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Ambient Air Quality Detection System Powered by Internet of Things-Based Sansevieria Plant (Case Study of Manduro Health Center)

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ABSTRACT

Puskesmas Manduro is one of the public health service centers located at Jl. Raya Ngoro KM 14, Manduro MG Village, Ngoro District, Mojokerto Regency, East Java. As a basic health service center, it is important to monitor air quality and maintain air quality in accordance with the Environmental Quality Standard (SBMKL). This study aims to design an Internet of Things-based air quality detection system that utilizes Sansevieria plants as one of the natural solutions in absorbing air pollution levels. The method used is the research and development method which includes system design, tool making, website design, tool integration, and system testing. The sensors used are MQ-7 sensors for carbon monoxide gas, MQ-135 sensors for nitrogen dioxide gas, MQ-131 sensors for ozone gas, Dust GP2Y1010AU0F sensors for PM2.5, and DHT22 sensors for temperature and humidity. The results of testing the system for three days obtained the average temperature 30.64°C, humidity 73.62%, CO 735.63 μg/m³. NO2 27.30 μg/m³, O3 32.13 30 μg/m³, and PM2.5 2.14 μg/m³. Based on the test results that have been carried out, it shows that the air quality monitoring system can provide data, graphs, and indicator levels for the Air Pollution Standard Index (ISPU). Air quality data obtained from sensors can be displayed on the LCD and also displayed in real-time through the website.

Keywords: *Manduro Health Center, Air Quality, Sansevieria Plants*

1. INTRODUCTION

Puskesmas Manduro is one of the community health service centers located at Jl. Raya Ngoro KM 14, Manduro MG Village, Ngoro District, Mojokerto Regency, East Java. [1]. Manduro Health Center, which is located next to the highway, experiences significant impacts from heavy traffic due to the high concentration of industrial companies that reach 33.24 percent, both large and medium industrial companies located in the Ngoro Industri Persada (NIP) area [2], making it important to monitor air quality. Efforts to improve and maintain air quality in the health center environment can also be done by planting plants around the health center to help absorb air pollution and produce oxygen. Sansevieria plants are one type of plant that is known to have the ability to reduce air pollution [3]. Research by the United States National Space Agency (NASA) shows that Sansevieria or tongue-in-law is able to absorb more than 107 elements of pollution that are present and harmful in the air [4]. It is also drought-resistant and low-maintenance, making it suitable for use in health center environments.

Air quality monitoring in health environments such as health centers is very important [5]. However, Manduro Health Center still does not have an adequate air quality monitoring system, either in the form of measuring devices or websites. Therefore, research was conducted to develop an Internet of Things-based air quality detection system that utilizes sansevieria plants as one of the natural solutions in absorbing air pollution levels. The air quality parameters to be detected are Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Ozone (O3), Particulate Matter (PM2.5), Temperature and Humidity. By integrating the IoT system, real-time information about pollution gas levels in the health center environment is generated, so that it can be identified and resolved quickly. This research is expected to contribute to environmental protection and public health efforts around Manduro Health Center through technological innovation and utilization of natural resources.

2. LITERATURE REVIEW

2.1 Standard of Environmental Health Quality (SBMKL) for Health Facilities

Specifically for public places and facilities in health care facilities including hospitals, health centers and clinics, the parameters that must be examined consist of physical, chemical and biological parameters. The measured SBMKL is adjusted to the type of service and room available at the health service facility [6].

Table 1. SBMKL Ambient Air Chemical Parameters

No	Parameters	Measurement Time	Quality Standard
A	PHYSICAL PARAMETERS		
1.	Temperature		20 – 30°C
2.	Humidity		40 – 70%
3.	$PM_{2.5}$	24 hours	55 $\mu g/m^3$
B	PARAMETER KIMIA		
1.	Carbon Monoxide (CO)	1 hour	10000 $\mu g/m^3$
		8 hours	4000 $\mu g/m^3$
2.	Ozone (O_3)	1 hour	150 $\mu g/m^3$
		8 hours	100 $\mu g/m^3$
3.	Nitrogen Dioxide (NO_2)	1 hour	200 $\mu g/m^3$
		24 hours	65 $\mu g/m^3$

2.2 Air Pollution Standard Index (ISPU)

Good air quality monitoring must follow the regulations or standards set by the relevant institutions. Indonesia through the Ministry of Environment and Forestry (MoEF) has issued Minister of Environment Regulation No. 14 of 2020 [7].

Table 2. Concentration Value Conversion

ISPU	PM2.5 (µg/m3)	CO (µg/m3)	O3 (µg/m3)	NO2 (µg/m3)
0-50	15,5	4000	120	80
51-100	55,4	8000	235	200
101-200	150,4	15000	400	1130
201-300	250,4	30000	800	2260
>300	500	45000	1000	3000

ISPU calculations are made based on the upper limit ISPU, lower limit ISPU, upper limit ambient, lower limit ambient, and ambient concentration values measured. The mathematical equation for ISPU calculation is as follows:

$$I = \frac{I_a - I_b}{X_a - X_b}(X_x - X_b) + I_b$$

Description:

I = Calculated ISPU

Ia = Upper limit ISPU

Ib = Lower limitISPU

Xa = Upper limit ambient concentration (μg/m3)

Xb = Lower limit ambient concentration (μg/m3)

Xx = Real ambient concentration of measurement results (μg/m3)

The results of the ISPU value calculation are used to categorize air quality conditions in a place. The qualification is based on the ISPU value of the main pollutant parameters.

Table 3. Categories of Air Pollution Standard Index (ISPU)

Range	Category	Explanation
1-50	Good	Excellent air quality levels, no negative effects on humans, animals and plants
51-100	Medium	Air quality levels are still acceptable to human, animal and plant health
101-200	Unhealthy	Air quality levels that are detrimental to humans, animals and plants
201-300	Very Unhealthy	Air quality levels that may indicate health risks to some segments of the exposed population.
>300	Dangerous	Air quality levels that may cause serious adverse health effects in the population and require immediate action

3. METHODS

This system design consists of a block diagram, hardware planning and software design.

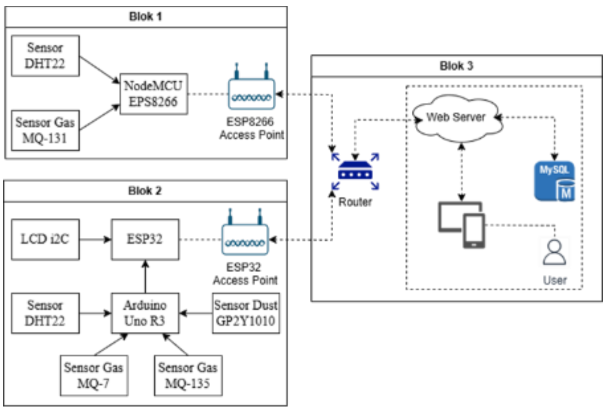

Figure 1. System Block Diagram

This IoT-based ambient air quality detection system consists of three main blocks. Block 1 involves DHT22 (temperature and humidity), MQ-131 (ozone) sensors, and an ESP8266 NodeMCU that connects the sensors to a Wi-Fi network. Block 2 uses an i2C LCD, DHT22 sensor, GP2Y1010AU0F (PM2.5), MQ-7 (carbon monoxide), MQ-135 (nitrogen dioxide), and an Arduino Uno R3 with ESP32 as the access point to send data to the router. Block 3 includes a router that connects the NodeMCU ESP8266 and ESP32 to the internet, sends data to the server, stores it in a MySQL database. Users can access via smartphone or laptop devices. The data flow includes collection by sensors, transmission via Wi-Fi, storage on the server, and access by users via the web interface.

3.1 System Flowchart

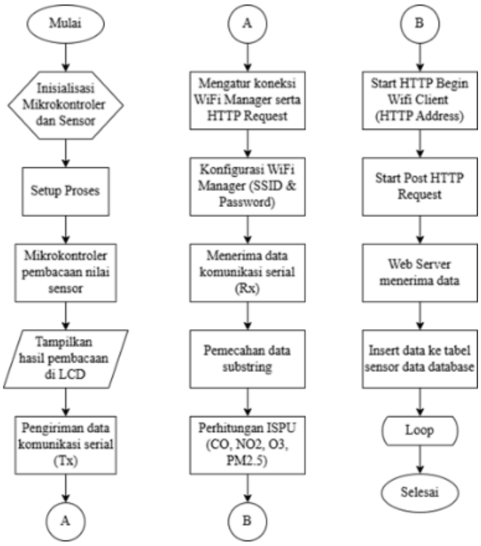

Figure 2 System Flowchart

The flowchart in Figure 2 shows the process flow from initialization to sending sensor data to the server. The process starts with the initialization of the microcontroller (Arduino Uno R3, ESP32, ESP8266) and sensors (MQ-7, MQ-135, MQ-131, DHT22, GP2Y1010AU0F). After the initial setup, the microcontroller reads the sensor values and displays the results on the LCD. The sensor data is then sent via serial communication to the ESP32, which sets up the WiFi connection and HTTP request configuration. Once the WiFi connection is established, the ESP32 receives data from the Arduino and ESP8266, breaks it down into substrings, and calculates the Air Pollution Standard Index (ISPU) for CO, NO2, O3, and PM2.5 parameters. Then, the ESP32 sets up an HTTP client connection and sends the data to the server using the HTTP POST Request method. The web server receives the data and stores it in a database table for further analysis. This process repeats to update the data periodically.

4. RESULTS AND DISCUSSION

The registration counter room was chosen as the placement of the device because it is a strategic place with a high level of mobility and density of visitors, making it possible to take representative air quality measurements. In addition, the registration counter room also has easy access to the internet network, which is needed to support the system developed in this study.


Figure 3. Placement of Tools and Plants in the Registration Counter Space

4.1 DHT22 Sensor Testing

The test was carried out by comparing the readings of the DHT22 sensor with the YS-02 Mini Hygrometer which was carried out for 10 times with the time taken in the morning, afternoon, and evening.

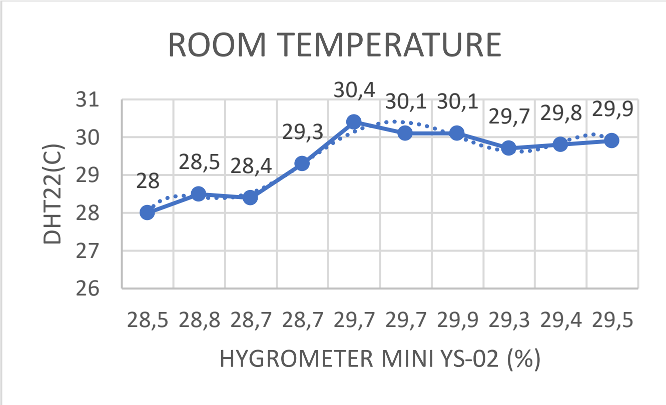

Figure 4. Temperature Comparison Chart

In the temperature test, the average temperature measured by the YS-02 Mini Hygrometer was 29.22°C, while the DHT22 sensor measured an average temperature of 29.42°C. The average difference between these two sensors is 0.42°C. The average error of the DHT22 sensor in the temperature test was recorded at 1.434%, with an average accuracy of 98.566%.

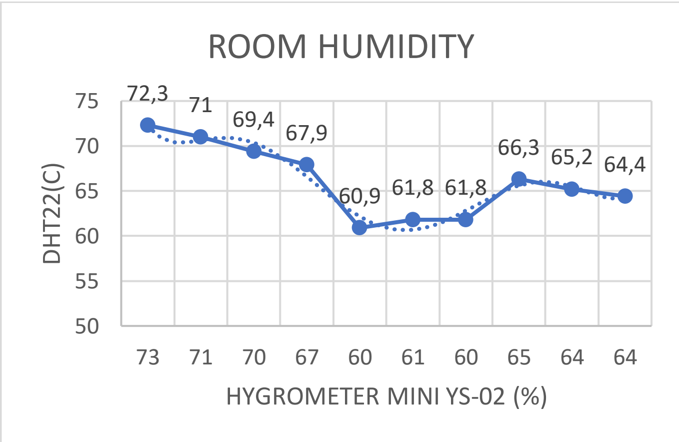

Figure 5. Humidity Comparison Chart

In the humidity test, the average humidity measured by the YS-02 Mini Hygrometer was 65.5%, while the DHT22 sensor measured an average humidity of 66.1%. The average difference between these two sensors is 0.86%. The average error of the DHT22 sensor for humidity testing was recorded at 1.344%, with an average accuracy of 98.656%.

4.2 GP2Y1010AU0F Dust Sensor Testing

The characteristics of this sensor are, where the higher the output voltage, the higher the Dust Density that is read[8]. The results of the linear equation between the Vo and Dust Density relationship are as follows:

$$\text{Dust Density } (mg/m^3) = 0.17x - 0.1$$

After getting the equation to convert the output voltage (Vo) into Dust Density (mg/m^3), the Dust Density unit (mg/m^3) will be converted to the unit $\mu g/m^3$. So that the following equation is obtained:

Dust Density (μg/m³) = (170×(V₀))-0.1

GP2Y1010AU0F dust sensor testing utilizes paper burning smoke emissions. Performed 10 times, to measure the level of smoke concentration with units (μg/m³). This test aims to see changes in sensor concentration to the amount of smoke density or density.

Table 4. Dust Sensor Response Testing

Trial to-	Vo	PM2.5
1	0.43 V	73.78 μg/m³
2	0.52 V	88.72 μg/m³
3	0.60 V	101.17 μg/m³
4	0.69 V	116.94 μg/m³
5	0.75 V	126.90 μg/m³
6	0.92 V	155.95 μg/m³
7	0.94 V	160.11 μg/m³
8	1.01 V	170.90 μg/m³
9	1.06 V	180.03 μg/m³
10	1.23 V	208.25 μg/m³

Based on testing the sensor response using paper burning smoke emissions, in the first experiment the PM2.5 value read was 73.78 μg/m³ with a voltage value of 0.43 V. And in the 10th experiment the PM2.5 value read was 208.25 μg/m³ with a voltage value of 1.23V. So the greater the value of PM2.5 that is read, the greater the voltage value.

4.3 MQ Sensor Testing (Sensor MQ-7, Sensor MQ-135, dan Sensor MQ-131)

To get the gas concentration value in ppm, it is necessary to convert the ADC value to voltage using the formula:

$$V_{RL} = \frac{ADC \times V_{REF}}{1023}$$

Description:

V_{RL} = Voltage at resistor RL
ADC = Value read from the sensor (between 0 and 1023)
V_{REF} = Reference voltage

$$V_{RL} = ADC \times (\frac{Vcc}{1024})$$

Next, calculate the value of Rs using the formula:

$$R_s = \left(\frac{V_{cc} \times R_L}{V_{RL}}\right) - R_L$$

Description:

R_s = Gas sensor resistance to be calculated
R_L= Load resistance, which is a constant resistor connected to the gas sensor
V_{cc}= Supply voltage applied to sensors and load resistors

In this study, the unit used is μg/m³ because it adapts to the Minister of Environment and Forestry Regulation No. 14 of 2020. The following is the formula used to convert gas concentration from ppm to mg/m³ [9]:

$$\text{Gas concentration} = 0.0409 \times \text{PPM} \times \text{Molecular Weight(MW)}$$

Description:

0.0409 = Conversion constant for converting ppm units to mg/m3
PPM = PPM value read on the sensor
MW = Molecular Weight of the gas measured in g/mol.

After obtaining the gas content in mg/m^3, the conversion is done again to get the unit $\mu g/m^3$ with the formula:

$$\text{Konsentrasi}\,\frac{\mu g}{m3} = mg/m3 \times 1000$$

The test was conducted for 60 minutes by utilizing motor vehicle emissions in measuring the concentration of CO, NO2, and O3 gases.

Table 5. MQ Sensor Measurement

No	Length of Measurement	MQ Sensor ($\mu g/m^3$)			Voltage (V)		Rs/Ro	
		MQ-7	MQ-135	MQ-131	MQ-7	MQ-135	MQ-7	MQ-135
1	0 minutes	0.57	17.82	0.91	0.37	0.06	29.89	77.69
2	10 minutes	3.5	80.95	1.17	1.03	0.12	9.05	39.92
3	20 minutes	9.41	154.96	5.35	1.23	0.17	1.12	30
4	30 minutes	9.99	243.83	9.43	1.31	0.13	1.02	24.57
5	40 minutes	11	322.39	17.98	1.47	0.17	0.88	21.73
6	50 minutes	12.47	414.41	32.08	1.68	0.22	0.72	19.46
7	60 minutes	16.68	668.23	46.98	2.21	0.36	0.46	15.77

Based on the test results, the MQ-7 and MQ-135 sensors show good ability to detect changes in CO and NO_2 concentrations with sufficient consistency. An increase in CO and NO_2 concentration is accompanied by an increase in output voltage and a decrease in R_s/R_o value, which indicates the sensor's response to an increase in CO and NO_2 gas levels in the environment. The MQ-131 sensor shows good ability to detect changes in ozone (O_3) concentration with high consistency. An increase in ozone concentration is accompanied by an increase in measurement duration, which indicates that this sensor is responsive and sensitive to ozone in the environment.

4.4 Overall System

Testing of the entire system was carried out in the Manduro Health Center registration counter room. This test was carried out with a scenario, namely by placing an air quality detection device in the room without any treatment, before and after the sansevieria plant. Data from the observation of temperature, humidity, CO, NO_2, O_3, and $PM_{2.5}$ can produce daily averages for 3 days as follows:

Table 6. Average Results of Air Quality Parameters For 3 Days of Measurement

Parameters	Calculation
CO ($\mu g/m^3$)	(721.404+810.7+678.7) / 3 = 736.93
NO2 ($\mu g/m^3$)	(34.817+28.7+20.8) / 3 = 28.10
O3 ($\mu g/m^3$)	(24.55+36.951+36.589) / 3 = 32.69
PM2.5 ($\mu g/m^3$)	(2.534+2+1.9) / 3 = 2.14
Suhu (°C)	(31.06+30.25+30.32) / 3 = 30.54
Kelembapan (%)	(71.93+72.5+76.54) / 3 = 73.65

Data were collected in the morning, afternoon, and evening for two days before the plants and 1 day after the plants.

1. Before the existence of Sansevieria plants

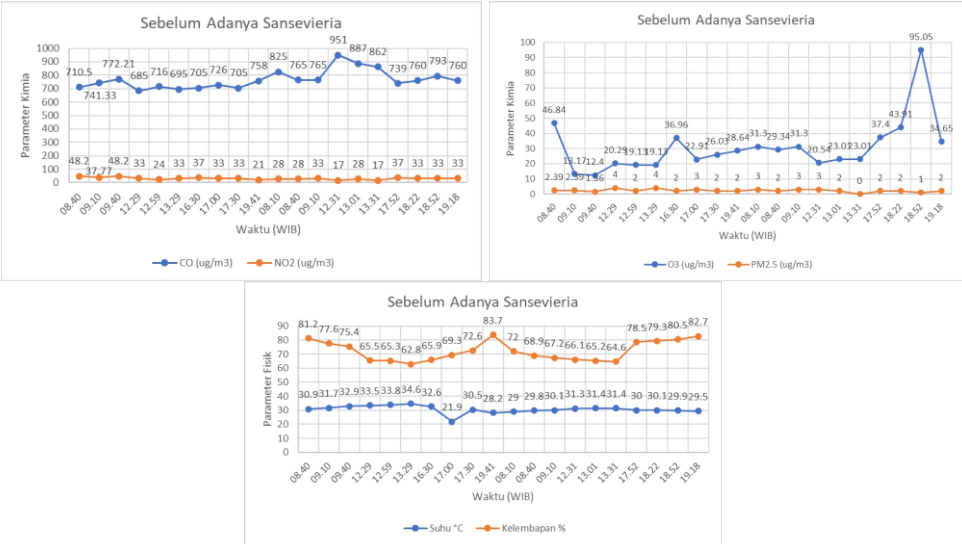

Figure 6. Parameters before the presence of sansevieria plants

Before plant application, CO concentration varied between 685.00 - 951.00 µg/m³, NO_2 varied between 17.00 - 48.20 µg/m³, O_3 varied between 12.40 - 95.05 µg/m³, $PM_{2.5}$ varied between 0.00 - 4.00 µg/m³, temperature ranged between 28.20 - 34.60°C, and humidity ranged between 62.80% - 83.70%.

2. After the existence of Sansevieria plants

Testing was carried out by giving Sansevieria plants which were placed in the registration counter room of the health center. The plants used amounted to 6 pots.

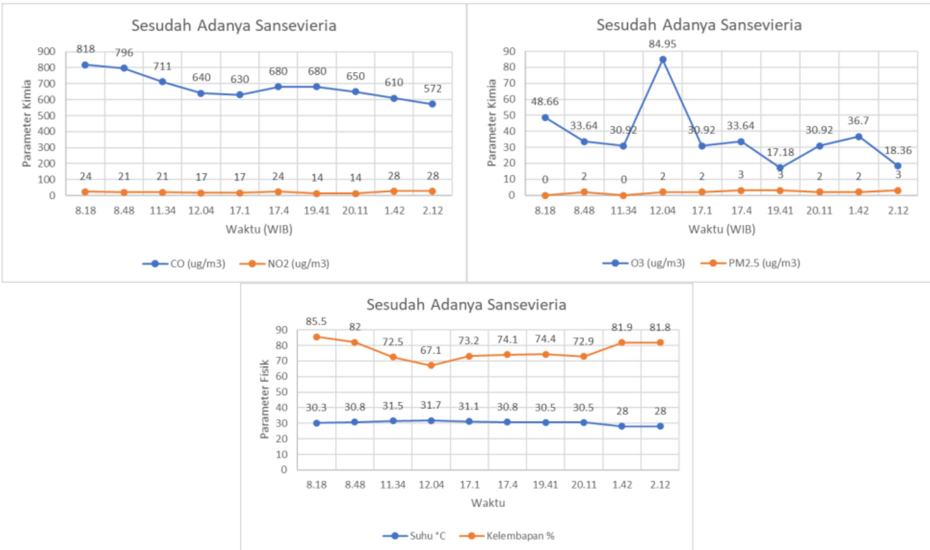

Figure 7. Parameters after the presence of sansevieria plants

After the plant application, CO concentration tended to decrease, with a range of 572.00 to 818 µg/m³, NO_2 concentration decreased with a range of 14.00 to 28.00 µg/m³, O_3 concentration decreased significantly with a range of 17.18 to 84.95 µg/m³, $PM_{2.5}$ concentration tended to decrease or remain low, with a range of 0.00 to 3.00 µg/m³, temperature decreased slightly with a range of 28.00 to 31.70 °C, and humidity ranged from 67.10% to 85.50%. The decrease in gas concentration, particulate dust, temperature, and humidity is also influenced by the number of indoor population and activities, the number of items that can absorb and reflect heat, thus affecting temperature and humidity, and other parameters (ventilation and weather).

3. Analysis of Monitoring Results with SBMKL
   a) During the three days of measurement, the temperature and humidity at the registration counter of Manduro Health Center were 30.54°C and 73.65%. In the SBMKL, the temperature and humidity for health facilities are set at 20-30°C and 40-70%. Thus, the measurement results show that the average temperature is slightly above the maximum limit (30°C) and the average humidity exceeds the maximum limit (70%). Therefore, the temperature and humidity at Manduro Health Center do not fully comply with the standards set by Permenkes No. 2 Year 2023.
   b) All CO measurement values are far below the maximum limit of 4000 μg/m³, NO_2 measurement values are far below the maximum limit of 65 μg/m³, all O_3 measurement values are far below the maximum limit of 100 μg/m³, $PM_{2.5}$ measurement values are far below the maximum limit of 55 μg/m³, so that air quality can be considered safe and in accordance with the standards of Permenkes Number 2 of 2023.

4. User Interface (UI)
   a) Login/Logout

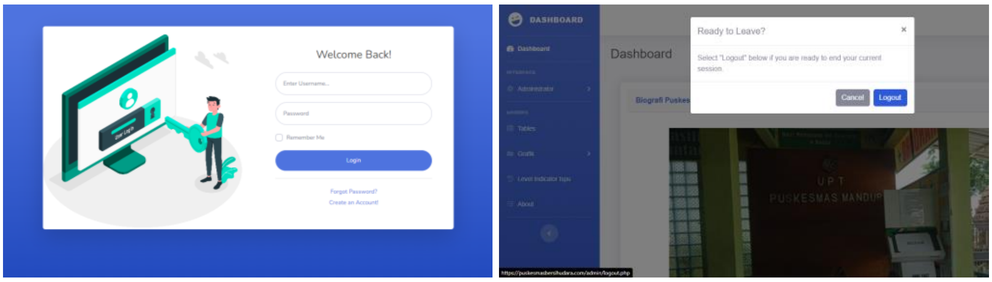

Figure 10. Website Login and Logout

   b) Dashboard Menu

On the dashboard menu there is a “Generate Report” button to view the sensor reading report. Also on the dashboard menu there is a picture of the health center, where there is an arrow to the right that can be clicked to see other images.

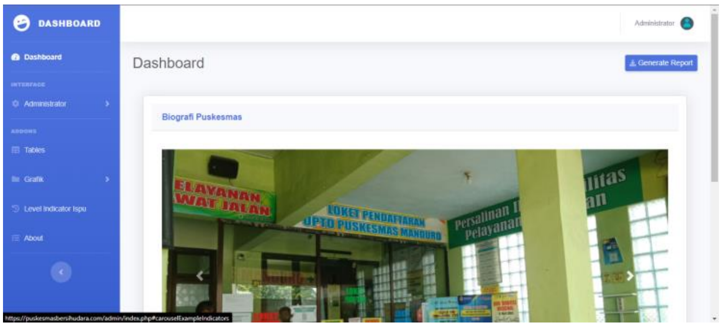

Figure 8. Dashboard Menu

   c) Table and Chart Menu

At the top of the table, there is a search form with two date inputs, namely start date and end date and a search button. This feature allows users to filter data based on a specific date range.

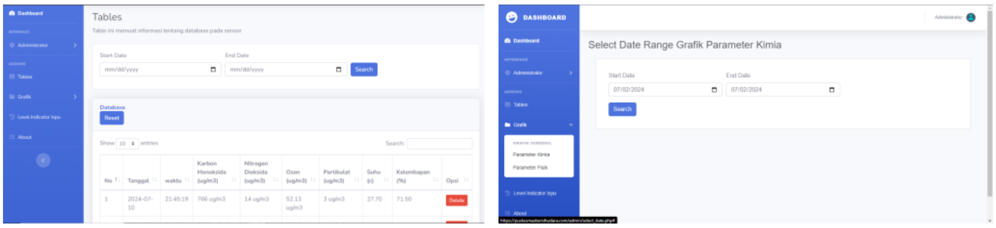

Figure 9. Tabel and Graphics Menu

The graph menu has submenus consisting of "Chemical Parameters" and "Physical Parameters". Chemical Parameters displays graphs of CO, NO2, O3, and PM2.5, while physical parameters display temperature and humidity.

d) ISPU Indicator Level Menu

In this menu, there are data visualizations in the form of bar graphs that display air quality data for various parameters such as CO, NO2, O3, and PM2.5. Each parameter is equipped with a "Detail" button below it.

Figure 13. ISPU Indicator Level Menu

5. ISPU Calculation

In this research, the method of determining air quality uses the Air Pollution Standard Index (ISPU). On the website there is an indicator level menu, where the menu uses the ISPU calculation formula. The following is an example of the calculation of the ISPU parameter formula when compared to manual calculations:

No	Tanggal	waktu	Karbon Monoksida (ug/m3)	Nitrogen Dioksida (ug/m3)	Ozon (ug/m3)	Partikulat (ug/m3)	Suhu (c)	Kelembapan (%)	Opsi
1	2024-07-14	08:03:56	83066 ug/m3	322 ug/m3	41.14 ug/m3	3 ug/m3	27.50	83.90	Delete

Figure 10. NO2 reading in the table menu of 322 ug/m3

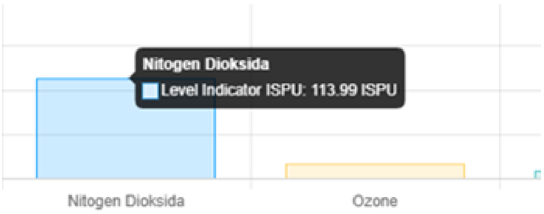

Figure 11 ISPU Calculation Result on Website

ISPU calculation:

$$I = \frac{I_a - I_b}{X_a - X_b}(X_x - X_b) + I_b$$

$$= \frac{200 - 100}{1130 - 200}(322 - 100) + 100$$

$$= \frac{100}{930}(122) + 100 = 113.11\ \mu g/m3$$

CONCLUSION

1. The designed system is able to detect various air quality parameters such as Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), and $PM_{2.5}$ at Manduro Health Center. The integration of Sansevieria plants is effective in reducing air pollutants as indicated by a decrease in gas concentration values. Before the plants, CO concentrations ranged from 685.00 to 951.00 ug/m^3 and NO_2 between 17.00 to 48.20 ug/m^3. After being planted, the CO concentration decreased to 572.00 to 818.00 ug/m^3 and NO2 to 14.00 to 28.00 ug/m^3.
2. The system was successfully integrated with a website for real-time air quality monitoring, facilitating data access and monitoring for users.
3. The test results show that the air quality detection system at Manduro Health Center has good accuracy and reliability. The DHT22 sensor has an error of 1.434% for temperature and 1.344% for humidity, with an accuracy of 98.566% and 98.656%. The dust sensor has an error of 5.144% with an accuracy of 94.856%. The MQ sensors (MQ-7, MQ-135, MQ-131) also showed good ability to detect changes in gas concentration, with an increase in gas concentration accompanied by an increase in output voltage and a decrease in R_s/R_o value, indicating the sensor's response to increasing gas levels in the environment.

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