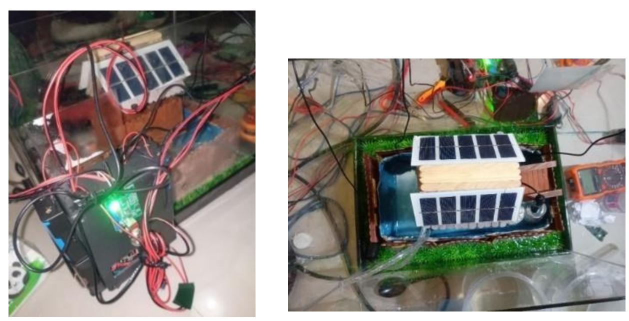

Figure 8. Integrated Sensor Working in Modern IRRFS prototype with 1:500 diminution scale

The measurement is carried out by applying certain pH water condition in fish pond to observe the 1st pump work, which connected to the pH sensor, to flow the water from the fish pond to the paddy field of the prototype, once the pH water of fish pond is below 5,5, and flowing them until the water level in the paddy field reaching optimum value, 3 – 3,5 cm in height, which is detected by the water level sensors and the signals will further be instructed to either back 1st pump to stop flowing the water or sending the signal to the 2nd pump to flow out the excess water of paddy field until the water level reaching 3,5 cm in height. Based on the trial, it is obtained that the integrated sensor is successfully working to maintain the water condition of the paddy field and fish pond by simultaneously operating according to the set parameters. The 1st pump will drain off the water of the fish pond once the pH reaches 5,49 and below, to the paddy field until its water level reaches 3,5 cm in maximum. Whereas, the 2nd pump will drain off the water of the paddy field once the water level exceeds 3,5 cm to the outside water drainage.

4. Conclusion

In this study, the design of integrated pH and water level sensors for the newly-designed Integrated Rice-Fish Farming System (IRRFS) has been successfully designed, developed, and evaluated. Furthermore, the design prototype of the new concept of MinaPadi, in which area arrangement is restructured, has been created in 1:500 diminution scale, to assist the developed integrating sensors experiment in case of its simultaneity according to the set parameter. Based on the test results in both calibration using manual testing comparison and the prototype experiment, it is shown that the integrated pH-water level sensors are able to work simultaneously with 1st pump and 2nd pump to maintain water uptake of fish ponds and paddy fields at the optimum value with the help of arduino uno-esp 32 as the microcontroller. The integrated pH-water level sensor shows a little error, indicating the sensor works in a stable state and poses with high accuracy. Hence, the experiment is only carried out to 1:500 diminution scale prototype, where the accuracy might be decreased as the application scale is enlarged. Further research and development can be carried out by upscaling the integrating pH-water level sensor for a real field of modern mina padi application.

Limitation and Future Research

This research was accomplished in 1:500 diminution scale, for both the pH – water level sensor integration system and new-designed of Integrated Rice – Fish Farming System (IRRFS) resctrution concept development. The accuracy will be slightly different from the real scale of operation. Thus, the author state that further research and development regarding pH – water level sensor integration system for IRRFS upscaling application can be carried out to obtain the more accurate sensors for modern farming in order to develop appropriate technology for agriculture purposes.

Acknowledgements

This research was supported by CSR Department of Pertamina Refinery Unit III Plaju, South Sumatra trough Social and Technology Innovation Challenge (SoTech) 2024 funding. We thank our colleagues from Industrial Chemical Engineering Department, Diponegoro University, who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper.

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