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*Original Article*

# Carbon Monoxide Monitoring System with Level-Indicated Warning and Automated Short Messaging System

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***Abstract*** - *Carbon monoxide gaseous emissions and its curbing are critical factors. These emissions are considered by-products from invented heating equipment, gas stoves, water heaters, enclosed car parking, etc. The effect of the gas will cause adverse effects on the persons exposed to it and require immediate attention if exposed to higher concentrations. This research focuses on implementing a monitoring system that senses the presence of carbon monoxide concentrations in the output of applications that produce carbon monoxide as a by-product. With the help of a microcontroller, an automated message with different status levels of monitoring and alarm is implemented. The system is equipped with a carbon monoxide sensor like MQ7 with fast response and high sensitivity. The output of the system is implemented using proteus simulation.*

***Keywords*** - *Carbon monoxide, Concentration, Message, Monitoring, Sensor.*

## 1. Introduction

Carbon monoxide (CO) gas is an odorless and tasteless gas, so it poses a challenge to detecting it. It is a lethal gas as it can kill a person in minutes; therefore, it also bears the title of Invisible Killer. [1] The main sources of CO are incomplete combustion of wood, gasoline, or coal, automobiles and generators operated in confined spaces, tobacco smoking, faulty furnaces or stoves, heating systems, etc.

According to the Centers for Disease Control and Prevention, about 430 people are losing their lives due to accidental CO Poisoning and around 50,000 people are admitted to emergency for the same reason. [2] The important reason behind Accidental poisoning is that CO is more easily absorbed by the blood than oxygen, and the oxygen in the blood is replaced by CO, which immediately causes death based on the amount of inhalation and the period of exposure. [3] The common symptoms of CO poisoning are headache, nausea, dizziness, fatigue etc. As these symptoms are similar to common flu, there are chances of misdiagnosis. Exposure to CO for a longer period may lead to damages that are irreversible. [4] According to [5], inhalation of an even smaller concentration of even 35ppm for a longer period will lead to the above-mentioned symptoms and higher concentrations like 3200 parts per minute (ppm) for 30 minutes or 12,800ppm for less than 3 minutes will lead to death or coma or respiratory arrest. According to [6], the limit of CO exposure in humans is 80 ppm for 15 minutes, 48 ppm for 30 minutes, 24 ppm for 1 hour, and 8 ppm for 8 hours. The threshold value is 25 ppm. Less than 25 ppm is still reasonably safe. The above facts clearly show the necessity and importance of early and quick detection and appropriate warning to reduce accidental poisoning to reduce death, and emergency conditions. CO detection and warning system constructed used CO detector TGS2442 along with PIC Microcontroller PIC16F917 for detecting and warning the occupants. [7] The detector senses the concentration of CO in the environment where it is mounted, and the output is fed to the microcontroller, which in turn turns on the LED, Alarm and LCD Display that shows the concentration of the CO in the space under consideration. The problem with the sensor is that it operates well when the temperature of the sensor is below 100°C.Polypropylene co-sensor is used to detect the lethal gas where the resistance of the polypropylene material used in the sensor changes its resistance with the concentration of the carbon monoxide gas to which it is exposed. [8]

The sensor output is compared with a reference voltage using an Op-Amp Comparator. The output of the comparator is either 0 or 1, indicating the presence and absence of the Killer gas. The sensor's output is fed to the AT89C52 microcontroller, which, based on the input, activates a relay to fetch the phone number stored in memory and then activates a relay to call the number to warn about the CO concentration in the premises where the system is installed. One of the existing methods for CO concentration detection and warning uses an MQ7 sensor for sensing CO existence, a Global Positioning System and Location Based Service. [9] CO levels at different places and various times, like morning, noon, and afternoon, were measured using sensors and GPS. Location-based service was integrated to provide SMS messages on Carbon monoxide Concentration in PPM and the corresponding Longitude and Latitude of the place of Measurement. It was concluded that the CO emission was higher during the afternoon. The air quality monitoring system uses an MA2 sensor for sensing LPG, alcohol co, hydrogen, and propane etc, an MQ7 Sensor for measuring CO concentration in the range of 20ppm to 20000ppm, and an MQ135 Sensor for measuring $CO_2$, alcohol, Smoke and Benzene, DHT11 for sensing temperature and humidity, Wi-Fi ModuleESP8266 which establishes Wi-Fi connection for Microcontroller. [10] All the sensors and Wi-Fi modules are connected to an Arduino board, which is also connected to an LCD, which displays air quality in ppm.

The Low-Power CO Detector measures CO concentration based on the current output of a carbon monoxide sensor. [11] The sensor's current output is converted to voltage and amplified to an appropriate level. The design uses an op-amp comparator to convert the analogy amplified voltage to a Digital signal. Power consumption is saved by activating the MCU only when needed using the digital signal. The MCU samples the analog signal, and the MCU is programmed to convert the sampled value to CO concentration. The paper discusses the CO concentration from 70+- to 400+- and the response time for the same is found to be in the range of 60 to 4 minutes, which is the minimum range. To save power when the CO concentration is above the minimum level, the MCU resides in standby mode but keeps monitoring the change in concentration with temperature, and as the concentration is above 65 ppm, the MCU goes into an alarm state. A packet is sent to the host every other minute, and Led is activated for visual indication.

The mobile monitoring facility has MQ7 for the detection of the presence of CO as it is sturdy even in temperatures ranging from -40ºC to 85ºC and has an SKM53 GPS Module starter kit, which has good positioning coverage in urban areas and foliage areas. The sensor unit and GPS module starter kits are integrated with Arduino. [12] Here, 2 MQ7 sensors are used to obtain accurate concentration results. MATLAB GUI is utilized for the real-time monitoring of the sensor output. The CO monitoring system is mounted on a vehicle and deployed in different areas for data collection, and the results are monitored in real-time. It was found that the industrial area measured the highest emission of CO, and the second was from Main roads due to vehicles.A gas leakage and detection system can detect the presence of liquefied petroleum gas utilizing an MQ2 gas sensor, LCD Module and a GSM system. [13] The system was found to be highly sensitive, and the incorporation of the GSM Module can alert the respondents. The system was, however, found to be useful in indicating warning that the threshold of concentration of detections has been reached; with no indications of concentrations of detections, the model can be further modified. An IOT-based gas detection and monitoring system is implemented for gas and oil pipelines. [7] The system utilizes sensors like MQ2, MQ5 and MQ7 to detect the presence of gases like methane, carbon monoxide, etc. An Arduino Nano, DS18B20 temperature sensor, and ESP8266 microcontroller were used to send the automated message utilizing the internet. Alerting using a buzzer onsite and email integration was also utilized. The system had a mechanism to automate the turn-off of valves if an alert message /or detection of a hazard was encountered. The system has an excellent monitoring system; however, there are no details on the concentration level of pollutants detected and level indications.

## 2. Materials and Methods

The research uses the MQ7 sensor to effectively detect and monitor carbon monoxide to effectively relay signals and hence warn the point sources for immediate reaction. As shown in the Figure 1, the sensor has a 6-pin configuration. As per the structure diagram given in the datasheet of Huawei Electronics (Huawei Electronics), there is a tube made of ceramic embedded with fine aluminum oxide. The highly sensitive nature of the sensor is attributed to the tin dioxide layer within the ceramic tube. Table 1 shows the health hazard caused due to CO inhalation.The electrode in the sensor structure is made of gold, and the electrodes are fixed into the generalized compartmental center part, which is further affixed to the coil concerned with heating purposes.

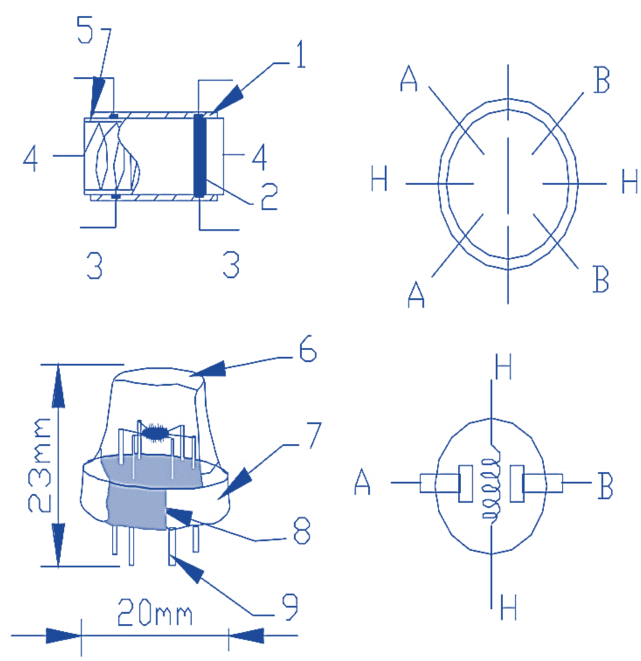


**Fig. 1 Structure of MQ7 Sensor**

**Table 1. Health hazard Vs CO ppm**

| Concentration of Carbon Mono Oxide | Duration of Exposure | Health Hazard |
|---|---|---|
| 35 ppm | 6–8 h | Headache, dizziness, nausea, loss of judgment and convulsions |
| 100–200 ppm | 2–3 h | |
| 400 ppm | 1–2 h | |
| 800 ppm | 45 min | |
| 1600 ppm | 20 min | |
| 3200 ppm | 5–10 min | |
| 6400 ppm | 1–2 min | |
| 1600 ppm | 2 h | Respiratory arrest, severe conditions (coma) and death |
| 3200 ppm | 30 min | |
| 6400 ppm | <20 min | |
| 12,800 ppm | <3 min | |

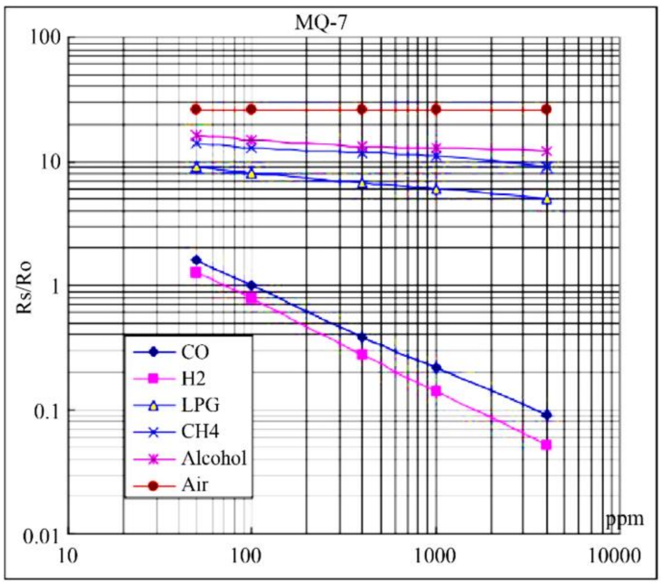


**Fig. 2 Sensitivity characteristics**

The highly sensitive feature of the sensor is attributed to its structure, where it can measure CO concentrations anywhere from 20 ppm to up to 2000 ppm. One of the critical input requirements to set up the required circuit is the relationship between the variable Rs/Ro to the ppm as given in the datasheet as per the figure given below, which shows the plot of Rs, which is the resistance of the sensor at different ppm of carbon monoxide and R0 which is the resistance of the sensor at 100 parts per million of the gas CO when the reference requirement for the air is considered to be clean air.

In order to develop the required framework, a linear equation based on the characteristics given above is required. From Figure 2, it can be noticed that the ratio RS/Ro is equivalent to 1 at 100 ppm of CO gas. The R0 value needs to be standardized to determine that set the standard conditions for the measurement, which is the relative humidity in the range of two points from the graph selected for the analysis purpose.

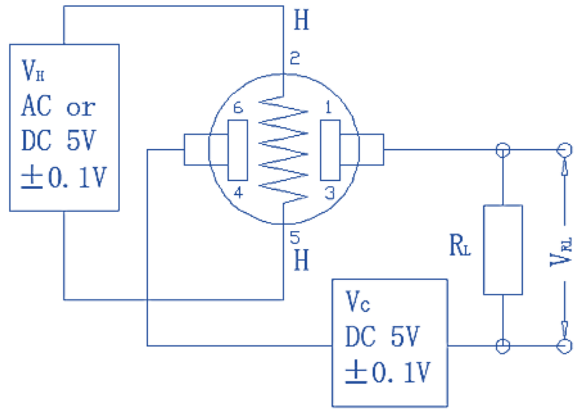


**Fig. 3 Circuit diagram to measure CO ppm**

For the calibration of the sensor, the ratio of RS/R0 is required for different CO concentrations. Based on literature review 4 critical levels of carbon monoxide were determined considering the concentration levels which are 35 ppm (exposure to prolonged period can cause several symptoms), 150ppm (more than 2-3 hours exposure may cause symptoms to appear), 400 ppm (exposure to 1-2 hours may cause symptoms to appear), 800 ppm (exposure to 45 minutes may onset symptoms) and 2000 ppm(exposure to less than 2 hours may cause symptoms to appear).

The key factor in the monitoring system is to identify the CO concentrations in the above-mentioned ranges and send an alert upon the identification of said ranges.

From the ratio of Rs/R0 in the clean air is found to be 25.75, i.e.

$$\frac{Rs}{R0} = 25.75$$

Where the term Ro is the sensor resistance in clean air, and Rs is the sensor resistance at different concentrations of CO. The value of Rs is a variable which depends upon the CO concentration.

Figure 3 can be used to conduct the calibration process to find the value of R0 in ambient conditions where the condition is assumed to be clean air. The voltage across the load resistance can be calculated using the concepts of the voltage divider rule and is found to be.

$$VRL = Vc \cdot \left(\frac{\text{Rs}}{\text{Rs+ RL}}\right)$$

$$Rs = \left[\frac{Vc}{VRL} - 1\right] \cdot RL$$

The system can be implemented with the help of Arduino connected with the help of the circuit diagram Figure 4 and considering a load resistance of 10 KΩ.

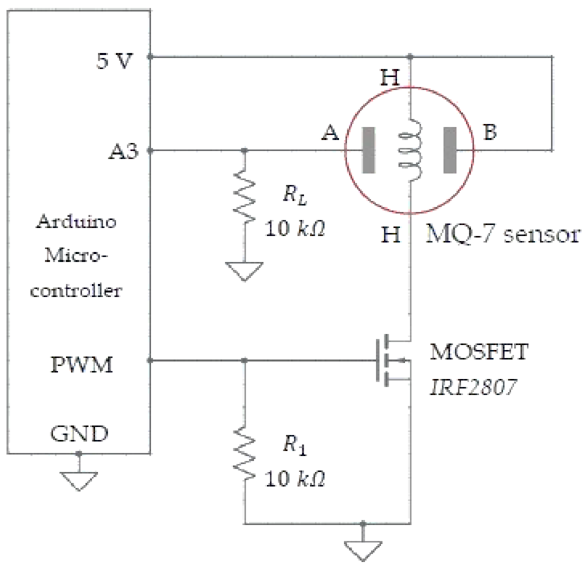


**Fig. 4 Circuit diagram with arduino**

**Table 2. CO ppm Vs. Rs/R0**

| Sl.No | CO PPM | Rs/R0 |
|---|---|---|
| 1 | 49.43 | 1.58 |
| 2 | 97.87 | 1.00 |
| 3 | 393.68 | 0.38 |
| 4 | 995.71 | 0.22 |
| 5 | 4005.08 | 0.09 |

Using the equations of resistance ratio and by applying the above equation to find Rs by applying the voltage divider rule, the value of R0 can be computed. The experimentally obtained value of R0 is 2.12 KΩ. Utilizing the data sheet of the MQ7 Sensor, the various ratios of resistance to different CO ppm can be considered as given in Table 2.

In order to develop the linear equation corresponding to the data points, as mentioned in Table 2. The concept of log-log plot and developing of the equation is to be considered.

Considering the logarithm on both sides of the exponential functions, we get

$$\log y = \log\left(a\, x^{(k)}\right)$$
$$\log y = \log(a) + k\ \log(x)$$

For any exponential function of the form $y = a\, x^k$ will appear as a straight line in the graph, which has logarithmic expressions on both axes, where the value of k is the slope and the value of a is the intercept along y axis.

The above equation can further be simplified and written in the generalized form given below.

$$Y = mX + b$$

In the above expression $X = \log(x)$ and the value of y is given as $Y = \log(y)$. The value of the constant b=log a, which is the value of intercept on the y-axis when the logarithmic value of the x coordinate is equivalent to zero. If the generalized equation must be expressed in a logarithmic scale, the following modifications have to be done which is

$$\log_{10} F(x) \ = m \log_{10} x \ + b$$
$$F(x) \ = x^m\, 10^b$$

To find the value of one of the constants, which is the slope, any of the two points of the sensitivity characteristics can be considered from Table 2.

$$\text{Log}[F(x1)] \ = \ m\ \log(x1) + b$$

The second point can be selected based on the equation given as

$$\log[F(x2)] \ = \ m\ \log(x2) + b$$

From the expressions for the two data points, the slope equation can be written as

$$m = \frac{\log[F(x1) - \log[F(x2)]]}{\log[(x2) - \log(x1)]}$$

This equation can be further simplified to

$$m = \frac{\log\left[\frac{F2(x2)}{F1(x1)}\right]}{\log\left[\frac{(x2)}{(x1)}\right]}$$

Since from the expressions for the two data points, the slope equation can be written as

$$m = \frac{\log[F(x1) - \log[F(x2)]]}{\log[(x2) - \log(x1)]}$$

In the above expression if we substitute, F2= F(x2) and F1=F(x1)

$$\left[\frac{F2}{F1}\right] = \ \left[\left(\frac{x2}{x1}\right)^m\right]$$
$$F2 = \frac{F1 \cdot\ x2^m}{x0^m}$$
$$F2 = F1 \cdot\ \left[\frac{x2}{x1}\right]^{\frac{\log\left[\frac{F2}{F1}\right]}{\log\left[\frac{x2}{x1}\right]}}$$

From the above-generalized expression, considering Table 1 and the characteristics as given in the datasheet, for the MQ7 sensor, the expression can be formulated considering F2=Rs/R0, and the value of slope with the considered data is computed to be as –0.652.

$$\frac{Rs}{R0} = \ 19.709(ppm)^{-0.652}$$

From the above expression, the value of Rs can be given as

$$Rs = \ R0[19.709(ppm)^{-0.652}]$$

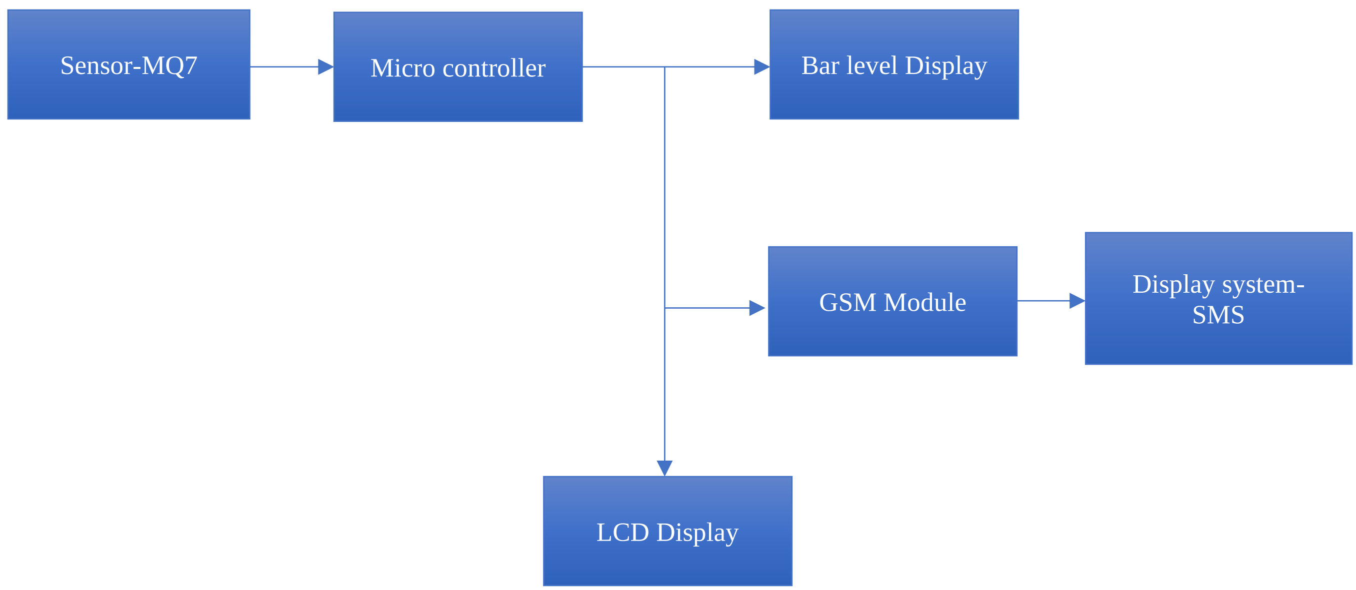


**Fig. 5 Block diagram of the proposed system**

**Table 3. ppm vs.RS Data Values**

| sl. no | R0 | ppm | Rs |
|---|---|---|---|
| 1 | 2.12KΩ | 35 | 4114 Ω |
| 2 | 2.12KΩ | 150 | 1592.90 Ω |
| 3 | 2.12KΩ | 400 | 840.344 Ω |
| 4 | 2.12KΩ | 800 | 534.793 Ω |
| 5 | 2.12KΩ | 2000 | 294.259 Ω |

From the above expression, by substituting 4 different CO ppm, the model will be developed with the help of values given in Table 3.

Figure 5 shows a block diagram of the system, and Figure 6 shows the algorithm, which shows the mechanism of programming the microcontroller and, hence, obtaining the required output. The first step is to initialize the ports, LCD and GSM and setting the data values in the devices. The output of the MQ-7 Sensor is connected to the ATmega16 microcontroller, which is primarily a variable sensor resistance in response to the ppm concentration of Carbon Monoxide.

In response to the specified value of Rs for the corresponding CO Monoxide, the data will be normalized and quantized by microcontroller programming. The output of the specified CO ppm will be relayed to Bar LED and LCD messages. Bar LED will have different output levels that vary for different CO ppm rates, which shows the distinction between critical CO ppm levels. In addition to the output from the bar LED, the LCD will have an output which indicates the CO ppm rate according to CO detection by the sensor resistance. A critical threshold of 150 ppm was selected for the model, considering the levels selected and the exposure time. This threshold ppm is computed to be present in the system, and if yes, from 150 ppm, a short message will be sent to the immediate responder via a GSM Module. As far as the warning is concerned for 35 ppm of CO, the LCD and Short message that will appear will be "initial warning". For 150 ppm, the LCD display will be "critical warning"; for 400 ppm, the display will be "Evacuation Warning," which is basically a direction to evacuate. As far as 800 ppm is concerned, the LCD display will be "highly critical", and for 2000 ppm, the display will be "highly hazardous". The display in the LCD will be reciprocated as a short message in the display module conjugated with the GSM Module when the threshold level, which is more than 150 ppm of CO level, has been attained. ATMEGA328P microcontroller is responsible for sending SMS messages to the respective mobile via a GSM module type SIM900D, and these messages also indicate the CO hazard levels.

## 3. Results and Discussion

The implemented systems are given in Figures 7, 8 and 9. The microcontroller implemented has 32 General-purpose input/output pins (4 ports). The conversion system implemented for the analog to digital in ATMEGA16 is 10-bit 8 channels. The memory capability of the selected microcontroller is impeccable, with a rating of 16KB programmable flash memory, and the ease of utility makes the microcontroller user-friendly. It has 3 counters and has a programmable USART (Universal asynchronous Receiver and Transmitter). ATMEGA328 microcontroller is also utilized for the short messaging system, which is embedded in the Arduino Uno development board. It has 14 digital I/O pins and the analog input pins are 6 and has a flash memory of 32Kilo Byte. The 8-bit data for the LCD (20X2) is connected to port D, and the control pins of the LCD are connected to port C.

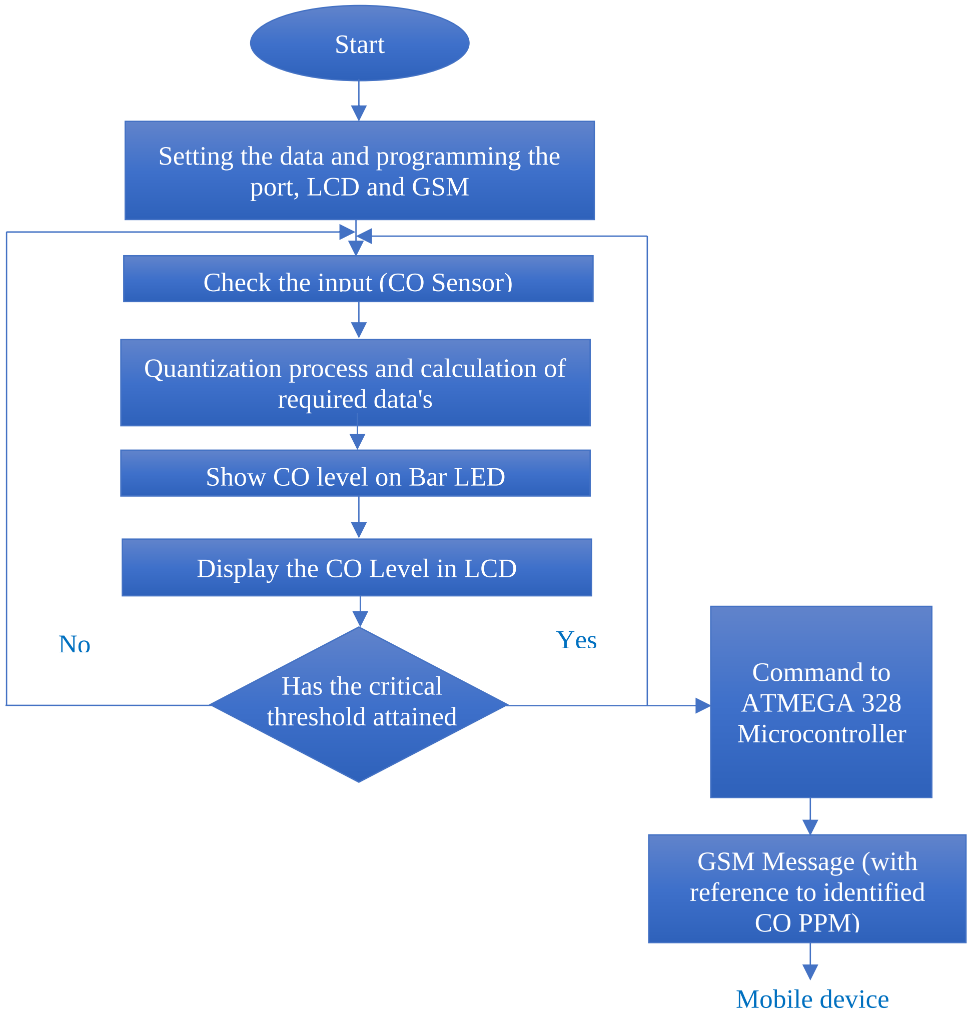


**Fig 6. Flow chart of the operation**

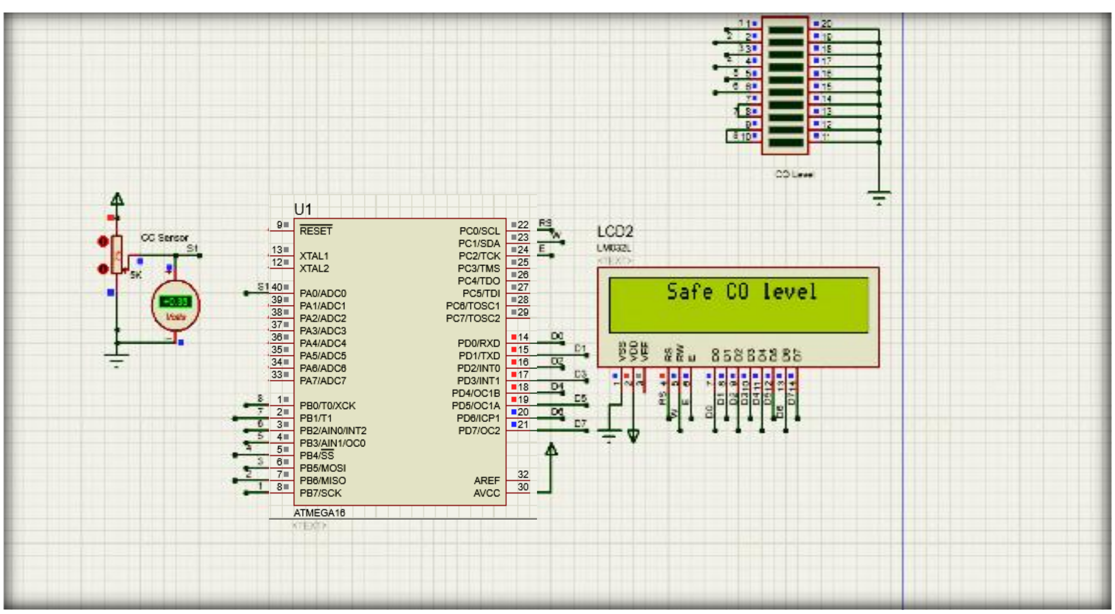


**Fig. 7 Level monitoring system for ppm below 35**

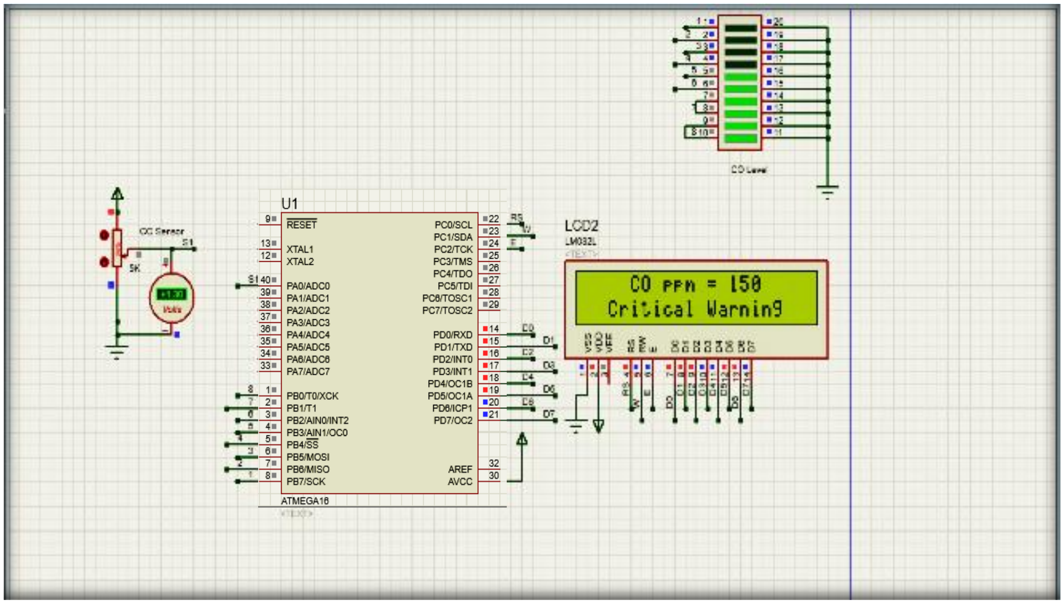


**Fig. 8 Level monitoring system for ppm 150**

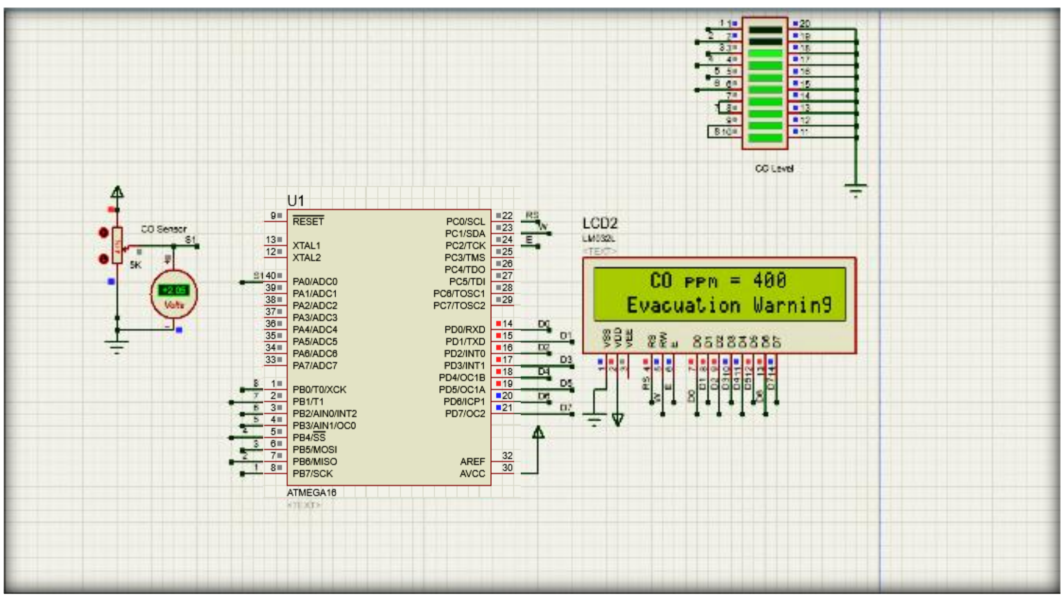


**Fig. 9 Level monitoring system for ppm 400**

Figure 7 shows the proteus simulation implementation where the ATMEGA16 Microcontroller is programmed with reference to the variable values of $R_s$ corresponding to varied concentrations of CO. The above-implemented system detects the CO PPM below 35 ppm, which is considered to be a safe level if identified early and if not exposed to a prolonged period of time. The bar led level indicates the minimal level.

Figure 8 of the implemented system detects the CO PPM at 150, and the warning message of critical warning appears in the LCD display correspondingly; the bar LED also has an indication of the level of CO with reference to the identified level. As per the implementation, the above-indicated system in Figure 7 is for the critical threshold level above, which is considered hazardous. An elevated level monitoring is identified in the bar led with monitoring using green color.

Figure 9 indicates an evacuation level scenario if identified early considering the elevated levels of CO; the identified indication as per the system is an evacuation warning. Elevated bar-led monitoring was also indicated as per the figure.

Figures 10 and 11 show highly critical and hazardous levels of CO monitoring for ppm concentrations of 800 and 2000, respectively; the LCD display as per the implementation, will have monitored indications of highly critical and hazardous due to elevated levels of CO.

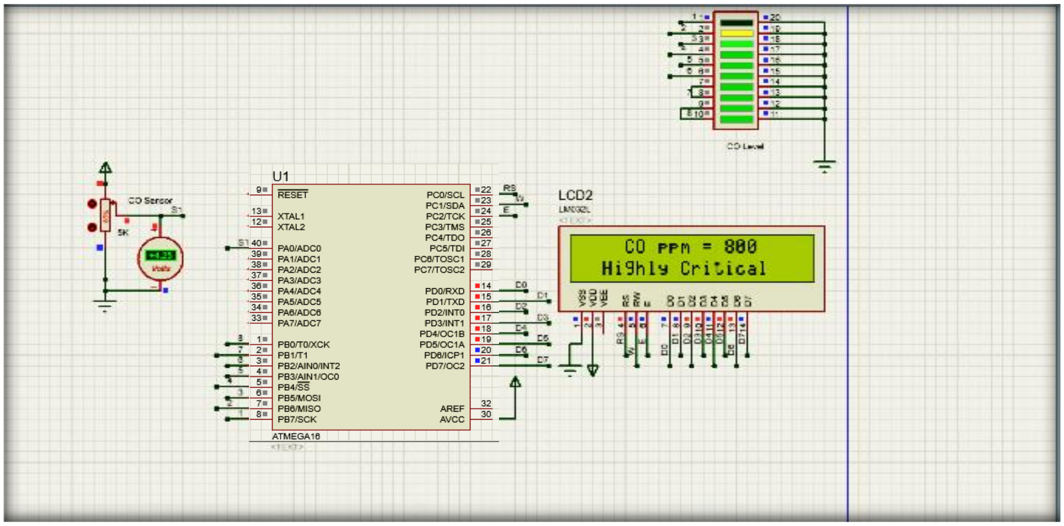

**Fig. 10 Level monitoring system for ppm 800**

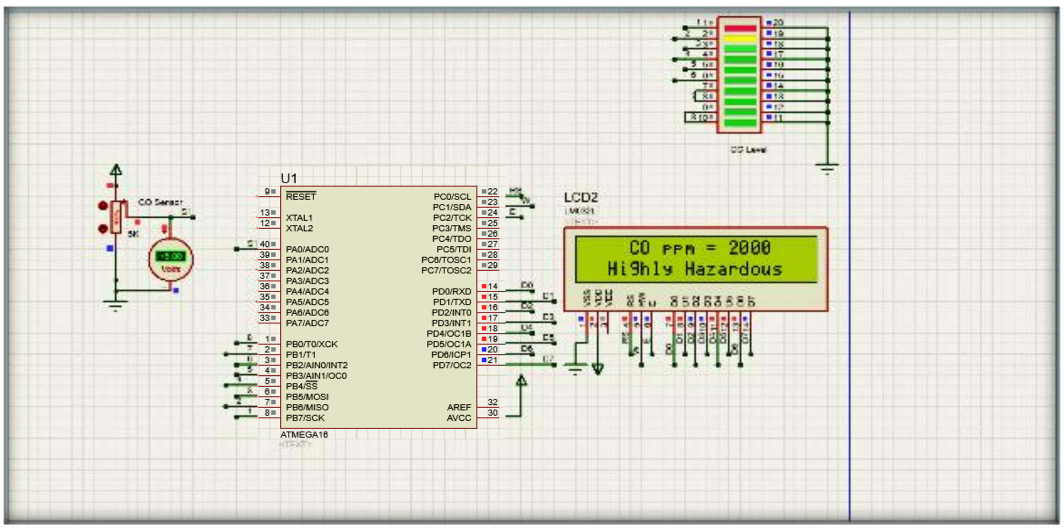

**Fig. 11 Level monitoring system for ppm 2000**

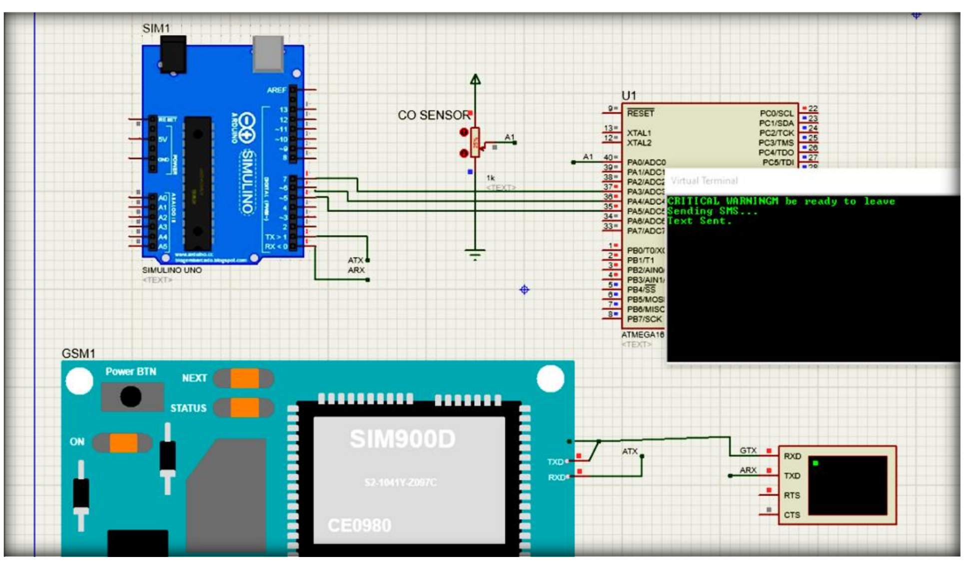

**Fig. 12 Automated messaging system for highly critical warning**

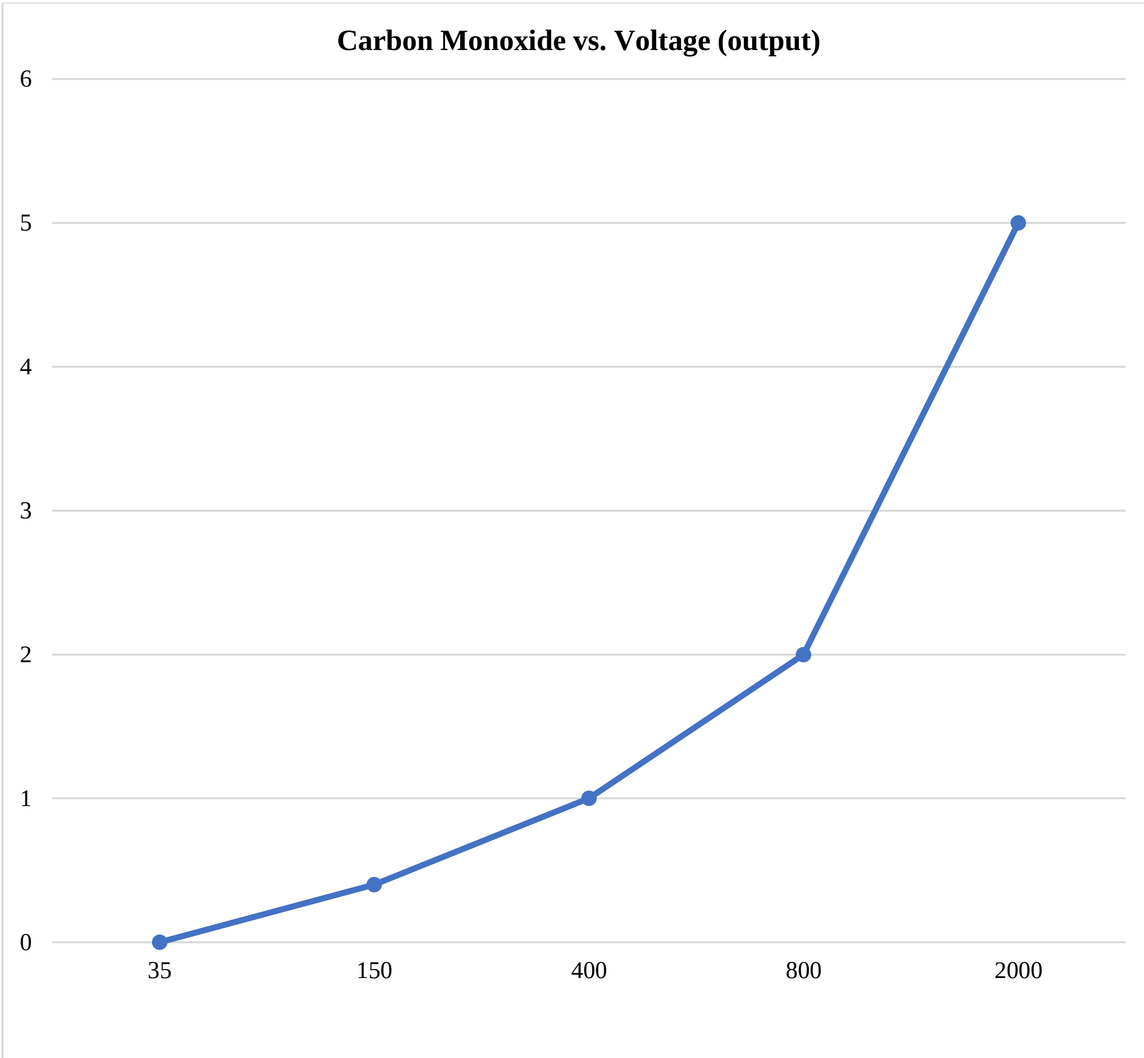


**Fig. 13 CO ppm vs. voltage**

Figure 12 shows the implementations for the automated messaging system in which two microcontrollers are implemented; the main one is the ATMEGA16 microcontroller, which is concerned with the calculations, Quantization, and decision-making besides controlling another ATMEGA328P microcontroller.

As per Figures 11 and 12, the short messaging system is implemented via the ATMEGA328 microcontroller, which is conjugated with the ATMEGA16 Microcontroller and programmed as per the output of the CO sensor.

Figure 13 shows the plot of CO ppm concentration versus Output voltage in the simulations. As per the data collated, it was observed that a linear trend, which is the proportional relationship between the sensor's output voltage and the ppm, was more or less noticeable. When compared to the sensitivity characteristics, the implemented system characteristics reflect the behavior of the sensor with reference to the CO ppm.

## 4. Conclusion

As per the obtained results, it was noticed that the system responds well to the changes in the sensor with moderate to high-level response with a linear relationship between the CO ppm and the output voltage. The automated messaging system implemented uses ATMEGA16 and ATMEGA328, which maximizes the usage of the microcontroller and hence the system's utility is also maximized. The system has its novelty owing to the consideration of resistance Rs in designing the system and utilizing it to program the microcontroller and, hence, automate the message. The above system can be further extended by including different microcontrollers with faster response times, and the minimization of microcontrollers can also be done as the next step.

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## References


[1] Rajitha Ariyaratne et al., "Understanding the Effect of Temperature and Relative Humidity on Sensor Sensitivities in Field Environments and Improving the Calibration Models of Multiple Electrochemical Carbon Monoxide (CO) Sensors in a Tropical Environment," *Sensors & Actuators B*, vol. 390, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[2] Nureni Asafe Yekini et al., "Gas Leakage Detector and Monitoring System," *International Journal of Engineering & Manufacturing*, vol. 12, no. 5, pp. 56-65, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[3] Abdülkadir Çakir et al., "Design of Carbon Monoxide (CO) and Smoke Sensor, and Creation of Warning System with Fixed Telephone Call Using these Sensors," *Resilience*, vol. 4, no. 1, pp. 23-32, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[4] Ioannis Christakis et al., "Air Pollution Monitoring via Wireless Sensor Networks: the Investigation and Correction of the Aging Behavior of Electrochemical Gaseous Pollutant Sensors," *Electronics*, vol. 12, no. 8, pp. 1-21, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] E. Ernyasih et al., "Health Risk Assessment through Probabilistic Sensitivity Analysis of Carbon Monoxide and Fine Particulate Transportation Exposure," *Global Journal of Environmental Science & Management*, vol. 9, no. 4, pp. 933-950, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[6] Marko Jäntti, and Markus Aho, "Quality Aspects of Digital Forest Service Management: A Case Study," *Software Quality Journal*, vol. 32, no. 1, pp. 75-94, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[7] Suman Lata et al., "Development of Greenhouse-Application-Specific Wireless Sensor Node and Graphical User Interface," *International Journal of Information Technology*, vol. 15, no. 1, pp. 211-218, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Turja Nandy, Ronald A. Coutu, and Cristinel Ababei "Carbon Monoxide Sensing Technologies for Next-Generation Cyber-Physical Systems," *Sensors*, vol. 18, no. 10, pp. 1-29, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[9] Janani Priyanka Perumpally Rajakumar, and Jae-Ho Choi, "Helmet-Mounted Real-Time Toxic Gas Monitoring and Prevention System for Workers in Confined Places," *Sensors*, vol. 23, no. 3, pp. 1-16, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Paulo Henrique Soares et al., "Use of Association Algorithms in Air Quality Monitoring," *Atmosphere*, vol. 14, no. 4, pp. 1-11, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[11] Purwantoro, Arip Solehudin, and Nono Heryana, "Mapping and Monitoring Pollution Levels of Carbon Monoxide (CO) Using Arduino and Location-Based Service," *ArXiv*, vol. 5, no. 6, pp. 1-5, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] Jiachen Yang et al., "A Real-Time Monitoring System of Industry Carbon Monoxide Based on Wireless Sensor Networks," *Sensors*, vol. 15, no. 11, pp. 29535-29546, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[13] Zhao-Cheng Zeng, Lu Lee, and Chengli Qi, "Diurnal Carbon Monoxide Observed from a Geostationary Infrared Hyperspectral Sounder: First Result from GIIRS on Board FengYun-4B," *Atmospheric Measurement Techniques*, vol. 16, no. 12, pp. 3059-3083, 2023. [CrossRef] [Google Scholar] [Publisher Link]