Implementing the Internet of Things in a Web-Based Air Pollution Detection System using NodeMCU

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Article Info :	**ABSTRACT**
Article History : Received : 12-12-2024 Revised : 18-12-2024 Accepted : 02-01-2025 Available Online : 29-01-2025 **Keyword :** **Air Pollution, Carbon Monoxide, Nodemcu, MQ-7 Sensor**	*Air pollution is one of the factors that causes health problems. Air pollution can be caused by several factors, two of which are natural factors and human factors. Plumpang District is one of the areas in Tuban Regency where there are many mining and industrial activities, especially limestone processing. Of course, this will cause an increase in the production of pollutant gases that are harmful to the body, one of which is carbon monoxide (CO). The use of the Internet of Things (IoT), microcontrollers, and sensors is expected to create a real-time air pollution monitoring tool. In this study, the MQ-7 sensor was used to detect carbon monoxide gas, and NodeMCU was used as a means of processing data to send data to the database. And later the information from the sensor readings will be displayed on the website page. The results of this study have succeeded in creating a real-time air pollution monitoring system which can then be developed to monitor air pollution itself.*

1. INTRODUCTION

Air pollution is one of the factors that causes health problems. Air pollution can be caused by several factors, including natural factors and human factors. Air pollution from natural factors can be caused by volcanic activity, forest fires, and the activities of microorganisms. Meanwhile, human factors are caused by burning rubbish, vehicle exhaust gases and industrial activities. Plumpang District is one of the areas in Tuban Regency which has a lot of mining and industrial activities, especially limestone processing. In the limestone processing industry, one of the processes is burning limestone. With so much limestone burning activity, of course, this will lead to an increase in production.

Pollutant gases are harmful to the body, one of which is carbon monoxide (CO). The increasing human need for technology makes the Internet of Things (IoT) a very interesting research field. The Internet of Things is one of the results of researchers' thoughts, making it possible for humans to easily interact with equipment such as sensor media, radio frequency identification (RFID), wireless sensor networks and other smart objects connected to the Internet network (Cahyono, 2016). "That air as a natural resource that influences the lives of humans and other living creatures must be protected and maintained to preserve its function for the maintenance of human health and welfare as well as the protection of other living creatures" (Government Regulation No. 41 of 1999 concerning Pollution Control Air). Air is a mixture of gases consisting of 78% nitrogen, 21.94% oxygen, 0.93% argon, 0.032% carbon dioxide, and other gases and particles found in the atmosphere (Tangguh, 2017).

Carbon monoxide (CO) is a poisonous gas that is odourless, colourless and tasteless. Because of the odourless nature of this gas, carbon monoxide (CO) is usually mixed with other

ISSN Print : 1979-7141
ISSN Online : 2541-1942

odorous gases so that carbon monoxide (CO) can be unknowingly inhaled at the same time as other gases are inhaled (Faroki et al., 2016). Carbon monoxide (CO) gas can be produced from the incomplete combustion process of wood, coal, fuel oil or carbon-based materials and other organic substances (Sasono, 2017). This gas hurts human health because it more easily forms Carboxy Hemoglobin (COHb) which can inhibit the flow of oxygen in the blood (Sasono, 2017).

In the first journal with title Co Gas Monitoring System in Mall Basement Parking in Jakarta Using Real-Time Methods Based on the Internet of Things (IoT). In this research, the author created a monitoring system which aims to detect carbon monoxide (CO) gas in the parking area. In this research the author used an MQ-7 sensor combined with an Arduino Uno, then to send data the author used the ESP8266 WiFi module which was then stored in the ThingSpeak cloud. The results obtained from this monitoring system show that the value of carbon monoxide (CO) gas levels in the basement parking lot is quite high, with an average value of 15.52ppm and the highest value of 17.27ppm (Adli & Arifin, 2019). The second research entitled Portable Air Pollutant Detection System Using MQ-7 and MQ-135 Sensors. This research shows that the use of the MQ-7 and MQ-135 sensors is ideal for detecting dangerous gases within certain limits. This tool also has a compact shape so it is easy to carry (Rosa et al, 2020). The third research is the Design and Development of Air Pollution Monitoring Tools in Industrial Areas Based on the Arduino Uno Microcontroller. This research creates a tool using MQ-7, MQ-135, and TGS2602 sensors to detect CO, NOx, and H2S gas. The ATMega328 microcontroller is used as the control brain in this tool, and the sensor reading results are displayed using a 16x2 LCD (Bahar, 2018). Motorized vehicles in Indonesia have become public facilities that are often used as a means of daily transportation for people from the upper middle class to the lower class with their motorized vehicles. Every household has more than one motorbike.

The Internet of Things (IoT) is a network of various types of sensors or sensing that are connected and communicate to process data connected to the Internet (Fragastia and Rahmad, 2019). On the internet, IoT has emerged as a big issue, with the expectation that billions of things or objects will be equipped with various types of sensors, radio frequency identification (RFID), wireless sensor networks and other smart objects. With a large number of things/objects and sensors connected to the internet in some cases, these interconnected things will automatically stream data in real-time. Of all the activities in IoT, one of the things that is of concern is to collect the correct raw data efficiently, but what is more important is to analyze and process the raw data into more valuable information (Cahyono, 2016).

A database is a collection of data that is connected and stored with each other in a medium and there is no duplicate data. Not all electronic data storage can be called a database. A data storage can be a database if it arranges, sorts, groups, and organizes the data stored according to its function or type. This sorting or grouping can be in the form of separate files or tables, or defined in the form of columns or data fields in each file or table (Yanto, 2016).

MySQL is a database processing program commonly called DBMS (Database Management System). This DBMS is open source, multiplatform and based on a relational database (Wicaksono, 2017). MySQL can be used for personal databases as well as databases at small to large-scale corporate levels.

The underlying factors are that the current system for detecting air pollution in the Tuban Regency area, especially in Popoan Hamlet, Kepohagung Village, and Plumpang District, is still minimally implemented. People do not know for sure what the air conditions are where they live. People don't know where they should look for information about the air conditions where they live. So far, people have only relied on their sense of smell, which we all know can only smell aromas and cannot detect what gas is inhaled, so if an unpleasant aroma appears, they cannot know for sure what is causing the unpleasant aroma around them.

ISSN Print : 1979-7141
ISSN Online : 2541-1942

NodeMCU is a microcontroller that has ESP8266 embedded on a board. With the ESP8266, NodeMCU has access to WiFi as well as a USB to serial communication chip, so it can design air pollution monitoring problems so that people can find out information about the condition of the air in the area where they live.

2. METHOD

The research methods used by the author to complete this research are:

1. Planning stage

a. System Design

Figure 2 below illustrates the design of the monitoring system used in this study. The MQ-7 sensor functions as a carbon monoxide (CO) gas detector, while the NodeMCU functions as a receiver that processes data from sensor readings. This data is then sent to a database via a Wi-Fi network connected to the internet. The website presents information about air quality levels.

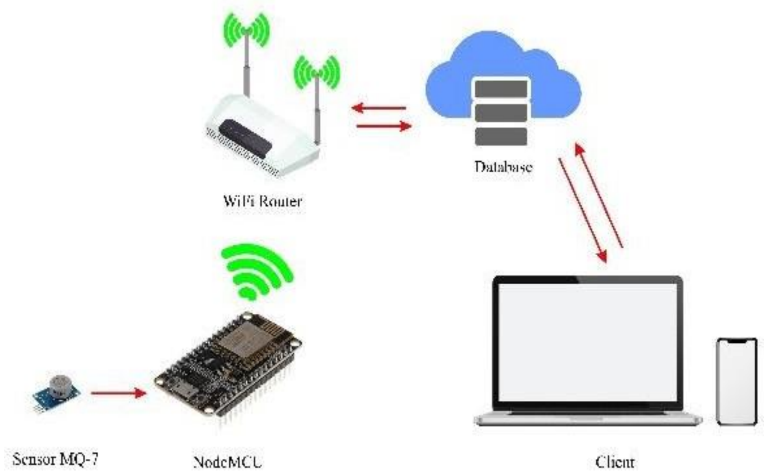

Figure 2 System Design

b. System Flowchart

This system flowchart explains the system's running mechanism.

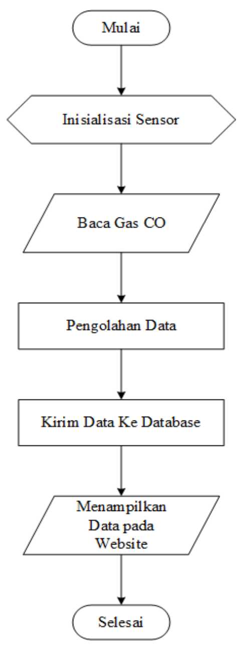

Figure 3 : Flowchart Sistem

ISSN Print : 1979-7141
ISSN Online : 2541-1942

The flowchart above outlines the operational principle of a carbon monoxide (CO) detection system that employs an MQ-7 sensor in conjunction with a NodeMCU microcontroller. The process begins with the initialization of the MQ-7 sensor to establish its baseline values. Once initialized, the sensor is capable of detecting the presence of carbon monoxide (CO) gas. It then gathers analog data, which is processed by the NodeMCU microcontroller to convert it into digital format. Equipped with an embedded WiFi module, the NodeMCU facilitates wireless data transmission. After processing the information, the NodeMCU transmits it to a database. Ultimately, this data is presented via a web interface.

c. Program Flow Chart

In this program flowchart, the mechanism of operation of the tool itself is explained as shown in the image below :

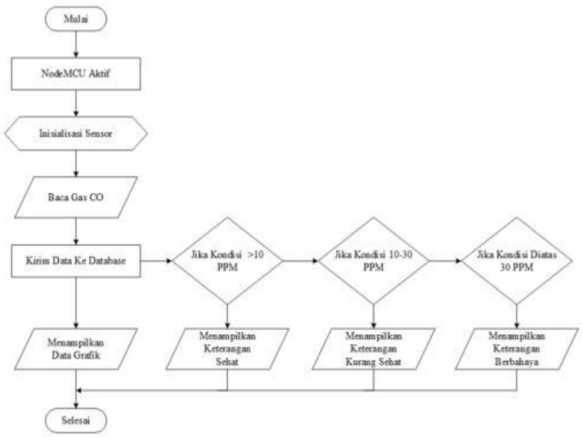

Figure 4: Program Flow Chart

Figure 4 illustrates the procedure for activating the device. The initial step involves powering on the device, which is facilitated by the NodeMCU microcontroller, equipped with an embedded ESP8266 WiFi module. Following this, the MQ-7 sensor must be initialized. Once the sensor gathers input values, these values will be processed and sent to a database, where they will be presented in the form of graphs and pertinent information. The information generated is based on specific conditions: if the sensor detects CO gas levels below 10 PPM, it will indicate a "healthy" status. If the levels are between 10 and 30 PPM, it will signal an "unhealthy" condition. Finally, if the sensor detects CO gas levels exceeding 30 PPM, it will issue a "dangerous" warning.

d. System Prototype

The system prototype that has been designed by the author is presented in the picture

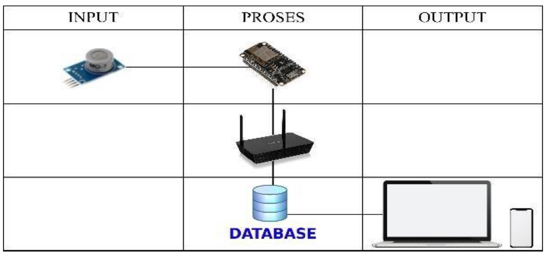

Figure 5 : Prototype Sistem

ISSN Print : 1979-7141
ISSN Online : 2541-1942

In Figure 5, the input comes from the MQ-7 sensor which will be forwarded to the data processing stage. Later in the sensor's working system, when the tool is turned on, the MQ-7 sensor will check the Carbon Monoxide (CO2) level, and then the sensor will send data to the NodeMCU microcontroller to process the data. The output itself is an interface in the form of a website display that can be accessed on mobile or desktop. To create the web interface design used in this research, HTML was combined with the PHP programming language.

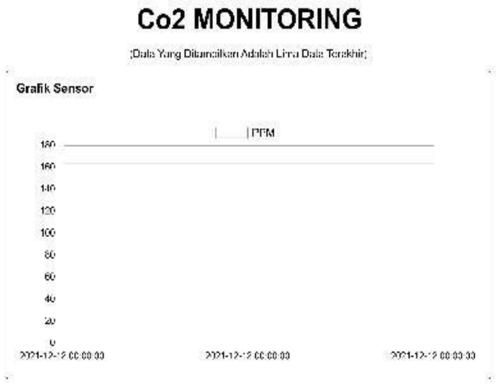

Figure 6 : Interface Design

In the interface design in Figure 6, the information to be conveyed in this research is the level of high and low values of carbon monoxide along with the reading time which is conveyed in graphical form.

3. RESULTS AND ANALYSIS

a. Sensor Reading and Calibration Method

To determine the sensor reading value in parts per million (ppm), you must first perform a calibration process on the sensor. This calibration is based on the mathematical data provided in the datasheet, specifically by identifying the RS/RO ratio. In this context, the RS value refers to the sensor's resistance at a specific carbon monoxide (CO) level being measured, while the RO value indicates the sensor's resistance in clean air, which corresponds to a CO level of 100 ppm. To find the RS value (sensor resistance), you can use the following formula:

RS = (Vc * RL / V RL) – RL (1)

Where,

RS = Sensor Barriers

Vc = Voltage of Electric Current Entering the Sensor

RL = Load resistance in the circuit

VRL = Outgoing Electric Current Voltage

If the values of Vc = 5 and RL = 1000 Ohm are known, then the next value that must be known is VRL. The VRL value can be found using the ADC (Analog to Digital Converter) function on the Arduino. To find out the ADC value, you can use the equation:

$$VRL = nilaiADC \times \frac{5}{1024} \tag{2}$$

By using the equation above, we have obtained the VRL value. After the VRL value is known, the next step is to find the RS value. The RS value can be found using the function:

$$RS = \left(Vc \times \frac{RL}{VRL}\right) - RL \tag{3}$$

Using the equation provided, we have determined the RS value. Once the RS value is established, the next step is to calculate the RO value. The RO value is determined under specific conditions and remains the same at both 20 ppm and 100 ppm (Adli & Arifin, 2019). At a carbon monoxide (CO) level of 100 ppm, the RO value matches the RS value. However, due to equipment limitations, creating an environment with a CO level of 100 ppm is quite challenging. Therefore,

ISSN Print : 1979-7141
ISSN Online : 2541-1942

for this calculation, we will use the typical CO levels found in normal air, which range from 5 to 15 ppm. As the RO value is a constant, it remains the same under either 20 ppm or 100 ppm conditions.

Once the RO value is known, you can then determine the PPM value. The PPM value can be determined using the equation:

$$PPM = 100 \times \left(\frac{RS}{RO}\right)^{-1.53} \quad (4)$$

By using the equation above, we can find out the steps to get the sensor reading value in PPM units.

1. Sensor Implementation

The sensor implementation was made with NodeMCU hardware and the MQ-7 sensor using Arduino software with a file extension (.INO). The MQ-7 sensor is used to detect carbon monoxide gas. The MQ-7 sensor is used because it is sensitive to carbon monoxide gas, stable and long-lived. The MQ-7 sensor uses a 5V AC/DC power supply, and has a measurement range of 20ppm – 2000ppm carbon monoxide

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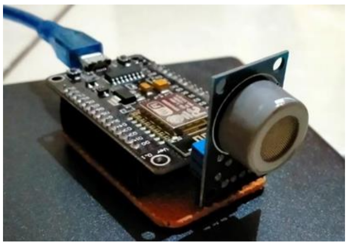

Figure 7 MQ-7 sensor

Information :

a) Pin A0 of the NodeMCU is connected to pin A0 of the MQ-7 Sensor
b) GND pin of the NodeMCU is connected to the GND pin of the MQ-7 Sensor
c) The NodeMCU power jumper pin is connected to the VCC pin of the MQ-7 Sensor

2. Database

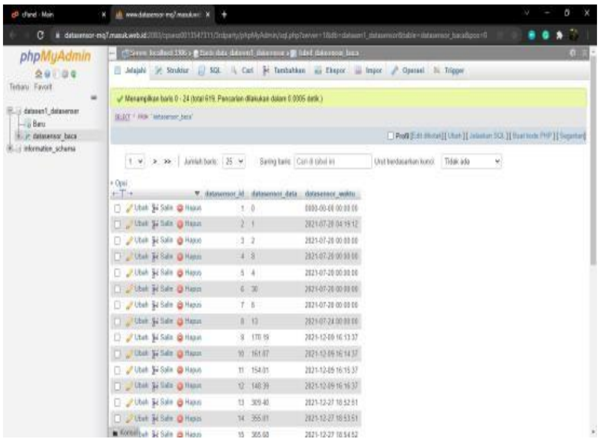

Figure 8 : Database Tables

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In figure 8 is a table from the database as a place to store sensor reading data and sensor reading times. The database in this system is named datasen1_datasensor.

1. Interface

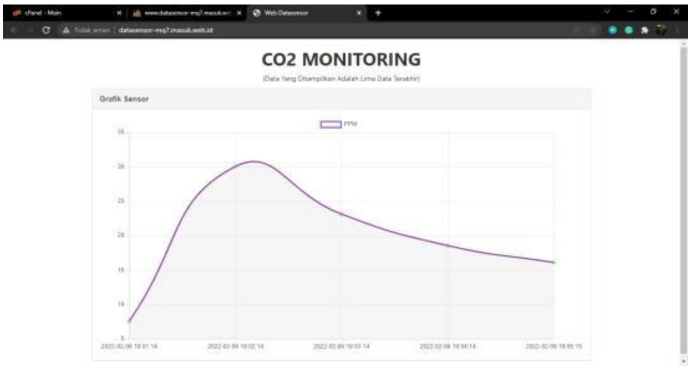

Figure 9 : Main Page Display Desktop Mode Interface

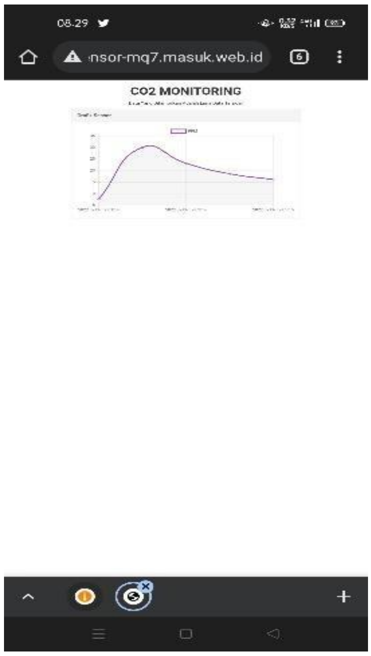

Figure 10 : Mobile Mode Interface Main Page Display

Figures 9 to 10 show the main interface page of this system. On this site, users do not need to log in, because this site is only a display medium for sensor reading results that have previously been stored in the database.

2. Sensor Testing

2.1 Sensor testing with normal room air conditions

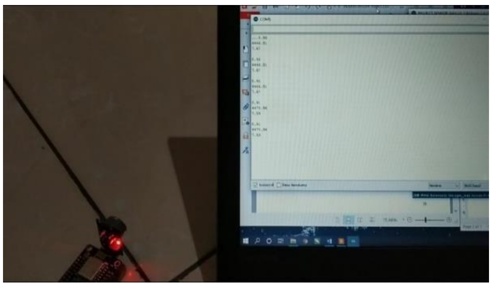

Figure 11 Sensor Testing with Normal Room Air Conditions

Figure 11 is a test when the room air conditions are normal, from the test in Figure 11 the results obtained are as in Table 1 below:

Table 1 : Result of Senser Testing with Normal Room Air Conditions

No	VRL	RS	PPM
1	0,92	4446,81	7,67
2	0,91	4475,94	7,59
3	0,91	4475,94	7,59

In table 1 it can be concluded that testing has been carried out and carbon monoxide readings have been obtained with normal room air conditions.

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2.2 Test sensors in air conditions with contaminants

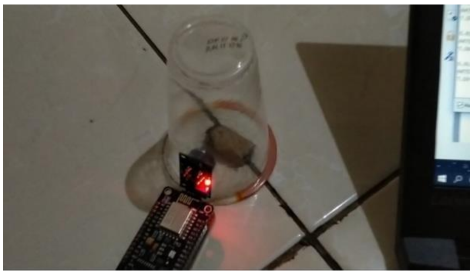

Figure 12 : Sensor Testing in Air Conditions with Contaminants

Conditioning is carried out using smoke from burning paper covered with glass. From the test in Figure 12, the following results were obtained:

Table 2 : Result of Sensor Testing in Air Conditions with Contaminants

No	VRL	RS	PPM
1	1,77	1820,94	30,06
2	1,58	2160,49	23,14
3	1,43	2494,88	18,57

In table 2 it can be concluded that testing has been carried out and obtained carbon monoxide readings in air conditions with contaminants.

Based on the results of the two test conditions, it can be concluded that if carbon monoxide gas is detected, the output voltage from the sensor will increase, and the sensor resistance will decrease as stated in the datasheet.

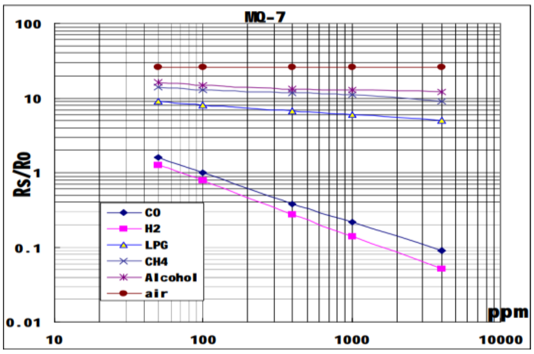

Figure 13 MQ-7 Sensor Datasheet (Hanwei, 2013)

3. Wireless Communication Testing

This test was carried out with the aim of finding out how the sensor communicates with WiFi, database and website.

Figure 14 : Serial Monitor Display of Sensor Condition Not Connected to WiFi

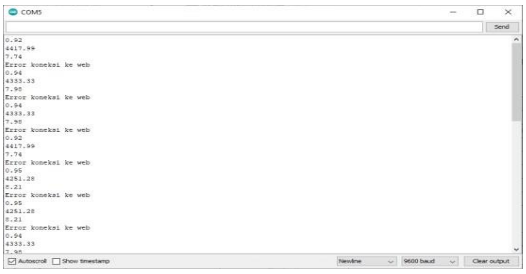

Figure 15 : Serial Monitor Condition Display Sensor Not Connected to Database

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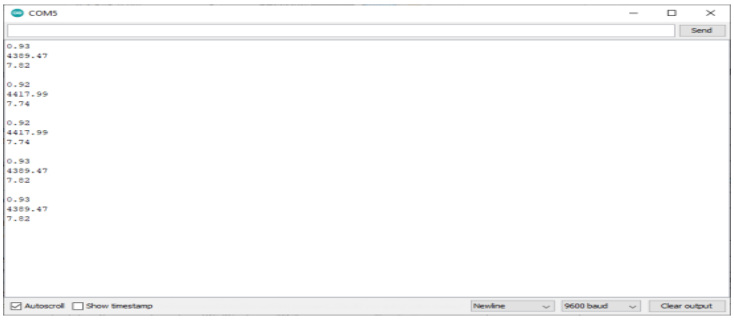

Figure 16 : Serial Display of Connected Sensor Condition Monitor

4. Sensor Test Data in Sumberagung Village

The sensor test results below are the test results in Sumberagung Village. Based on the author's observations, in Sumberagung Village there tends to be minimal industrial activity, especially the limestone processing industry, so the carbon monoxide gas detected tends to be in the range of 7.5ppm – 9ppm.

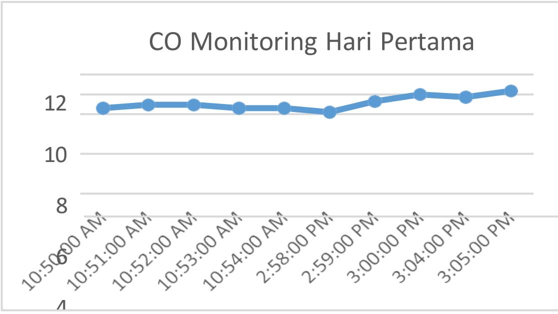

Figure 17 : Display of Sensor Test Data in Sumberagung Village on the First Day

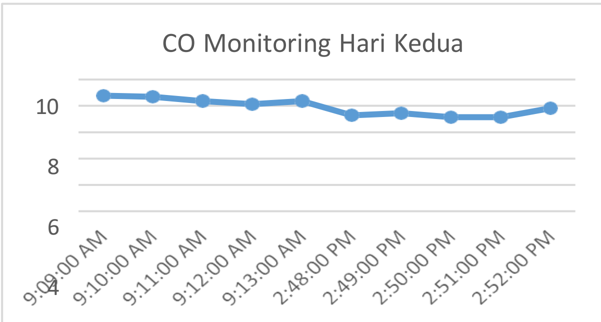

Figure 18 : Display of Sensor Test Data in Sumberagung Village on the Second Day

5. Data Sensor Test Data in Kepohagung Village

The sensor test results below are the test results in Kepohagung Village. Based on the author's observations, in Kepohagung Village there are several limestone kilns. Moreover, there are two limestone kilns on an industrial or factory scale. So the detected carbon monoxide gas tends to increase in the morning and decrease in the afternoon. This is in line with the working hours or operational hours of the factory itself.

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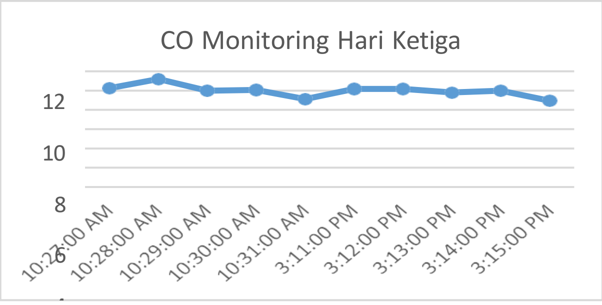

Figure 19 : Display of Sensor Test Data in Kepohagung Village on the Third Day

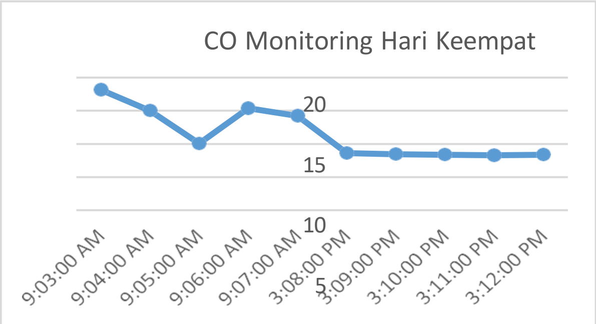

Figure 20 : Display of Sensor Test Data in Kepohagung Village, Fourth Day

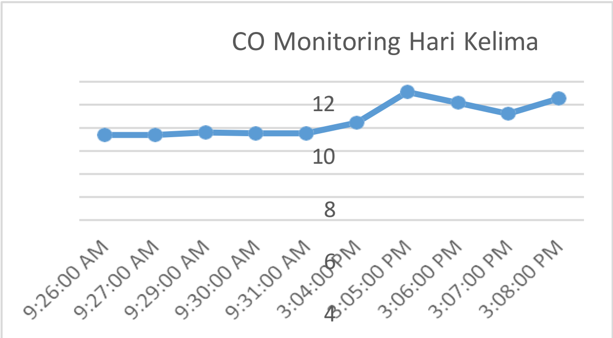

Figure Figure 21 Display of Sensor Test Data in Kepohagung, Village Fifth Day

6. Sensor Test Data in Kesamben Village

The sensor test results below are the test results in Kesamben Village. Based on the author's observations, in Kesamben Village there are several limestone kilns run by the community. Some of the limestone kilns in Kesamben Village are not very big, but they are quite dense. From the results of carbon monoxide gas sensor readings in Kesamben Village, it tends to experience ups and downs at uncertain times. As observed on the first day, there was an increase in carbon monoxide gas in the afternoon, while on the second day carbon monoxide gas experienced a slight increase in the morning.

ISSN Print : 1979-7141
ISSN Online : 2541-1942

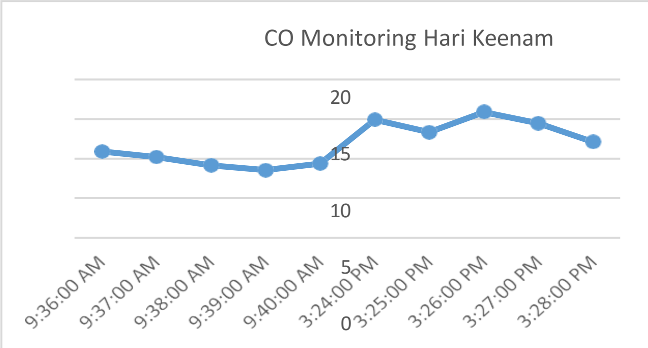

Figure 22 Display of Sensor Test Data in Kesamben Village on the Sixth Day

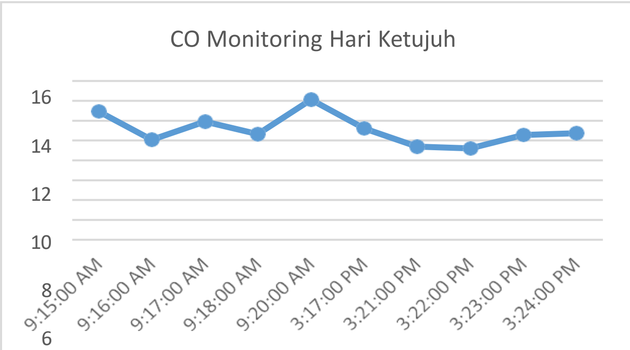

Figure 22 : Display of Sensor Test Data in Kesamben Village on the Seventh Day

7. Average Sensor Test Result Data

Based on observations made by the author, sensor test results have been obtained per day for seven days. The following is the average data from sensor test results for seven days.

Table 3: Average Result Data of Sensor Test

No.	Waktu	PPM
1	2/1/22 10:50 AM	8.75
2	2/1/22 2:58 PM	9.51
3	2/2/22 9:09 AM	8.47
4	2/2/22 2:48 PM	7.36
5	2/3/22 10:27 AM	10.13
6	2/3/22 3:11 PM	9.81
7	2/4/22 9:03 AM	14.57
8	2/4/22 3:08 PM	8.42
9	2/5/22 9:26 AM	7.47
10	2/5/22 3:04 PM	9.89
11	2/6/22 9:36 AM	9.62
12	2/6/22 3:24 PM	14.13
13	2/7/22 9:15 AM	11.92
14	2/7/22 3:17 PM	10.2

4. CONCLUSION

After completing this research, the following conclusions can be drawn:

a. The sensor is able to detect high and low levels of carbon monoxide gas, but the data displayed is less accurate because there is no comparative data such as a CO meter.
b. The results of the sensor performance test show that if carbon monoxide gas is detected, the output voltage of the sensor will increase, and the sensor resistance will decrease, this is what is written on the datasheet.
c. The sensor can detect carbon monoxide gas at 1-minute intervals.
d. The database can store sensor reading data.
e. The website can display sensor reading data that has previously been stored in the database.

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ISSN Online : 2541-1942

5. ACKNOWLEDGEMENTS

The research is self-funded and is also the result of the final assignment research of Informatics Engineering students

6. DECLARATION OF COMPETING INTEREST

We declare that we have no conflict of interest.

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