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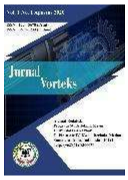

IOT INTEGRATED AUTOMATIC WATER FILTER SYSTEM USING COARSE FILTER MEDIA AND UPFLOW METHOD

Panangian Mahadi Sihombing[1*], Michael Stevano Sinurat[2], Nurhafni Carol[3], Lukcy T Simanjuntak[4], Indah Vusvita[5], Nur Adilah[6], Sari Novalianda[7], Andri Ramadhan[8], Heri Yusuf Simbolon[9]

[1,2,3,4,5,6] Electrical Engineering, Politeknik Negeri Medan, Jl. Almamater No. 1 Kampus USU, Padang Bulan, Kec. Medan Baru, Kota Medan, Sumatera Utara 20155

[7] Electrical Engineering, Faculty of Engineering, Universitas Al-Azhar Medan, Jl. Pintu Air IV No.214, Kwala Bekala, Kec. Medan Johor, Kota Medan, Sumatera Utara 20143

[8] Informatics Engineering, Universitas Nahdlatul Ulama Sumatera Utara, Jl. Gaperta Ujung No.2, Tj. Gusta, Kec. Medan Helvetia, Kota Medan, Sumatera Utara 20125

Email: *panangianmahadi@polmed.ac.id

Info Article	Abstrac
Historical Articles: Received: month dd, yyyy Accept and revise: month dd, yyyy Approved: month dd, yyyy **Keywords**: Water Quality, Backwash, IoT. 	Currently, many Indonesian people do not have access to drinking water provided by Regional Drinking Water Companies (PDAM) or Regional Public Companies (Perumda). People often use surface water and/or groundwater directly to meet their needs for clean water and drinking water. Therefore, a system that can filter water is necessary to meet the standards for clean water quality. This research aims to develop an automatic water filter system based on the Internet of Things (IoT) that can filter water to achieve a standard water quality. The novelty of this study lies in its application of an automatic backwash system based on predetermined parameters. The research method is based on research and development (R&D), which consists of several systems, namely venturi aeration, filters, automation, and IoT. Venturi aeration functions to oxidize the metal content, allowing it to settle before entering the filter. This is to extend the filter's lifespan. The filter is in the form of a 3-inch-diameter polyvinyl chloride (PVC) pipe, composed of three types of sand media: silica, green manganese, and activated carbon. Silica functions to reduce turbidity. Green manganese functions to reduce the content of manganese, iron, or hydrogen sulfide, and activated carbon functions to eliminate odors and the yellow color. The automation system comprises a microcontroller, several sensors, and a solenoid valve, enabling the technology device to perform automatic filtration and backwashing. The IoT system includes a microcontroller integrated with each sensor, which can be connected to the internet via a router. This enables the display of reading results from each sensor through the ThingSpeak platform, which is installed on an Android device. Based on the results and discussions, it has been concluded that the resulting prototype is capable of automatically carrying out the filtering and backwash processes. Furthermore, it is also

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known that there is an improvement in water quality, which includes turbidity, total dissolved solids (TDS), and pH.

Kata Kunci: Kualitas Air, Backwash, IoT.

Abstrak

Saat ini, banyak masyarakat Indonesia yang tidak memiliki akses air minum yang disediakan oleh Perusahaan Air Minum Daerah (PDAM) atau Perusahaan Publik Daerah (Perumda). Orang sering menggunakan air permukaan dan/atau air tanah secara langsung untuk memenuhi kebutuhan mereka akan air bersih dan air minum. Oleh karena itu, sistem yang dapat menyaring air diperlukan untuk memenuhi standar kualitas air bersih. Penelitian ini bertujuan untuk mengembangkan sistem filter air otomatis berbasis Internet of Things (IoT) yang dapat menyaring air untuk mencapai kualitas air yang standar. Kebaruan dari penelitian ini terletak pada penerapan sistem pencucian balik otomatis berdasarkan parameter yang telah ditentukan. Metode penelitian tersebut didasarkan pada penelitian dan pengembangan (R&D), yang terdiri dari beberapa sistem, yaitu aerasi venturi, filter, otomatisasi, dan IoT. Aerasi venturi berfungsi untuk mengoksidasi kandungan logam, memungkinkannya mengendap sebelum memasuki filter. Ini untuk memperpanjang umur filter. Filter tersebut berupa pipa polivinil klorida (PVC) berdiameter 3 inci, terdiri dari tiga jenis media pasir: silika, mangan hijau, dan karbon aktif. Silika berfungsi untuk mengurangi kekeruhan. Mangan hijau berfungsi untuk mengurangi kandungan mangan, zat besi, atau hidrogen sulfida, dan fungsi karbon aktif untuk menghilangkan bau dan warna kuning. Sistem otomasi terdiri dari mikrokontroler, beberapa sensor, dan katup solenoid, memungkinkan perangkat teknologi untuk melakukan filtrasi otomatis dan pencucian balik. Sistem IoT mencakup mikrokontroler yang terintegrasi dengan setiap sensor, yang dapat dihubungkan ke internet melalui router. Ini memungkinkan tampilan hasil pembacaan dari setiap sensor melalui platform ThingSpeak, yang diinstal pada perangkat Android. Berdasarkan hasil dan pembahasan, telah disimpulkan bahwa prototipe yang dihasilkan mampu melakukan proses penyaringan dan backwash secara otomatis. Selain itu, diketahui juga bahwa ada peningkatan kualitas air, yang meliputi kekeruhan, total padatan terlarut (TDS), dan pH.

INTRODUCTION

Access to safe and clean drinking water is a basic human need necessary for health and sustainable development [1], [2]. Clean water and drinking water that do not meet the requirements can cause various types of diseases [3], [4]. Currently, access to drinking water in Indonesia remains low, as indicated by Presidential Instruction (Inpres) Number 1 of 2024, which concerns the Acceleration of Drinking Water Supply and Domestic Wastewater Management Services [5]. However, the Presidential Instruction has been delayed, so a technological device is needed to overcome the problem of low access to drinking water. In addition, the high cost of installing distribution pipes borne by customers, as well as the cloudy color of water from Regional Drinking Water Companies (PDAM)/Regional Public Companies (PERUMDA), especially

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during rainy weather, reinforces the need for this research to be carried out [6]. This research is urgent because it concerns the fundamental rights of the community to improve the welfare and quality of public health related to waterborne diseases, reduce the prevalence, and prevent stunting. Additionally, reducing the rate of excessive groundwater extraction is necessary to avoid environmental damage.

This study proposes a low-cost and straightforward technological device that filters water to improve the quality of clean water. The device is inexpensive and concise because it is made from a 3-inch polyvinyl chloride (PVC) pipe that contains three types of coarse filter media: silica sand, green manganese sand, and activated carbon sand. 3-inch PVC pipe replaces the use of Plastic Reinforced Fiberglass (FRP) filter tubes [7], while coarse filter media replaces the use of membrane filters [8], [9]. In addition to being more affordable, both components are readily available on the market, enabling users to repair pipes and replace filter media independently. Furthermore, the improvement of clean water quality parameters that will be produced by the technology device includes turbidity parameters, total dissolved solids (TDS), and pH [10], [11], [12].

This study uses silica sand to reduce turbidity [13], green manganese sand to lower water hardness [14], and activated carbon sand to reduce odor and yellow color [15]. The proposed technological device operates automatically for both the filter and backwash processes. This device is also integrated with the Internet of Things (IoT), so that the water quality can be known before and after the filter [16], [17], [18]. Thus, the resulting device is expected to be an alternative for producing drinking water of better quality.

Some of the troubleshooting approaches to produce such filter systems are as follows. The filter system is designed using an upflow method composed of several main components, including a pump, a venturi aeration system, a tank, a 3-inch PVC pipe, and coarse filter media for quick filtration. The upflow method is used to facilitate the backwash process. [19]The automation system is designed using a microcontroller that is connected to two solenoid valves and several sensors, including pressure, water level, and turbidity sensors. The technology device will filter if the water level in the clean water tank is below the predetermined limit. Meanwhile, for backwash, if the water turbidity in the clean water tank exceeds the predetermined limit, IoT systems are designed using a microcontroller that can be connected to the internet network through a router and a platform as an interface between machines and humans. The microcontroller is connected to several sensors, namely water level, pH, TDS, and turbidity. So, the output of each sensor can be monitored through an Android or a computer. [20]The performance testing of technological devices was carried out using a statistical formula approach, including R Square (R^2), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) [6], [21], [22].

State of The Art

In 2020, Orlando, M., developed a device capable of monitoring pH, turbidity, and water levels using IoT technology. Additionally, it can control the water tap at three different levels. The water tap can be opened if the pH and turbidity of the water meet the standards [20]. In 2021, Lakshmikantha, V., developed a device capable of monitoring pH, turbidity, conductivity, carbon dioxide, humidity, and temperature using IoT technology [23]. In 2023, Sarifudin, S., developed a tool to monitor water turbidity. Able to control filter and backwash work automatically based on water level and turbidity, and equipped with Human Machine Interface (HMI) technology [24]. In 2023, Isvahady has also produced a device capable of monitoring IoT-based turbidity. Able to control the water filter automatically based on turbidity. The water filter is composed of silica sand, activated carbon, and gravel. The water tap can be opened if the turbidity meets the standard [25]. In 2024, Guna M H. produced a device capable of monitoring turbidity and

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pH. Able to control the water filter and backwash automatically based on turbidity by using five solenoid valves. The filter is composed of silica, zeolite, and activated carbon [3]. In 2024, Wardani, A., developed a device capable of monitoring turbidity and pH using IoT technology. Able to control the water filter automatically using three containers and three pumps. The filter is composed of activated sand, silica, zeolite, and activated carbon [10].

Research Novelty

Some of the novelties resulting from this research are that the device can monitor water levels, turbidity, TDS, and pH levels using IoT technology. This pernate utilizes a venturi aeration system to reduce the metal content naturally. The device can also automatically control filters and backwashes based on water level, TDS, turbidity, and pH. This device is equipped with a manual filter and backwash system. This device utilizes six solenoid valves and two pumps. The filter is composed of silica sand, green manganis, and activated carbon.

RESEARCH METHODS

The research process is illustrated sequentially in the flowchart shown in Figure 1. Based on the image, three main activities are involved in designing an IoT-integrated automatic water filter system. First, creating a piping system for filtering is required. The manufacture of the filtration piping system utilizes 3-inch PVC pipe and coarse filter media, such as sand. Second, designing an automatic filter system. This process involves six solenoid valves, integrated with an automatic float switch, which controls the pump's operation. The automatic control referred to in the filter system includes the automation of the filter process and the backwash process. The filter process functions to filter raw water and produce clean water, while the backwash process is necessary to clean the coarse filter as a result of the filtration process. Third, creating an IoT-based water level monitoring system. This process is carried out using an A02YYUW waterproof type water level sensor and an ESP32 board, which is connected to the router.

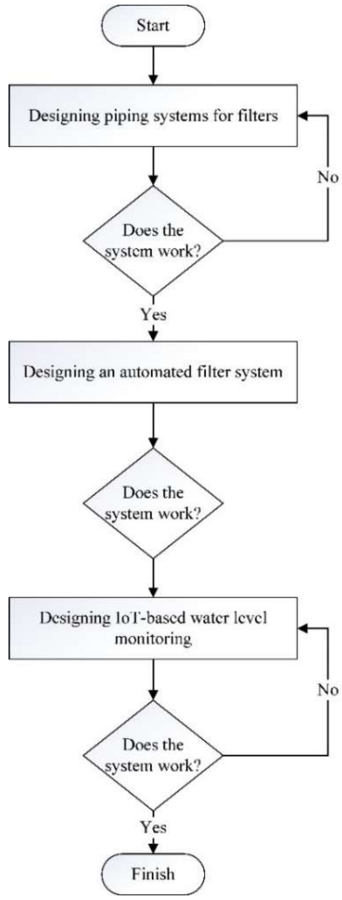

Figure 1 Research Flow Chart

The IoT-integrated automatic water filter system consists of two primary processes: filtration and backwashing. The two processes are shown in Figures 2 and 3, respectively. The filtration process begins with the suction of raw water by the raw water pump, which fills the Aerated Water Tank through the venturi aeration system (sprayer). Raw water can be in the form of surface water, groundwater, or reservoirs. The sprayer functions as an oxidizer to reduce the metal content in the raw water before it enters the filter section, thereby reducing the workload on the filter. Solenoid Valves 1 (V1), V2, and V5 will be open while V3, V4, and V6 remain closed so that the aeration pump drains water from the aeration tank to the filter section by upflow method and

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then to the Clean Water Tank. The upflow method is a water filtration method that utilizes a flow of water from the bottom to the top, making it easier and more efficient during the backwash process.

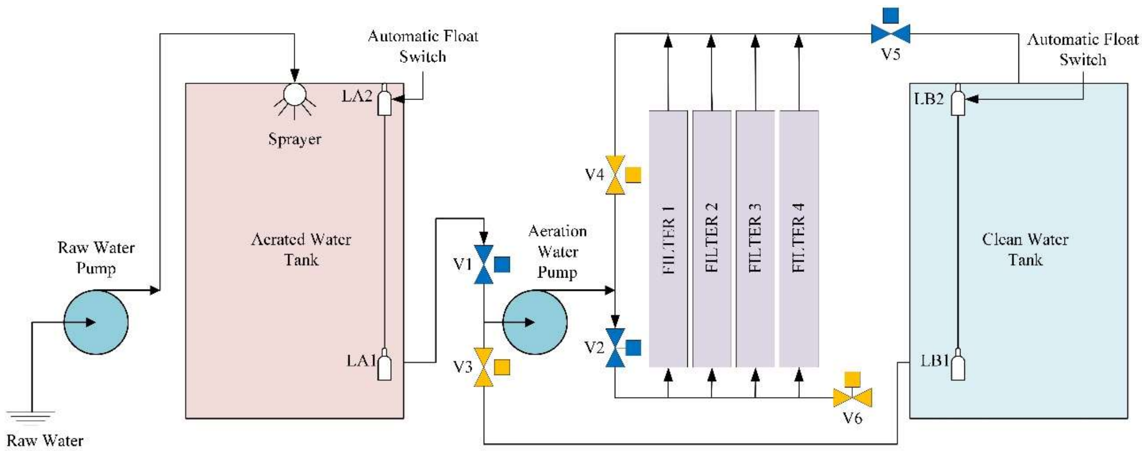

Figure 2 Filtration

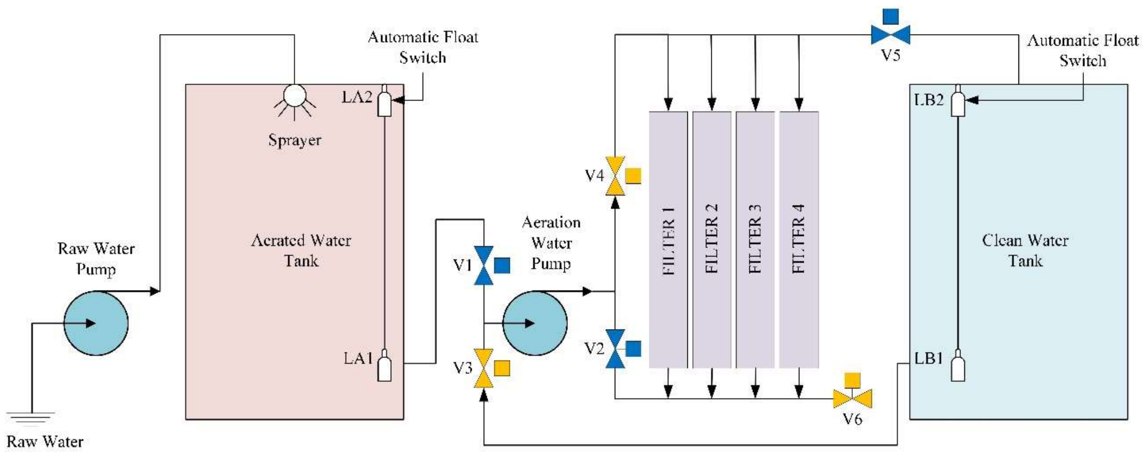

Figure 3 Backwash Process

Each water tank is equipped with a water level sensor consisting of two floats, one installed on the minimum side (LA1, LB1) and the other on the maximum side (LA2, LB2). The sensor acts as an automatic switch, so that each pump will operate automatically if the water level in the tank reaches the minimum level (±10cm), but will stop working if the water level exceeds the maximum level (±70cm).

The backwash process occurs automatically if the parameters in Table 1 are met. In the table, the information requirements for clean water tank levels are provided to avoid damage to the valve and pump systems. Because it is feared that the water pump will work without draining water. Meanwhile, the requirement of the chemical properties of water is necessary to avoid wasting clean water.

Table 1 Backwash Process Parameter Requirements

Parameter	Value
Clean Water Tank Level	> 40cm
Outlet Water Pressure	> 5kPa
Clean Water Turbidity	> 25NTU
TDS	> 1.500mg/l

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The backwash process uses clean water to clean each filter. So, V3, V4, and V6 will be open, while V1, V2, and V5 will remain closed. Thus, clean water will be pumped by the Aeration Pump to the filter with a top-down flow. Figure 4 is a block diagram of the IoT-integrated water filter control system. Based on the image, the IoT-integrated automatic filter system consists of an ESP32 microcontroller connected to a router, relay, LCD, and multiple sensors.

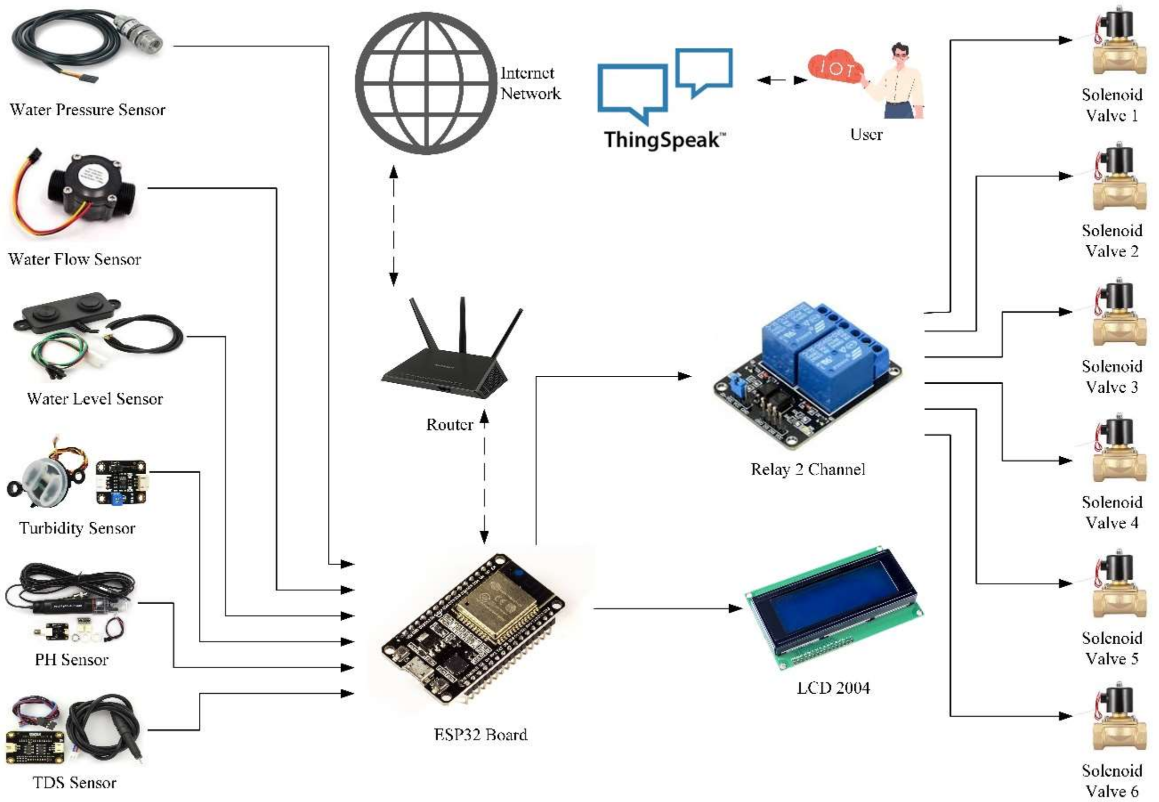

Figure 4 Diagram Block

Some of these sensors include water pressure sensors, water flow sensors, A02YYUW water level sensors, turbidity sensors, PH sensors, and total dissolved solids (TDS) sensors. Each sensor functions to transmit the results of its sensor readings in electrical quantities to the ESP32 board, which is then processed and displayed on the 2004 LCD. The ESP32 also connects to the internet via a router and sends the sensor readings to the ThingSpeak server, which serves as both an interface for the user and a platform for data storage. The ESP32 controls the operation of each Solenoid Valve based on the data from each sensor to perform the filter and backwash processes.

ANALYSIS AND EVALUATION

The results of the design for the IoT-integrated automatic water filter system (FATOI), utilizing coarse filter media and the upflow method, are presented in Figure 5 below. Based on the drawing, the FATOI system is integrated with a support iron, allowing it to be portable. Each solenoid valve is also equipped with an indicator light to indicate whether the solenoid valve is in working condition (green) or not working (red). Additionally, pressure gauges and flow meters were installed on the inlet and outlet sides of the FATOI system to determine if the system is clogged and/or leaking. On the top side of each 3-inch PVC pipe is a lid that

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can be opened and reclosed. This feature is designed to facilitate the replacement of rough filters [26], [27].

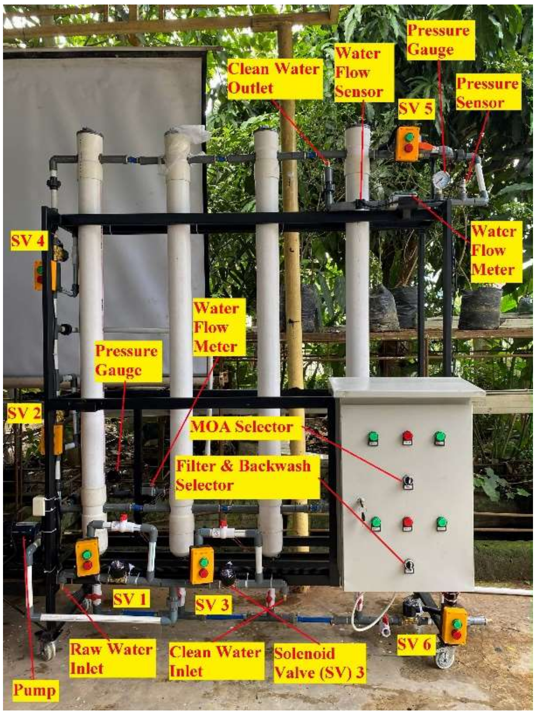

Figure 5 IoT-Integrated Automatic Water Filter System

Figure 6 is a series of electrical panel installations of the FATOI system. Based on the image, it can be seen that the FATOI system is equipped with two switch selectors, one of which functions as a Manual Off Auto (MOA). Meanwhile, the other switch selector is used for manual filter and backwash processes. Furthermore, six solenoid valves are supplied with a single-phase power source through an automatic float switch.

Figure 7 shows the design and construction of the FATOI system's electrical panel installation. Figure 7 shows the ESP32 processor equipped with a 2004 LCD and several sensors connected to the inlet and outlet pipes of the filter system. Based on these images, it can also be seen that the FATOI system can display the results of measurements made by each sensor. Figure 8 shows the water filter process using the FATOI System, while Figure 9 shows the sensor position on the sensor box. Based on Figure 8, it can be seen that the FATOI System has successfully filtered the water entering through the inlet and discharged it at the outlet.

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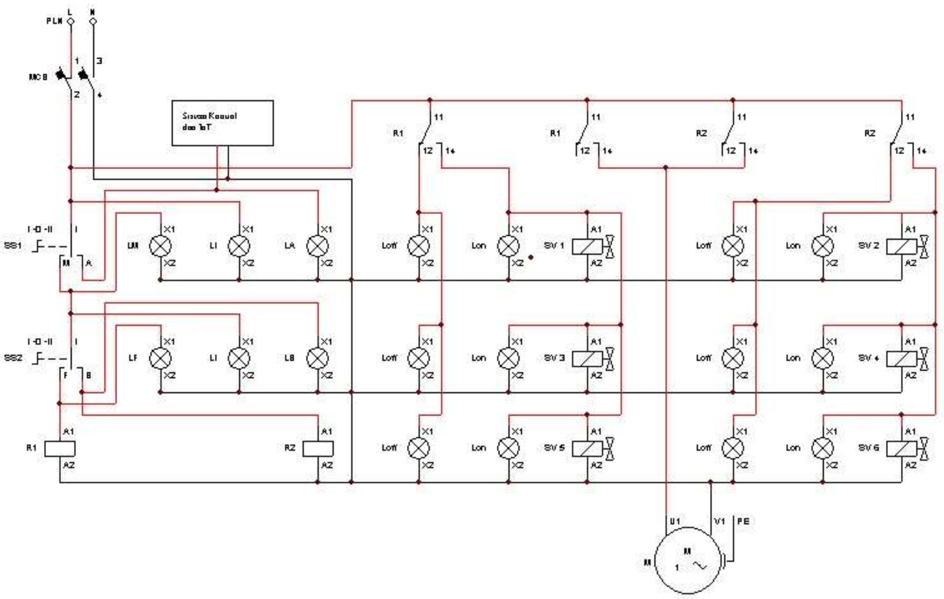

KETERANGAN	
SS	Selector Switch
M	Manual
I	Idle
A	Automatic
LM	Manual Lamp
LI	Idle Lamp
LA	Automatic Lamp
F	Filter
B	Backwash
LF	Filter Lamp
LB	Backwash Lamp
Loff	Off Lamp
Lon	On Lamp
SV	Selenoid Valve
R	Relay
M	Motor

Figure 6 A Series of Electrical Panel Installations of the FATOI System

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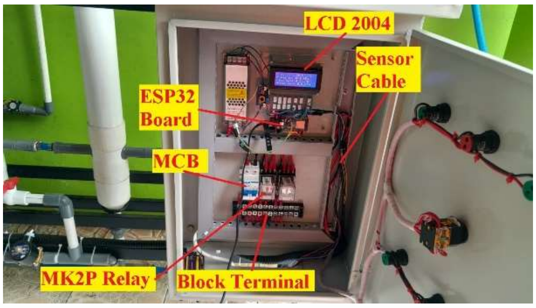

Figure 7. Design and Build Electrical Panel Installation of FATOI System

Figure 8. Water Filter Process Using the FATOI System

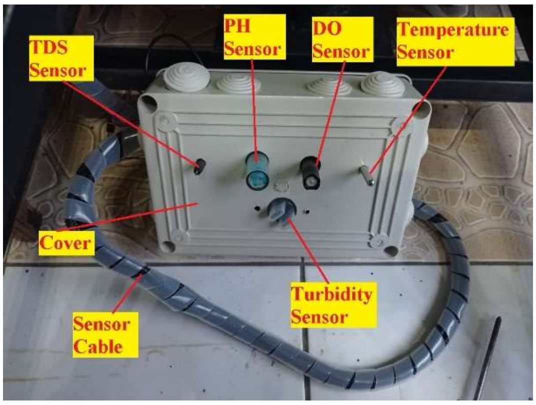

Figure 9. Sensor Position on the Sensor Box

Meanwhile, based on Figure 9, it can be seen that each sensor is arranged in a box, providing it with the appropriate capabilities for a watery environment. Figure 10 illustrates the sensor testing process of the FATOI System, which involves measuring water quality using a specific tool. The two measurement results were compared to determine the performance of each FATOI System sensor. The parameters measured include temperature, PH, TDS, and turbidity.

Figure 10 Sensor Testing Process of the FATOI System

The parameters measured to determine the performance of the filter tool produced are shown in Table 2. Table 2 presents the expected water quality parameters based on the filtration results. Based on the data from the two tables, it is evident that the FATOI system can operate optimally due to its low error value. Likewise, the water tank level value can be measured using a sensor, which is displayed on the LCD screen. The FATOI system has also successfully displayed the results of each measurement on the ThingSpeak platform. Figures 11 and 12 are the curves of the sensor measurements.

Figure 11 DO and Turbidity Curve on ThingSpeak

Figure 12 Temperature, pH, and TDS Curve on ThingSpeak

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Table 2 Test Results Achievement

Performance	Performance Achievements
Interpretation results of pH, TDS, turbidity, and water level sensor performance measurements	RMSE = 0,31; and MAPE < 4,4%.
The 2004 LCD is capable of displaying water quality measurement data from each sensor.	Yes
Sensor measurement data can also be monitored via Android or a computer	Yes
The FATOI system is capable of automatically filtering and displaying a special indicator light.	Yes
The FATOI system is capable of performing the backwash process automatically and displays a special indicator light	Yes

Table 3 Water Quality Parameters Measurement Results (After Filtration)

Parameter	Value
Clean Water Tank Level	> 20cm
Turbidity	< 5NTU
TDS	< 500mg/l
pH	6,5 - > 8,5

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CONCLUSION

Based on the results and discussions, it can be concluded that the FATOI system provides effective filtration results because it is equipped with an automatic backwash system. In addition, the FATOI system also produces clean water with water quality parameters that meet clean water standards.

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