Indonesian Physical Review
Volume 07 Issue 03, September 2024
P-ISSN: 2615-1278, E-ISSN: 2614-7904

Design of Carbon Monoxide (CO) Measurement Tool Using SIM900A and Solar Panel Based on Wemos D1 Mini

Risa Annisa[1], Khairul Saleh[2*], Naqiyatun Muallifah [2], Muhammad Rizki Bahtiar [2]
[1] *Physics department, Faculty Mathematics and Natural Science University Indonesia, Indonesia*
[2] *Physics department, Faculty Mathematics and Natural Science University of Sriwijaya, Indonesia*

**Corresponding Authors E-mail: khairul_saleh@unsri.ac.id*

Article Info

Article info:
Received: 24-02-2024
Revised: 15-06-2024
Accepted: 24-06-2024

Keywords:
CO; MQ-7; Solar Panel; SIM900A and Wemos D1 Mini

How To Cite:
R. Annisa, K. Saleh, N. Muallifah dan M. R. Bahtiah, "Design of Carbon Monoxide (Co) Measurement Tool Using SIM900A and Solar Panel Based on Wemos D1 Mini", Indonesian Physical Review, vol. 7, no. 3, p 338-349, 2024.

DOI:
https://doi.org/10.29303/ipr.v7i3.318.

Abstract

With abundant natural resources, East Kalimantan has a major environmental issue: forest fires. Several cases in East Kalimantan currently garner pros and cons regarding relocating Indonesia's new capital to the region. Fires in peatlands are usually dominated by smoldering processes, resulting in the highest emissions of carbon monoxide (CO) particles. Carbon monoxide gas is odorless, colorless, and tasteless, making it difficult to detect, yet highly toxic, and can cause illness in humans. Considering the dangers caused by CO gas, this research aims to create a CO gas detector to determine air pollution conditions in the environment. This research uses an MQ-7 sensor to detect CO gas, where the data is processed into parts per million (ppm), Wemos D1 Mini as the microcontroller, and SIM900A module as the data transmitter to the website. The system uses solar panels to fulfill its power needs independently. The device's characteristics can measure CO levels ranging from 51.55 to 907.61 ppm with an average accuracy rate of 95.10% and precision of 97.18%. The model performed well overall.

Introduction

Fires constitute pollution [1]. During the dry season, peatland fires are highly prone to occur. Peatland fires are usually triggered by the community itself as a means of opening new land quickly and without incurring significant costs by burning the land. The occurrence of fires during the dry season is extremely dangerous because the dryness of the land causes the fire to spread rapidly, making it difficult to extinguish [2]. Based on the latest IQAir 2021 world air quality report released in March 2022, Indonesia is ranked 17th as the country with the highest level of air pollution in the world and ranked 1st in the Southeast Asia region, with PM2.5

concentrations reaching 34.5 per cubic metre[18]. In 2019, fires in East Kalimantan amounted to 68.524 hectares, comprising 62.851 hectares of mineral land and 5.673 hectares of peatland. This figure significantly increased compared to 2018, which was around 27.893 hectares [3]. Fires in peatlands are usually dominated by the smoldering process, resulting in the highest emissions of carbon monoxide particles. Carbon released during forest fires includes carbon dioxide, carbon monoxide, hydrocarbons, and other particulate matter in smaller amounts [4]. The gas produced from carbon monoxide is odorless, colorless, and tasteless, making it difficult to detect, yet highly toxic and often causing diseases in humans [5]. The impact of uncontrolled forest fires results in relatively large amounts of hazardous haze. Air pollution is characterized by high levels of the Air Pollution Standard Index (ISPU) [6]. Considering the numerous dangers posed by CO gas, this research aims to develop a CO gas concentration measurement device to assess air pollution levels in the environment and the health hazards posed by CO gas to human beings. Need for this Research: Existing solutions have limitations. While previous research by Sarungallo et al. (2017) developed a CO gas concentration measurement device, it lacked the capabilities of real-time data monitoring and remote access. Prayogo et al. (2020) introduced real-time monitoring but did not use solar panels, limiting its adaptability and scalability. Improving upon existing solutions: This research aims to address the limitations of previous studies by developing a cost-effective, IoT-based CO gas concentration measurement device. This device will offer several advantages: Real-time and remote monitoring: The device will enable real-time monitoring of CO gas levels from any location with internet access, facilitating faster and more informed decision-making regarding fire response and air quality management. Flexibility and scalability: The device will utilize standard IoT protocols and communication technologies, making it adaptable to various network infrastructures and potentially scalable for wider deployment. By addressing the limitations of previous research and incorporating desired functionalities like real-time, remote monitoring, and cost-effectiveness, this research can significantly contribute to improved air quality monitoring and peatland fire management in Indonesia.

Theory

Carbon monoxide (CO) gas is the largest contributor to air pollution, at around 59% of gasoline fuel exhaust emissions. Carbon monoxide pollution can cause various diseases, such as lung disorders, reduced blood element concentrations, and even heart attacks [7] Carbon monoxide has a harmful impact on the environment and human health, even leading to death [24]. One of the pollutants that has large enough composition in the air is carbon monoxide (CO). Substances that resulting from incomplete combustion reactions This substance that is produced from incomplete combustion reactions is widely produced from motor vehicle exhaust, cigarette smoke from residual combustion [19]. Air comprises a multitude of gases, each with varying concentration levels. Generally, fluctuations in gas concentrations within the atmosphere lead to air quality alterations, consequently posing detrimental effects on human health, particularly when air quality undergoes drastic changes. As air quality remains imperceptible to the naked eye's sensory faculties, determining the acceptability of air quality levels proves challenging [8]. Co gas can be minimised by periodically checking all ducts, such as water heaters, generators and others, ducts related to combustion or those that can cause a fire should be vented outside the house and the ducts used are not clogged. The increased amount of Carbon Monoxide (CO) gas can increase the risk of poisoning in car occupants [23]. Those who own a car should check the car air conditioning system and be aware of leaks and avoid starting the car in a tightly closed garage [25]. Hence, the necessity arises for sensors, as a device that detects and responds to changes in a physical or environmental quantity and converts that information into a usable signal, typically an electrical signal. This signal can then be processed by other electronic devices, such as microcontrollers, to gain insights into the measured quantity [9]. The necessity arises for sensors, such as the MQ-7 sensor, a gas sensor used in equipment to detect carbon monoxide (CO) gas. To detect carbon monoxide (CO) gas, the MQ-7 sensor has a low cost and can detect multiple gases. The specifications of the MQ-7 sensor are to use an input voltage of 5 volts and a carbon monoxide (CO) gas measurement sensitivity of 20-2000 ppm [10]. The MQ-7 sensor's output yields analog voltage, and its functionality spans across six pins, with four pins designated for signal acquisition and the remaining two pins dedicated to supplying heating current [11]. An embedded system includes a larger system supported by a microcontroller chip, which is one of the most important components of the system. supported by a microcontroller chip, which is one of the control devices used as control of the embedded system control device used as control of the embedded system [12]. Moreover, a Microcontroller like the Wemos D1 Mini boasts Wi-Fi functionality [13]. The Wemos D1 Mini can be operated from 3.3 volts to 12 volts. The Wemos D1 Mini generally gets its power from a micro-USB cable connected to a computer. cable connected to a computer. For portability purposes, the Wemos D1 Mini can be operated with a power bank, a series of AA batteries, a 9-volt box battery, or a lithium battery pack. The volt box or lithium battery combined with a charger module is essential [14]. It interfaces with the SIM900A module, facilitating GSM/GPRS communication utilizing the SIM900A core IC [15]. The programming of the Wemos D1 Mini via the Arduino IDE ensures seamless communication with the MQ-7 sensor and the SIM900A module [16]. Web pages containing information formed in one domain are called a website to display air quality mentoring results using the website. A website consists of several interconnected web pages. The relationship between web pages with other web pages is called a hyperlink [17]. By leveraging these integrated components, a comprehensive system emerges that is adept at monitoring and analysing air quality parameters. By utilizing cutting-edge sensor technology and microcontroller integration, the system detects the presence of CO gas and contributes to the broader understanding and mitigation of air pollution challenges.

Experimental Method

Hardware Design

In the hardware design phase, a Photovoltaic Solar Power System (PVSPS) is employed as the primary electrical energy source for the field equipment. The PVSPS consists of a polycrystalline solar panel with a maximum power (Pmax) of 20 W, a 20A solar charger controller, and a 12 Volt dry cell battery with a capacity of 7.2 AH. The solar panel converts solar energy into electrical energy, which is then directed to the battery. The charging current for the battery is regulated by the solar charger controller to prevent overcharging. Electrical power is supplied through the USB port of the solar charger controller to the Wemos D1 Mini microcontroller. The MQ-7 sensor and SIM900A module are provided with a voltage of 5V from the Wemos D1 Mini microcontroller. This ensures that both devices receive sufficient voltage to operate optimally. This setup guarantees stable and safe electrical energy provision for all components deployed in the field, enabling the devices to function effectively and consistently.

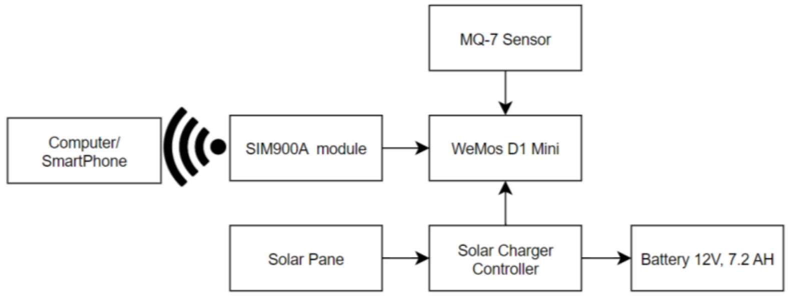


Figure 1. Hardware Design

Software Design

The CO gas measurement system is programmed using the Arduino IDE software. The IoT system with a GSM module is controlled using AT Command instructions. The website uses HTML, CSS, JavaScript, and PHP programming languages with a MySQL database. The data processing flow of CO gas levels from measurement to data display on the website can be seen in the following flowchart. The diagram below illustrates the program design created by the Arduino IDE. This software architecture ensures seamless integration and operation of the CO gas measurement system, facilitating data processing, storage, and visualization for effective monitoring and analysis.

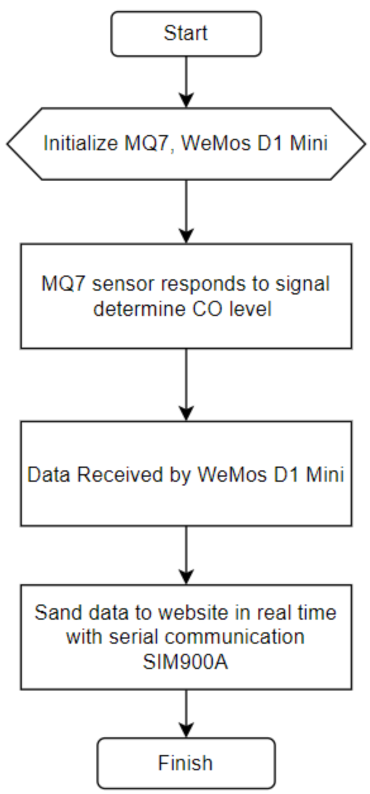


Figure 2. Software Design

Result and Discussion

Hardware Result

The hardware device for detecting carbon monoxide has been successfully constructed according to the design, as shown in Figure 3.

Figure 3. Hardware Result

The operation of this device begins with the activation of the Wemos D1 Mini microcontroller, powered by a 5V power supply, providing a voltage of 5 Volts to the MQ-7 sensor aims to make the sensor more sensitive and relatively stable when taking data. which then executes instructions provided by the designed software. Subsequently, the MQ-7 sensor starts detecting carbon monoxide. Here is the pin configuration connecting the MQ-7 sensor to the Wemos D1 Mini: [Specify the pin configuration here]. The measured data from the MQ-7 sensor is then transmitted via the SIM900A module to the website. This process enables real-time monitoring and analysis of carbon monoxide levels, contributing to effective air quality and safety management.

Table 1. MQ7 sensor pin configuration with Wemos D1 Mini

Wemos D1 Mini	Sensor MQ-7
5V	5V
GND	GND
A0	A0

Software Result

Some software used to build this CO-level monitoring system is as follows. The Arduino program uploaded to the microcontroller to control the sensor and send data can be viewed in the Appendix. The CO level data is sent from the device to the website database using the "GET" method. In the Arduino program, "AT+HTTPACTION=0" is used to send data using the "GET" method, which sends data via URL. Subsequently, the CO level data in the PHP program will be captured using "$_GET". The database preparation is performed by accessing the "phpMyAdmin" page, then creating a new database named "kadar_co" containing two necessary tables as follows:

Table 2. Supporting software and description

Software	Description
Arduino IDE	To create a program to be uploaded to the microcontroller
XAMPP	Web server open source for managing browser
Sublime text	To create code and text for website display
Browser	Where to see the website display/coding results

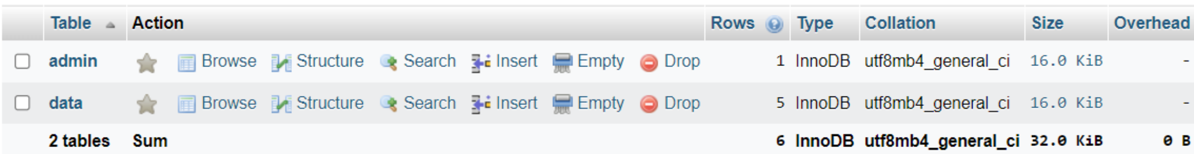
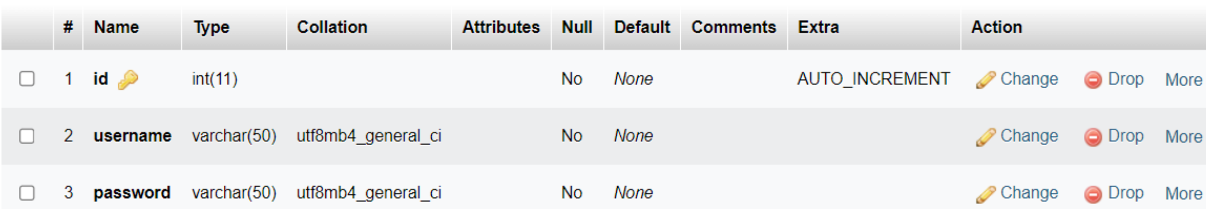


Table	Action	Rows	Type	Collation	Size	Overhead
admin	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_general_ci	16.0 KiB	-
data	Browse Structure Search Insert Empty Drop	5	InnoDB	utf8mb4_general_ci	16.0 KiB	-
2 tables	Sum	6	InnoDB	utf8mb4_general_ci	32.0 KiB	0 B

Figure 4. Database structure

Figure 4. shows an overview of the database structure, which consists of a single table named "*admin*." This table is likely responsible for managing administrative data.



#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
1	id	int(11)			No	None		AUTO_INCREMENT	Change Drop More
2	username	varchar(50)	utf8mb4_general_ci		No	None			Change Drop More
3	password	varchar(50)	utf8mb4_general_ci		No	None			Change Drop More

Figure 5. Admin table structure

Figure 5 provides a detailed view of the "admin" table structure. It consists of five fields: 'id,' 'username,' 'password,' 'email,' and 'tables. The 'id' field is an integer type set to auto-increment, ensuring a unique identifier for each record. The 'username,' 'password,' and 'email' fields are of varchar type, allowing them to store string values. The 'tables' field is also an integer type; its purpose is unclear from the image, but it might be used to manage relations with other tables or data.

Figure 6 shows the details of the structure of the "data" table. It includes five fields: 'id,' 'date,' 'time,' 'entry,' and 'status.' The 'id' field is an integer type set to auto-increment, similar to the 'id' field in the "admin" table. The 'date' and 'time' fields are likely used to timestamp each record. The purpose of the 'entry' and 'status' fields is unclear from the image, but they might be used to store specific data entries and their respective statuses.

	#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
☐	1	**id**	int(11)			No	*None*		AUTO_INCREMENT	Change Drop More
☐	2	**date**	date			No	*None*			Change Drop More
☐	3	**time**	time			No	*None*			Change Drop More
☐	4	**co_level**	double			No	*None*			Change Drop More
☐	5	**status**	text	utf8mb4_general_ci		No	*None*			Change Drop More

Figure 6. Data table structure

Moreover, for the visualization of the website, an array of software applications were developed, the details of which are documented in the Appendix section. The completed suite of applications was subsequently propagated to the World Wide Web via a web hosting service coupled with a domain name system. The culmination of this research, a fully functional website, is accessible via the URL "kadarco.monitoringcurahujan.xyz", which exhibits the following content:

Figure 7. Display On Smartphone

1. Test the characteristics of the MQ-7 sensor from the datasheet

This CO sensor test aims to determine whether the sensor can work properly and correctly in detecting CO gas. The CO sensor used is MQ7. The MQ7 sensor has good sensitivity to carbon monoxide gas [22]. In the MQ-7 sensor datasheet, there is a calibration testing graph conducted by the manufacturer. This graph can be seen in Figure 8

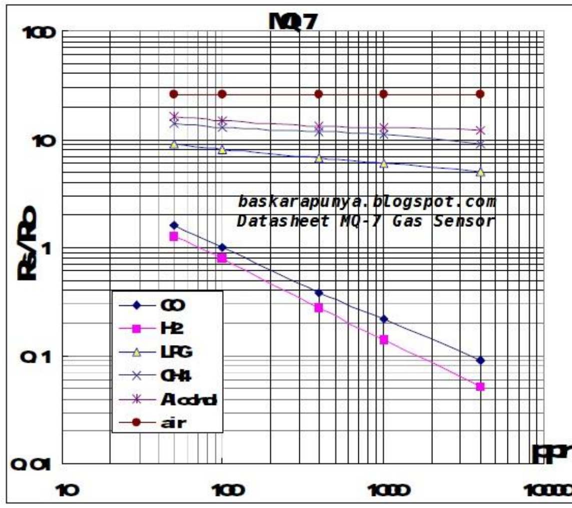


Figure 8. MQ-7 Sensor Characteristics [20]

which is used to obtain the ppm (parts per million) value that we will test, carried out using a web plot digitizer. Then, a comparison of the ppm value of CO with *Rs/Ro* (Resistance ratio of MQ-7 sensor), as shown in the table below :

Table 3. The comparison of ppm values and *Rs/Ro* from the datasheet

ppm	*Rs/Ro*
49.69199949638451	1.5967615229659327
60.23388130456043	1.375431228953113
69.74311267120578	1.250840018494338
80.01713986260529	1.153069992233223
89.31581838868436	1.0629420128316311
98.78589984551441	0.9932406647302054
100.49111375154958	0.9891721209593526
196.382800192977	0.6178299037675066
299.3141999451498	0.46468385616884983
393.9950052083314	0.3791336585057236
499.9642970523149	0.3310413006673409
600.5021806921678	0.2929969057130023
695.304541899871	0.2664562554972561
797.7315414440457	0.24898365586904053
898.6299768356033	0.23265680430066366
1003.0584940612893	0.21740056952119008
1994.0440501038886	0.1427707284041632

In table 3 it can be seen that the value at a concentration of 100 ppm *Rs/Ro* value is close to 1. Table 3 can be concluded that the value of the sensor resistance ratio (*Rs/Ro*) is inversely proportional to the CO gas concentration so that the equation can be written as follows :

$$\frac{R_S}{R_O} = \frac{1}{Konsentrasi\ gas\ (ppm)} \quad (1)$$

The mathematical model is then carried out using the line equation approach using Microsoft Excel, so that the mathematical model can be obtained as shown in the table below:

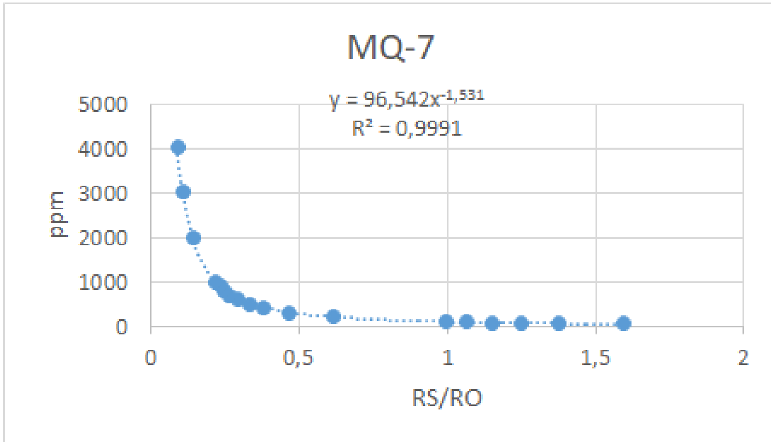


Figure 9. Graph with trendline regression from datasheet

Based on the sensor sensitivity characteristics explained in the datasheet [21], the *Rs/Ro* of the sensor represents the detected ppm value. The *Rs/Ro* value is in the range of 0-2, the higher the *Rs/Ro* value, the lower the detected gas ppm value. It can be seen from the graph that the sensor used and calibrated to determine its ppm value has a sensitivity character obtaining an R^2 value of 0.9991. From Figure 9 by using trendline regression of the relationship data between ppm CO and *Rs/Ro*, the equation is obtained:

$$y = 96{,}524x^{-1{,}531} \qquad (2)$$

The trendline is derived from the curve on the graph, and from a computational perspective, using this trendline makes it easier to implement on a microcontroller. The value of the trendline will later be incorporated into the Arduino program, thereby producing the value to be tested in the form of ppm. The notation is written as pow(R, p), where R represents *Rs/Ro* and p represents the exponent of the equation (-1.531). Meanwhile, y from the trendline equation represents the ppm value that will be measured by the sensor in the future.

2. Field test of MQ-7 sensor characteristics

Before testing the sensor from the field, the sensor for 48 hours, so that the sensor is more sensitive to CO gas. Testing Sensor testing in the field is done using a closed container (bottle). The use of bottles is done to prevent wind (mixing with other gases) that can interfere with the concentration in the chamber (bottle). with other gases that can interfere with the concentration in the room (bottle) measurement. Then this bottle is channelled to the paper combustion emission gas drain. paper burning. MQ-7 sensor testing can be seen in Figure 10.

Figure 10. MQ-7 sensor measurement

Sensor measurement is carried out as a reference to how much accuracy and precision of a measuring instrument. Before direct measurements are taken in the field, sensor testing is carried out, where the results of precision and accuracy in the sensor characteristics testing table based on the manufacturer's datasheet (not yet calibration). Sensor testing uses AS8700A as a reference. Performed 5 times with the same treatment. The following are the results of the MQ-7 sensor data characteristic test. This study utilizes the MQ-7 sensor, and from the table above, it can be seen that the accuracy, precision, and error values from the conducted tests are provided. The designed device exhibits good performance with the highest accuracy value of 98.64 and precision of 99.07. To Field test of MQ-7 sensor characteristics we need formula :

$$Bias = |x - \bar{x}| \quad (3)$$

$$\sigma = \sqrt{\frac{\Sigma_{i=1}^{N}(|x-\bar{x}|)^2}{N-1}} \quad (4)$$

$$Accuracy = 100\%(1 - \frac{Bias+3\sigma}{x}) \quad (5)$$

$$Precision = 100\%\ (1 - \frac{3\sigma}{\bar{x}}) \quad (6)$$

$$Error = 100\%|\frac{\bar{x}-x}{x}| \quad (7)$$

Description :
$\bar{x}$ = Mean accepted value
x = Experimental Value
σ = Standar Deviation

Conclusion

The carbon monoxide (CO) level measuring device using the MQ-7 sensor based on the Wemos D1 Mini and SIM900A module has been successfully designed, where data is transmitted to a website. The designed device is capable of measuring CO levels ranging from 51.55 to 907.61 ppm, with an average accuracy of 95.10% and precision of 97.18%. Before taking measurements, important to note that the MQ-7 sensor datasheet provides a calibration testing graph. This graph is instrumental in determining the ppm value and understanding the sensor's sensitivity characteristics. However, it is observed that the accuracy and precision levels are nonlinear with the addition or subtraction of ppm values. The researcher concludes that there are errors during data collection, specifically due to inadequate sealing of the gas container, resulting in CO gas leakage. This insight highlights the importance of meticulous attention to the hardware design and calibration process, ensuring airtightness and precise measurement capabilities of the device. Further refinement and testing of the device's components and assembly methods may help mitigate such errors in future iterations.

References

[1] A. P. Tampubolon and R. Boedisantoso, " Distribution Analysis of Carbon Monoxide and Particulate Pollutants from Forest Fires in South Sumatra," *Jurnal Teknik ITS*, vol. 5, no. 2, Dec. 2016.

[2] G. Bagaskara, R. Amri, and Y. Rahayu, " Design of a Fire Detection System for Kayuan Peatland by Utilizing the Characteristics of the Heat It Generates," *SINERGI*, vol. 21, no. 3, p. 157, Nov. 2017. doi:10.22441/sinergi.2017.3.001

[3] "Permen LHK No. 14 tahun 2020," Database Peraturan | JDIH BPK, https://peraturan.bpk.go.id/Home/Details/163466/permen-lhk-no-14-tahun-2020 (accessed Feb. 5, 2024).

[4] A.D. Nurhayati, E. Aryanti, and B.H. Saharjo, "Greenhouse Gas Emission Content of Peat Swamp Forest Fires in Pelalawan, Riau," *Jurnal Ilmu Pertanian Indonesia*, vol. 15, no. 2, p. 78-79, Aug. 2010.

[5] L. Agustinus, F.A. Setyaningsih, and T. Rismawan, "Design of a Microcontroller-Based Co Level Detection Prototype as Air Quality Information," *Jurnal Coding Sistem Komputer Untan*, vol. 3, no. 2, p. 44-53. 2015.

[6] E. I. Maranatha and I. M. Kusmayadi, " Construction of Forest and Land Fire News in the Jambi Tribune," *Journal of Journalism Studies*, vol. 3, no. 2, p. 153, Jan. 2020.

[7] S. K. Sarungallo, I. G. P. R Agung and L.Jasa, "Design of Carbon Gas Emission Test Device Monoxide (CO) Based on Microcontroller, " *Teknologi Elektro*, vol.16, no.1. 2017.

[8] E. Nasrullah, dan Y.Raharjo, " Design of an Ambient Air Quality Monitoring Device Based on ATMega 8 AVR Microcontroller with Dot Matrix Viewer," *Jurnal Rekayasa dan Teknologi Elektro*, vol.1, no. 3, p.1-9. 2009.

[9] "A Survey of Environmental Monitoring Sensors for IoT-Based Applications" by A. Al-Fuqaha et al. in Sensors (Switzerland), vol. 17, no. 7, p. 1630, 2017. https://www.mdpi.com/journal/sensors/special_issues/environ_IoT (accessed March. 5, 2024).

[10] I. Prayoga, D. Triyanto and Suhardi, " Realtime Air Quality Monitoring System with Unhealthy Air Quality Hazard Warning Using Push Notification," *Jurnal Komputer Dan Aplikasi*, vol.8, no.2, p. 91-102. 2020.

[11] Manurung, M. Darmawan and R. F. Iskandar, "Perancangan Alat Ukur Kadar Karbon Monoksida (CO) Pada Kendaraan Berbasis Sensor MQ-7", *e-Proceeding of Engineering*, no. 5, vol.2 ,p.1-9. 2018.

[12] H. Jaya, et al, Embedded Systems and Robotics. Makasar : University of Makasar, 2017.

[13] "Espressif Systems, "ESP8266EX Datasheet". https://www.espressif.com/sites/default /files/documentation/0a-esp8266ex_datasheet_en.pdf (accessed Feb. 23, 2024).

[14] A. Dinata, Fun Coding with MikroPhyton. Jakarta : PT Elex Media Komputindo, 2018.

[15] "E. D. Atmoko, https://elibrary.unikom.ac.id/id/eprint/4040/8/UNIKOM_ ERI% 20DWI%20ATMOKO_BAB%202.pdf (accessed Feb. 23, 2024).

[16] H. Santoso, "Monster Arduino Implementation Internet Of Things on the Network GPRS". https://project.elangsakti.com/ebook-monster-arduino-3/. (accessed Feb. 23, 2024).

[17] Yuhefizar, H. A. Mooduto and R. Hidayat, Easy Way to Build Interactive Website Using Joomla Content Management System Revised Edition. Jakarta: PT Elex Media Komputindo, 2009.

[18] "R. S. Sipayung, https://setkab.go.id/peningkatan-polusi-udara-di-indonesia-perspektif-ekonomi-berdasarkan-teori-freakonomics/ (accessed June. 14, 2024).

[19] Hamdiana, Paniran and I. M. B. Suksmadana, "Design Of Carbon Monoxide's Level Measuring Instrument Based On Microcontroller In The Application Of The Houseplant testing as Pollutant Gases's Reducer," *Dielektrika*, vol.3, no.2, p.130-139. 2016.

[20] Ya'Kut, Haris A., et al. "Design of Carbon Monoxide (Co) Gas Measurement System Using Mq-7 Sensor Based on Atmega 16a Microcontroller,"*Brawijaya Physics Student Journal*, vol. 2, no. 1, 2014.

[21] Zagita, Muhammad F. A. B. "Rancang Bangun Sistem Pemantauan Dan Pengendali Kualitas Udara Diruang MI (Manual Insert) PT. Smart Meter," *Jurnal Teknologi Elektro*, vol. 12, no. 1, Jan. 2021, pp. 16-21, doi:10.22441/jte.2021.v12i1.004.

[22] "K. Laksana, DESIGN OF TOXIC GAS (CO) DETECTOR IN VOLCANO ACTIVITY AREA https://repository.its.ac.id/58906/1/10311500010009-Non_Degree.pdf" (accessed June. 14, 2024).

[23] K. Charisma., et al. "DESIGN OF CO AND TEMPERATURE MONITORING TOOL IN CAR CABIN BASED ON TELEGRAM NOTIFICATION," *Journal Ahli Muda Indonesia*, vol.3, no.1, p.75-82.2022.

[24] S. Suryaningsih., et al. "Design Of Co Gas Level Measuring Instrument Based Wireless Rf For Condition Monitoring Air Pollution." *Journal Science and innovation physic*, vol.1, no.1. p.45-50. 2017.

[25] F. D. Astuti, carbon monoxide (CO) detector https://eprints.uwhs.ac.id/1805/1/Fitrianah%20Dwi%20Astuti.pdf" (accessed June. 15, 2024).