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IoT-Based Safety Helmet for Monitoring Carbon Monoxide Levels in Mining

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ABSTRACT

This research discusses the development of an Internet of Things (IoT)-based safety helmet designed to monitor carbon monoxide (CO) levels in high-risk areas, such as mining. The helmet is equipped with an MQ-7 sensor that detects CO concentration and provides alerts through a buzzer and notifications to the Blynk app when CO levels exceed 35 ppm. The test results show that the helmet can detect CO levels in real-time with good accuracy and able to provide a "Danger" notification as early warnings of potential gas poisoning hazards..

***Keywords**: safety helmet, carbon monoxide, internet of things.*

1. INTRODUCTION

The mining industry, especially underground mining, faces challenges related to exposure to hazardous gases, one of which is carbon monoxide (CO). CO is a toxic gas that is colorless and odorless, produced from the incomplete combustion of carbon-based materials such as coal and petroleum fuels. This gas binds to hemoglobin faster than oxygen, thereby reducing oxygen supply to the body. According to data from NIOSH (National Institute for Occupational Safety and Health), CO exposure above 35 ppm for 8 hours is hazardous and can cause headaches, nausea, and concentration issues, with higher exposures potentially leading to death (Darwanto et al., 2024).

Data from the International Labour Organization (ILO) shows that exposure to hazardous gases, including CO, causes up to 10% of workplace accidents in mining. Many incidents are detected too late because PPE often lacks sensors to detect toxic gases. Cases in South Kalimantan in 2023 and other incidents in the underground mines of PT Freeport in 2013 and 2017 highlight the importance of strict monitoring of hazardous gases (Tisna Wijaya & Ramdhan, 2022). IoT-based safety helmets with CO MQ-7 sensors offer a solution for real-time monitoring. These helmets detect CO concentrations, provide warnings via buzzers when dangerous gas levels are detected, and, with IoT, transmit data directly to safety officers for early detection and quick response to gas threats in high-risk areas.

2. METHOD

2.1 System Algorithm

System algorithm flowchart is seen by Figure 1. The process begins with system initialization to prepare the devices and components. The MQ-7 sensor detects CO levels in the environment, and the data is processed by the ESP8266 microcontroller. The system checks whether the CO concentration exceeds the threshold of 35 ppm. If the CO level is below 35 ppm, the system provides a safe notification without activating the buzzer. However, if the CO concentration exceeds 35 ppm, the system issues a danger notification and activates the buzzer as a warning. This process is repeated continuously to monitor CO levels in real time.

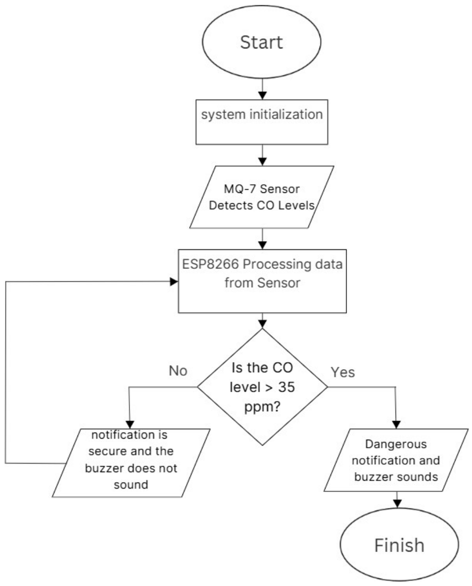

Figure 1. System Algorithm Flowchart

2.2 Device Design

The MQ-7 sensor is used to detect CO levels in the environment, while a step-down module ensures that the voltage from the battery meets the device's requirements. The data from the sensor is processed by the NodeMCU ESP8266, which also controls outputs and sends notifications via the Blynk application.

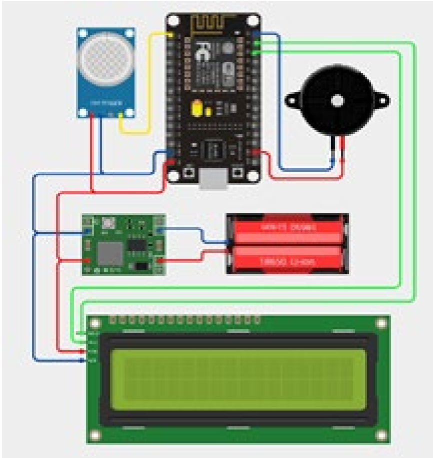

Figure 2. Schematic Circuit

The CO levels are displayed in real-time on an LCD for easy monitoring, and the buzzer provides an audible warning if the CO level exceeds the predefined threshold. Figure 2 is the circuit diagram of this safety helmet system.

2.3 Physical Design

This sensor system will be integrated into a safety helmet worn by workers, ensuring it does not hinder mobility. Below figures are the physical design of this Safety Helmet:

Figure 3. Outer Physical Design

Figure 4. Internal Physical Design

4. RESULTS AND DISCUSSION

Testing was conducted by simulating exposure to carbon monoxide (CO) emitted from vehicle exhaust. Figure 5 is the device testing. The sensor was connected to the exhaust via a 30 cm pipe to channel CO gas directly to the MQ-7 sensor, ensuring accurate measurements. The vehicle engine was started, allowing CO gas to flow through the pipe to the sensor. Data on CO concentration (ppm), detection time, buzzer status (On/Off), and IoT notification (Blynk) were recorded periodically. Testing continued until the CO concentration exceeded the 35 ppm threshold. Table 1 shows the test result.

Figure 5. Device Testing

Table 1. Test Result

No.	Time (mm:ss)	Engine Condition	CO Level	Buzzer	Blynk Notification
1.	00:00	Off	2.95 ppm	Off	Safe Notification
2.	00:10	On	11.20 ppm	Off	Safe Notification
3.	00:25	On	16.61 ppm	Off	Safe Notification
4.	00:40	On	22.23 ppm	Off	Safe Notification
5.	01:00	On	25.46 ppm	Off	Safe Notification
6.	01:15	On	27.77 ppm	Off	Safe Notification
7.	01:40	On	36.21 ppm	On	Danger Notification
8.	01:50	On	43.67 ppm	On	Danger Notification

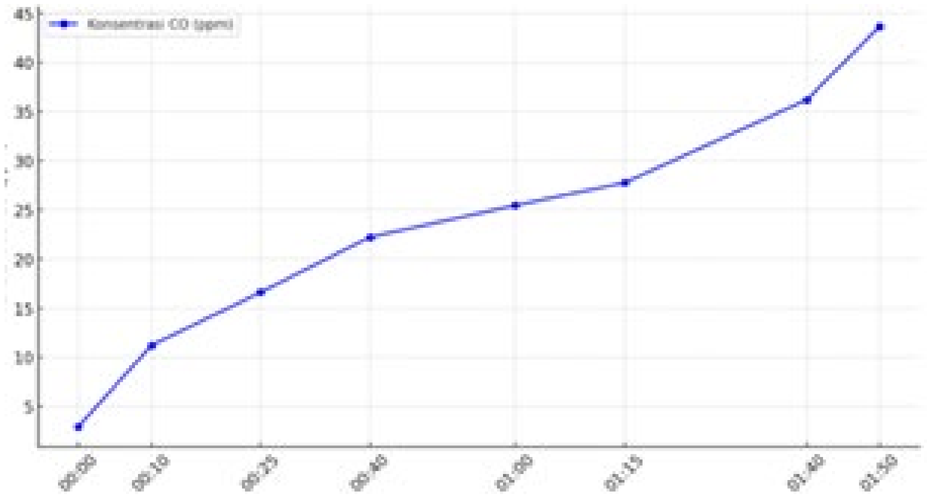

Figure 6. Graph of Time (minute:second) versus Changes in CO Concentrations (ppm)

Figure 6 descibes x-axis as time (minute:second) againts y-axis as the changes of CO concentration (ppm). When the CO concentration remains below the safe threshold of 35 ppm, the system indicates a safe status via IoT Blynk notifications and keeps the buzzer inactive. However, when the CO concentration exceeds the threshold, the system automatically activates the buzzer as a local warning and sends a "Danger" notification through the Blynk application, providing remote information to the user.

The sensor's linear response to changes in CO levels and the effectiveness of the IoT system demonstrate that this IoT-based safety helmet is reliable as a hazardous gas monitoring tool, particularly in work environments such as mining environment.

5. CONCLUSION

Based on the results, it can be concluded that the IoT-based safety helmet for carbon monoxide (CO) monitoring has been successfully designed and tested. The system is capable of detecting CO concentrations in real-time with a good level of accuracy. This system also enhances workplace safety by providing early warnings of potential carbon monoxide poisoning risks. During testing, the CO levels remained below 35 ppm until 01:15, but increased to 36.21 ppm at 01:40, triggering the buzzer and a "Danger" notification.

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