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Biotoilizer automatic system prototype : automatic fertilization system integrated with bio-toilet based on Internet of Things (IOT)

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KEYWORDS	ABSTRACT
	Human urine is one of the primary wastes in urban areas, which has not been maximally processed and utilized until now. Human urine can be processed into biofertilizer with special processing procedures to minimize the negative impact of using urine as fertilizer and avoid odor, dirt, and contamination of pathogenic bacteria in the processing process. This prototype aims to design a Biotoilizer Automatic System with processing human urine into a biofertilizer and an automatic fertilization system. This system is equipped with a DC water pump, pH sensor, YL-69 sensor, ultrasonic sensor, real-time clock (RTC) NodeMCU microcontroller, and Arduino Uno. The method used in this research is an experimental method by designing technical designs and making prototypes of an Internet of Things (IoT) based automatic fertilization system that utilizes solar panels and is integrated with Bio toilets and designing software. The system's test results can process urine into a biofertilizer and fertilize automatically 95% based on regulated conditions and can be monitored with an application via a smartphone

Introduction

Human urine is one of the primary wastes in urban areas. Healthy people can produce as much as 1-1.3 L of urine per day (Nagy and Zseni, 2017). Human urine waste in Indonesia has not been maximally processed and utilized. People prefer to dispose of their urine waste directly into a septic tank or directly into the river rather than having to process it (Nuriyani, 2014). Human urine itself can be processed into liquid organic fertilizer (LOF) at a low cost (Ranasinghe et al., 2016). Processing of human urine into LOF is carried out using special processing procedures to minimize the negative impact of its use as fertilizer (Shaw, 2010). LOF derived from human urine is known to have a higher nutrient content than LOF urine from cows or other animals (Meriatna et al., 2018). Every human being can produce urine with N content of 11 g/day, P content reaching 0.9 g/day, and K content reaching 2.4 g/day (Nagy and Zseni, 2017).

LOF applications derived from human urine have been carried out by farmers both in Indonesia and other countries. Plants used as objects for fertilizing human urine LOFs also vary, namely tomatoes, cabbage, wheat, corn, rice, bamboo, rai grass, lettuce, and tomatoes (Karak et al., 2011). Jayanti and Kadir (2020) produced the highest number of gambas fruit at a concentration of 30% - 40% human urine LOF. The application of human urine fertilizer to maize plants in Arba Minch, Ethiopia, showed an increase in height, stem diameter, and leaf length of maize, which was directly proportional to the increase in the concentration of fertilizer used (Kassa et al., 2018). LOFs derived from human urine can also increase soil pH, soil organic C content, total N, available P, exchangeable K, and NPK uptake in maize plants (Putra et al., 2018).

The production of LOF from human urine has been widely carried out, but the processing and fertilization system used is still manual. Nepal is one of the countries that has developed technology to manufacture fertilizer from human urine through the Urine Diversion Dry Toilet. However, suctioning and harvesting fertilizer are done manually (Devkota et al., 2019). A pilot plant for processing urine-based fertilizers has been built in Durban, South Africa, involving household toilets

as a producer of materials for fertilizer production. However, transportation and irrigation in the fields are still done manually (Eawag, 2015). Until now, no technology integrates the concept of bio-toilet, human urine LOF production, and direct fertilization on land that works automatically.

Related Work

Internet of Things (IoT) and Solar Power Generation (PLTS) are technologies currently developing rapidly. Tools integrated with the IoT system can be easily monitored and controlled by users only through smartphones. Through the Ministry of KOMINFO in Press Release No., 115/HM/KOMINFO/04/2021 accelerates the development of digital transformation with one of its implementation derivatives, IoT technology. PLTS is also an energy source that can be developed in Indonesia, especially the city of Pontianak is a city traversed by the equator. The Ministry of Energy and Mineral Resources of the Republic of Indonesia, in a Press Release No. 290, Pers/04/SJI/2020, stated that it would accelerate rooftop PLTS by preparing the Energi Surya Nusantara program. This program supports the use of solar electricity in the community. Sprinkler irrigation system with IoT based regulates irrigation time and duration. The system developed is equipped with sensors that can continuously monitor the temperature and humidity of the soil. IoT-based system with a new design of NPK sensors using Light Dependent Resistor (LDR) and Light Emitting Diodes (LED) is proven to be useful for farmers (Lavanya et al., 2019).

This study aimed to produce a prototype of the Automatic Biotoilizer System. The Biotoilizer Automatic System is an innovative tool that integrates the concept of a bio-toilet, processing human urine LOF and fertilization on land that can work automatically. This tool is equipped with an IoT system so that everything from processing to fertilizing the land can be controlled via the user's smartphone. It can be a solution for people who are uncomfortable processing human urine into LOF because it is dirty, has a strong odor, and was contaminated with bacteria. The use of solar energy sources in this tool can also increase the efficiency and effectiveness of its application in the community, especially farmers, to support smart farming 4.0. The research was conducted to determine the success rate of tool prototypes and improvements if deficiencies were found during the testing process, so that could be applied in the community. This research was conducted to produce a tool that can perform processing,

harvesting, and distribution of fertilizers automatically on the land that can help farmers and can be used in city parks to save fertilizer costs. The results of this paper can also be used as a reference for further research.

Research Methods

The research was conducted from May to July 2021 at the Faculty of Agriculture, Tanjungpura University. The tools and materials used in this study are presented in Figure 1.

Solar panels (photovoltaic) are a number of solar cells that are used to convert energy from the sun into electrical energy using a principle called the photovoltaic effect. To get maximum electrical energy, the surface of the solar panel must be faced towards the sun. The electricity generated by the panel is then stored in the battery or battery through a solar charger controller. The solar charge controller (SCC) is used to regulate the charging current from the solar panel to the battery without causing "overcharge" and maintain the condition of the charge in the battery so that it is always fully charged (fully charged state). In addition, SCC functions to prevent the battery from "over-discharging" if the battery voltage is too low (Low Voltage Disconnect). Furthermore, electrical energy from the battery or solar panel will be forwarded by the SCC to the Arduino Uno microcontroller and NodeMCU ESP8266 by first reducing the voltage from the 12V DC battery to 5V DC using a step-down transformer.

Arduino Uno will be connected to several sensors including a Real-Time Clock which is used as a timer on the device system in real-time by using a backup supply in the form of a battery; YL-69 or soil moisture sensor; and the ultrasonic sensor HC-SR04 as a sensor for measuring the height of the liquid organic fertilizer in the tank which will turn on the red LED, yellow LED, or green LED according to the distance read by the ultrasonic sensor. While the pH sensor will be connected to the NodeMCU ESP8266, to read the degree of acidity in the urine fermentation process. Sensor data received will be processed and converted to standard units by the microcontroller so that it can be read easily by the user. Next, Arduino Uno is serially connected to the NodeMCU ESP8266 enabling send and receive data to each other. NodeMCU is equipped with an ESP8266 WI-FI module, thus it is suitable for IoT-related projects. NodeMCU is used to be able to send and receive data from smartphones.
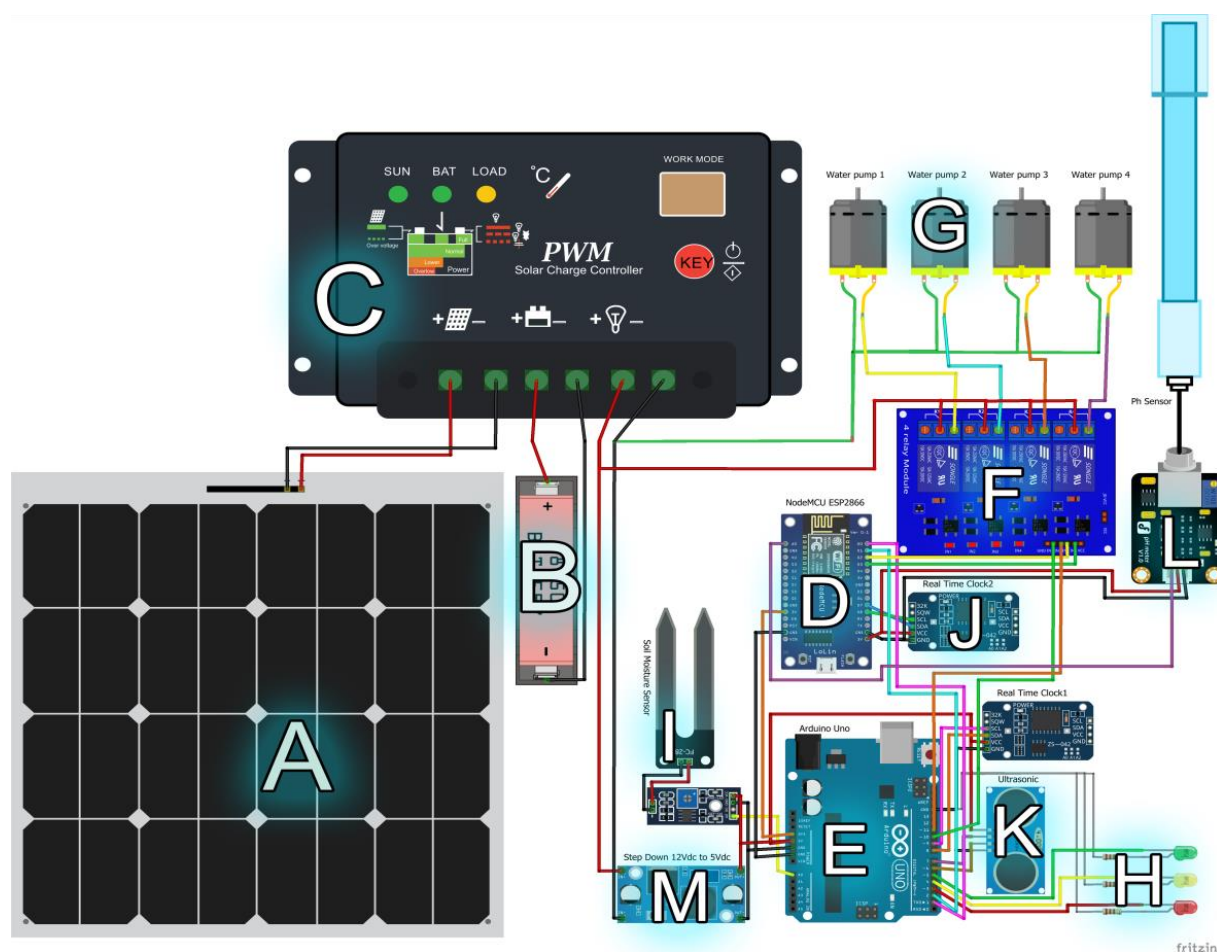
Figure 1. Hardware schematic: (a). Solar Panel, (b). Battery, (c). Solar Charge Controler, (d). NodeMCU ESP2866, (e). Arduino Uno, (f). Relay, (g). Water pump, (h). LED, (i). YL-69 sensor, (j). Real Time Clock, (k). Ultrasonic sensor HC-SR04, (l). pH sensor, and (m). Step-dDown Transformer.

The Water Pump is used to transfer the fermented urine from the fermentation tank to the POC storage tank through a pipeline using electrical energy supplied from the battery/battery for its operation. There are 4 water pumps in this prototype, each of which is connected to a 4 channel relay which functions as a switch to disconnect and connect electricity from the battery to the water pump as scheduled in the microcontroller program.

Prototype Design
This design stage is done by sketching the initial design of the Biotoilizer Automatic System based on the data that has been obtained. The sketch will later be used as a reference in making the 3D Biotoilizer Automatic System design. The devices used in the implementation of this tool include a solar panel system, battery, Solar Charge Controler (SCC), NodeMCU ESP8266, solenoid valve, water pump, pH sensor, soil moisture sensor (YL-69), Real-Time Clock (RTC), Step-

down as well as programs as prototype work system instructions.

Prototype Construction
The prototyping process is carried out according to the software and hardware concepts in Figure 2. The working principle of the Biotoilizer Automatic System is an automatic fertilization system and remote control based on NodeMCU ESP2866. This tool has several tanks with different functions. Each tank has an aerator/chimney that functions as a drain for gas from chemical processes in the tank. The first tank serves as an initial reservoir for fresh urine before the fermentation process is carried out. In the first tank, there is a pipe as a channel that connects it to the second tank, a solenoid valve component, and an RTC to automatically drain urine every six days. The pipe is installed at 30 cm from the bottom of the first tank. The bottom of the tank that contains sediment does not get carried away when the pipe drains the urine.
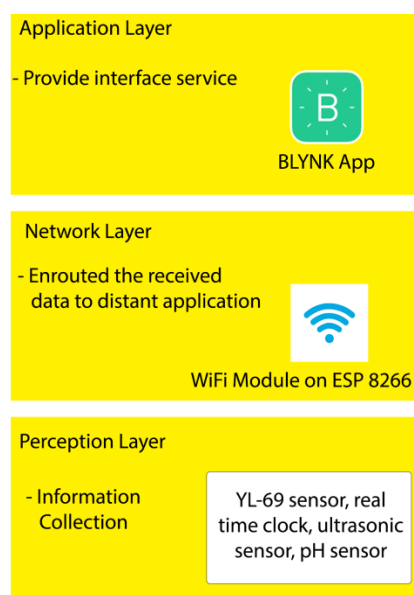
Figure 2. Three layers of IoT architecture

In the second tank, a fuel cap can be opened when entering EM4 as a bio activator to help accelerate the process of urine fermentation into liquid organic fertilizer. In this tank, there is a pH sensor to detect the level of acidity or alkalinity of the LOF. LOF output in the third tank depends on the RTC and the soil moisture sensor. When the RTC detects that it has been a week since the last fertilization and the soil moisture is 40%, the faucet (solenoid valve) will automatically open for 2 minutes to drain the fertilizer into the crop field. This tool is powered by a solar panel system as an energy source. Solar panels will convert energy from sunlight into electrical energy. The electrical energy will enter the Solar Charge Controller, thus it can be stored in the battery.

Software Application Design
This Automatic Biotoilizer System uses the BLYNK application installed on an Android smartphone to communicate between the smartphone and the NodeMCU ESP8266 via a WiFi network. BLYNK is a platform for Mobile OS applications (iOS and Android) from Blynk Inc. It provides a cloud computing service to store data on the IoT system, a server provider to enable users easily connect their devices to smartphones on the IoT system, and an interface service in the form of widgets to display information that easily read by the user. Each of these widgets is adjusted to a microcontroller pin that is connected to the sensor and then adjusted to the program created. This application is used to monitor the time and

date set on the microcontroller, monitoring soil moisture, urine pH value, the level of liquid organic fertilizer (LOF) in the tank, and there is a control to turn on the fertilization pump. The interface display on the BLYNK application can be seen in Figure 3.

Users can view sensor reading data on the BLYNK application screen. These data include the urine pH value from the pH-4502C sensor, displaying pH readings from 0 to 14. Then, there is the reading of the soil moisture value by the YL-69 sensor with the YL-38 control board, where this sensor reads the water content in the soil. As a planting medium, it converts the data into an intermediate percentage that users can read easily. Users can also monitor the height of the biofertilizer in the tank by ultrasonic sensor readings in the monitor. Biofertilizer in the tank can be seen as almost full or even exhausted. Widgets are also added for Real-Time Clock sensor readings so that users can see the real-time contained in the microcontroller. Users know time differences between the microcontroller and real-time to ensure the suitability of the fertilization schedule that has been set on the microcontroller used. There are also two buttons in this application, each of which can control the relay on the tool system. The first button (left) is used to turn on relay 1 (water pump 1). In contrast, the second button (right) is used to turn on relay 2 (water pump 2) so that fertilization can be carried out outside the automatic fertilization schedule that has been set on the microcontroller.
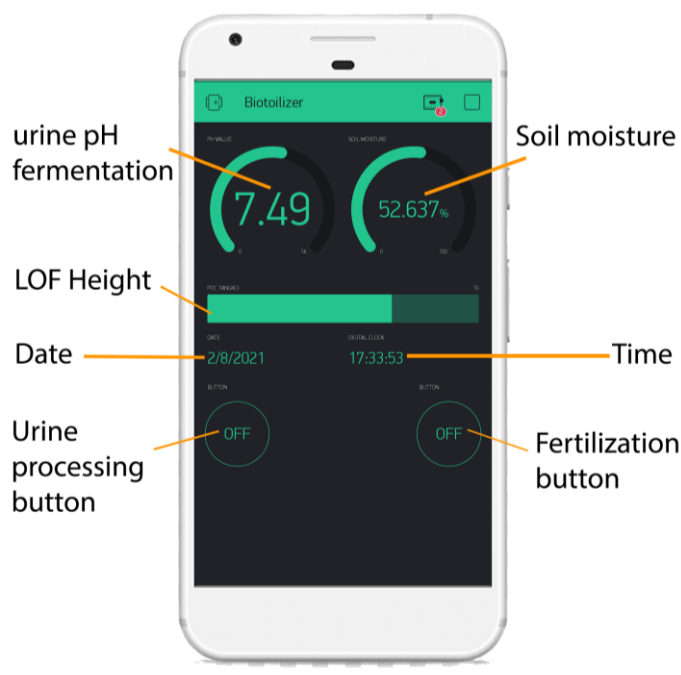
Figure 3. Interface Display on the BLYNK Application

Results and Discussion

The automatic fertilization flow in the Biotoilizer Automatic System can be seen in Figure 4. This bio-toilet is connected to a urine reservoir for the incubation process assisted by microorganisms from EM4. This incubation place is connected to a pH sensor to detect the maturity level of the biofertilizer. The water pump delivers the ripe biofertilizer to the biofertilizer reservoir automatically. The incubation chamber is designed to be closed to prevent ammonia from evaporating and causing unpleasant odors. Incubation is carried out until the pH is above 9. After the pH sensor shows the urine pH reaches 9, the water pump automatically turns on and distributes the urine from the incubation to the biofertilizer reservoir. This biofertilizer shelter is also connected by a fertilizer pipe to the agricultural land directly. This tool works automatically using RTC detection and sensors with the NodeMCU ESP2866 Microcontroller to control the time and duration of LOF flow activation to the field. However, controlling the fertilization time and duration of this tool can also be done using IoT technology which can be controlled via a smartphone application.

Settings and monitoring of the automatic fertilizer watering device system can be done using a smartphone that has an application installed. Figure 5 shows the communication flow between the BLYNK application on a smartphone and the device system. Communication between the system and the BLYNK application is 2-way, namely, communication from the BLYNK application to the system (relay work orders) and communication from the system to the BLYNK application (sensor reading data). In the communication device above, the results of sensor readings such as pH, soil moisture, the ultrasonic, real-time clock will be sent to Arduino Uno to be converted from the sensor voltage value into a standard value that is easy to read by the user. Then the Arduino Uno will be connected to the NodeMCU serially so that the sensor reading data can be sent via the internet network. In the process of sending the data, the data will enter the BLYNK server, which will then be sent to the user's smartphone via WiFi or a connected internet network to be displayed on the BLYNK application according to the widget that has been set. The prototype of the Biotoilizer Automatic System that has been made can be seen in Figure 6.

Testing the Automatic Dispensing of Fermented LOFs to the Final Storage Tank.

This test aims to prove the accuracy of the time sensor that has been set with the microcontroller. The microcontroller will automatically turn the water pump when it has reached the predetermined time limit of 6 days. High pH can cause the breaking of hydrogen bonds that serve to hold DNA strands together. Disruption of hydrogen bonds destroys activity, causing denaturation and death of bacteria.
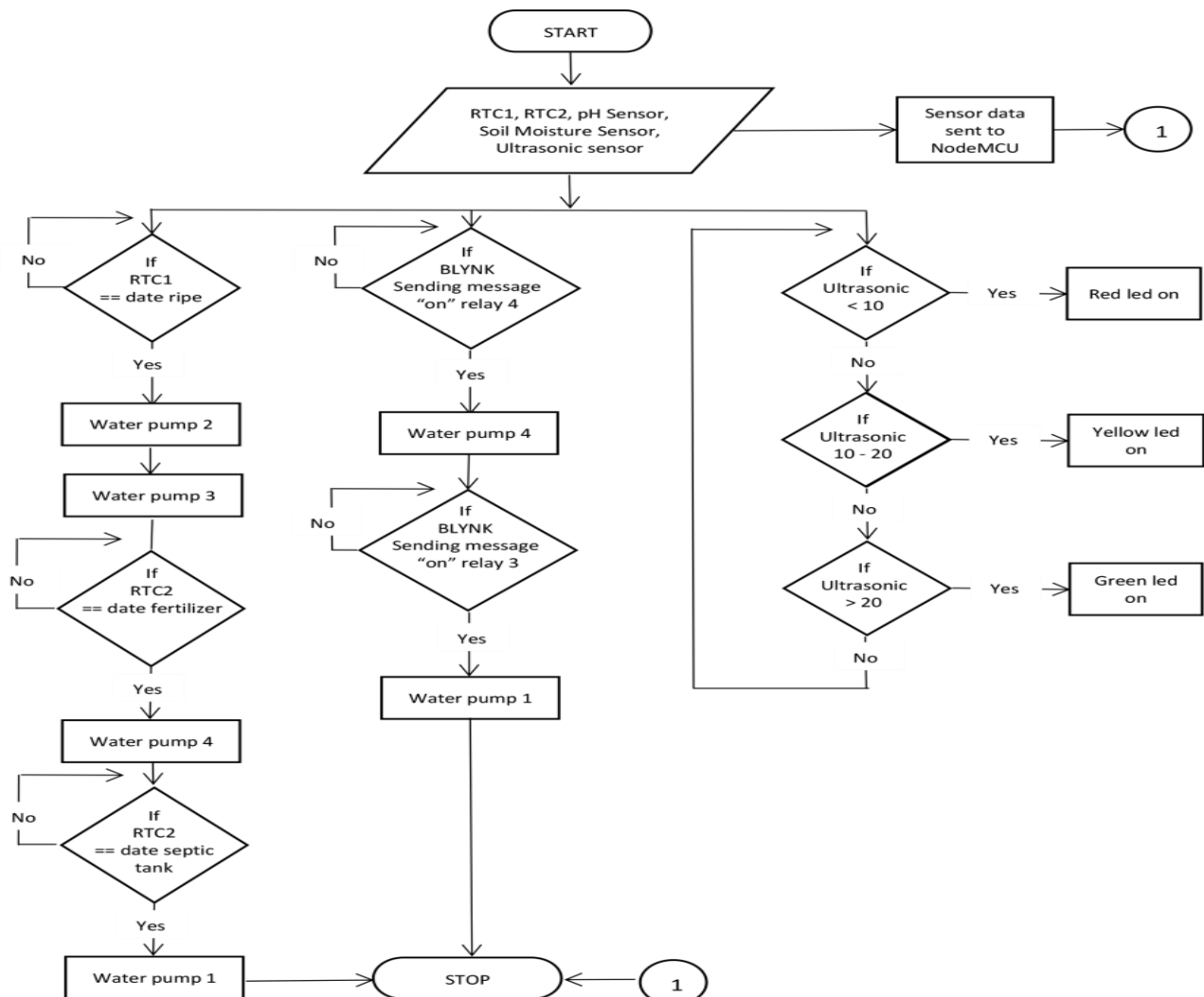
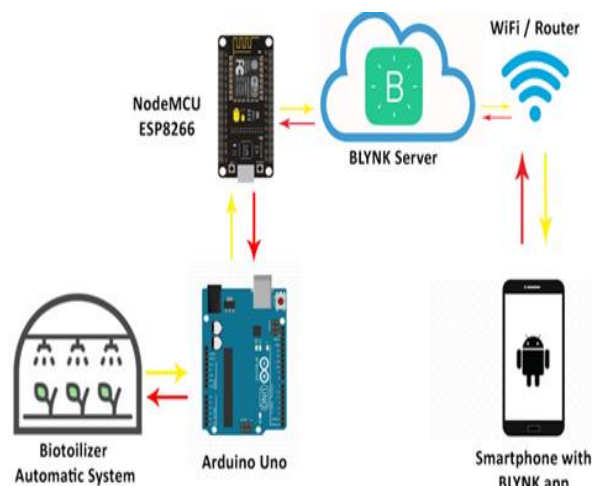**Figure 4.** Workflow diagram of the Biotoilizer Automatic System

Figure 5. Device Communication System

Figure 6. Prototype Biotoilizer Automatic System

The test was carried out with 12 trials. The test results in Table 1 show that the tool works well. Human urine that has been fermented in the storage tank flows automatically into the LOF tank, ready to be used every six days according to the settings set on the device. This tool will not work if it does not match the time set on the device.

Table 1. Test results for automatic dispensing of fermented LOFs to the final storage tank

No	Microcontroller	Device	
	Day	Day	Water Pump
1	6	2	Off
2	6	3	Off
3	6	4	Off
4	6	5	Off
5	6	6	On
6	6	1	Off
7	6	2	Off
8	6	4	Off
9	6	6	On
10	6	3	Off
11	6	5	Off
12	6	6	On

Table 2. Test results of automatic fertilization through the NodeMCU ESP2866 program

No	NodeMCU ESP2866 Program		Device		
	Time (WIT)	Day	Time (WIT)	Day	Solenoid Valve
1	16.00	Monday	15.00	Tuesday	Off
2	16.00	Monday	16.00	Thursday	Off
3	16.00	Monday	16.00	Saturday	Off
4	16.00	Monday	16.00	Monday	On
5	16.00	Monday	17.00	Wednesday	Off
6	16.00	Monday	17.00	Thursday	Off
7	16.00	Monday	16.00	Friday	Off
8	16.00	Monday	16.00	Sunday	Off
9	16.00	Monday	16.00	Monday	On
10	16.00	Monday	16.00	Wednesday	Off
11	16.00	Monday	16.00	Friday	Off
12	16.00	Monday	16.00	Monday	On

Note: WIT : Western Indonesian Time

Automatic Fertilization Testing Through NodeMCU Program ESP2866

The purpose of this test was to prove the accuracy of the fertilization time that has been set with the automatic fertilization program carried out by this device. The faucet (solenoid valve) automatically opens for 2 minutes to drain the fertilizer into the crop field once a week since the last fertilization, and soil moisture is detected at 70%.

The test was carried out with 12 trials. The results of the automatic fertilization test in Table 2 show that the tool is running well. The faucet (solenoid valve) automatically opens to flow liquid organic fertilizer to the plants according to the time that has been set on the tool. Liquid organic fertilizer will only flow to plants

automatically once a week, namely on Mondays at 16.00 WIB, other than the specified time the tool does not turn on. The best time for fertilization for plants is in the afternoon at 16.00 WIB for the fertilization.

Conclusion

The Biotoilizer Automatic System is equipped with applications to monitor time, humidity, and pH. Communication between the system and the BLYNK application is 2-way, namely, communication from the BLYNK application to the system (relay work orders) and communication from the system to the BLYNK application (sensor reading data). The system's test results can process urine into a biofertilizer

and fertilize automatically 95% based on regulated conditions and can be monitored with an application via a smartphone.

The automatic testing results on LOF fermented to the final storage tank and automatic fertilization testing through the NodeMCU ESP2866 automatic fertilization program showed that the tools can performed well. The fermented human urine in the storage tank was automatically transferred to the LOF tank, ready for use every six days as scheduled. The faucet (solenoid valve) automatically opens to flow liquid organic fertilizer to the plants following the time scheduled on the system. Yet, further improvements are essential, include packaging (enabling for application in various agricultural locations and conditions), and addition of security systems (i.e. usernames and passwords for better control and safe operation).

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