Carbon monoxide detection using IoT

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***Abstract*— Carbon Monoxide Detection Based IoT was selected to be the title for this project. IoT platform in recent year have grown and expanded to different applications. These Carbon Monoxide Detection System was designed and implemented with the use of problem statements, investigating previous work done by other people whilst reviewing the work that was done and proposed methodology was given. The finalised design was built and thus enhanced with real environmental testing that took place in several locations. The overall system was tested and evaluated. Thus, based on the design and implementation of the system, the results were obtained.**

***Keywords*— Carbon monoxide, microcontroller, detection system, arduino, Internet of Things**

I. INTRODUCTION

In this day and age, safety and welfare have an important role in ensuring that a secure protections system is enforced. Despite the advancement in technology in recent years, yet we have been neglecting and filled with naivety to take care of the world in which we reside. According to the World Health Organization or WHO (2020), around 91% of the world population live in areas where air pollution crosses the limits set by WHO guidelines. This allows the breathing capacity in such environments to be difficult thus, reducing life expectancy of a human by 1-2 years.

Carbon Monoxide is a colourless, odourless gas which can be harmful if inhaled in large quantities [1]. Among the source of Carbon Monoxide is the exhaust of motorized vehicles or even in factories that uses machinery that burns fuels. Breathing air with a high concentration of Carbon Monoxide decreases the amount of oxygen that needs to be delivered to the organs. Carbon Monoxide particle will attach itself with the haemoglobin and once it has attach3ed itself, it becomes extremely difficult to get rid of it. At this point, the blood oxygen is then replaced by carbon monoxide in which this condition is referred to as carboxyhaemoglobin (COHb) [2]. With high concentration exposure to the hazardous gas, it may even cause an untimely death. The rate of speed in which the COHb forms is dependent on how much of the toxic gas is breathed by a person which is measured in per particle million, PPM. Higher the concentration of PPM is consumed, the rate of death by a human is increased due to lack of oxygen to the organs.

Without the presence of a gas detector, it becomes impossible to detect the hazardous gas. Since it has no colour or taste, it is then almost possible for a human to detect its deadly presence lest a detection and monitoring system is placed.

The advancement, growth, and implementation of technology in multiple industries is bar none. The intention of such advancement is to improve the daily life with such technology in place. Keeping that in mind, few issues were picked out that could be a feasible goal in this research as follows:

- Limited functions of Carbon Monoxide detection system.
- Lack of usage of IoT application in monitoring and detection system.
- To increase the efficiency of resolving Carbon Monoxide not being detected.

IoT is the most innovative resource in manufacturing, commercial, and residential structures every day, playing a critical role [3-7]. The proposed system would firstly have more functions as compared to the detections systems that are available in the market currently. Besides that, the IoT platform is the current technology trend in the industrial revolution, there are not many Carbon Monoxide Detection systems that fully utilizes the IoT platform. The current detections systems that are available in the market have limited functions. Some of the functions include the basic detecting of the hazardous gas that is in increase and just simple alerts such as changes in the colour of LED to indicate the increase in the concentration of the gas. In the proposed system, more functions are added such as a buzzer that will make a sound immediately when the concentration of the gas crosses into the dangerous level as well the system sends an alert message to the user. Next, IoT platform is not utilized despite being the technological trend at the current generation. The current systems, most of them do not implement the IoT platform such as monitoring through mobile application etc.

[8] had proposed a system that uses a low-cost Carbon Monoxide detector that alerts users when there is a high intensity of Carbon Monoxide through light and sound alarms by using a mobile application. While, [9] had proposed the development of IoT prototype design and implantation for carbon monoxide detection using WeMos D1 mini board programmed by Arduino IDE software. [2] developed an integrated system for a vehicle capable of detecting and sensing gases such as Carbon Monoxide. The Authors were focused on improving automotive safety by developing a system that measures Carbon Monoxide concentration within a vehicle that is integrated with an alarm system to notify users via mobile phone of possible Carbon Monoxide poisoning and thus activating power window when high levels of Carbon Monoxide is detected inside the vehicle.

[10] had proposed a standard Internet of Things (IoT) based approach which is a cost-effective alternative to

conventional air quality monitoring systems. The authors mentioned that the solutions available are not able to be accessed by the public and is specifically meant for organization use due to high cost and less usability. [11] proposed to create a system that will detect air pollution and particulate matter at Pandacan, Manila. The authors mentioned that factors such as smoke from vehicles and factories as well as dust and debris contribute to air pollution which causes health problems for general public. [12] proposed an Atmospheric Air Surveillance System (AASS) that allows web monitoring of Carbon Monoxide and Carbon Dioxide concentration in the surrounding air. The authors stated that the damaging effects affects not only to humans but to all living beings hence the system was proposed to tackle the issue at hand. The device has a microcontroller, multiple sensors and a Global Positioning System (GPS).

[13] proposed an Internet of Things (IoT) based air pollution monitoring system, notably Carbon Monoxide and Sulfur Dioxide. The authors seek to monitor the air pollution that is caused by vehicles in Indonesia. The system includes a CO-B4 and SO2 -BF electrochemical sensors, Blynk application on smartphone and ESP8266 NodeMCU board. [14] proposed a system that tests the emission standards of Tamil Nadu in a real time process using different sensors namely smoke sensor which is positioned at the vehicle exhaust. The authors wanted to identify the amount of gas being emitted by vehicles and is it following as according to the emission standards. [15] proposed a system that monitors the concentration of Carbon Monoxide and temperature within a close space. The authors noticed the lack of use of IoT in detecting Carbon Monoxide. IoT was used to monitor the data collected by the sensors, interpreting and displaying the given data after analysis. [16] proposed a system to monitor carbon monoxide sensor system using real time mobile and interfacing to measure level of carbon monoxide contamination in real environment. The system included and MQ-7 carbon monoxide sensor, SKM53 GPS Module starter kit, Arduino Uno and MATLAB as software.

The proposed system tackles this problem by creating a web server that constantly update the data from the sensors on the concentration of the gas. Lastly, Carbon Monoxide is an incredibly hazardous gas hence the proper authorities need to handle this in case of very high concentrations, however current systems do not have the functions to alert the users via text or call in case there is a leak or increase in concentration. The proposed system tackles this by including the operation by contacting the user when there is a sudden increase of the concentration of the gas which then becomes a danger to the public.

Therefore, the aim of this research is, using a gas detector to monitor the concentration of Carbon Monoxide in the environment with the means of IoT to transfer data to the Internet to allow the monitoring of the gas from a remote location.

II. SYSTEM IMPLEMENTATION

A) Overall Block Diagram

The integrated system consists of two sections. The first being the carbon monoxide sensor and detection section and the second section is the controlled room section. The figure below then shows the overall block diagram of the project. Fig 1. shows the overall block diagram.

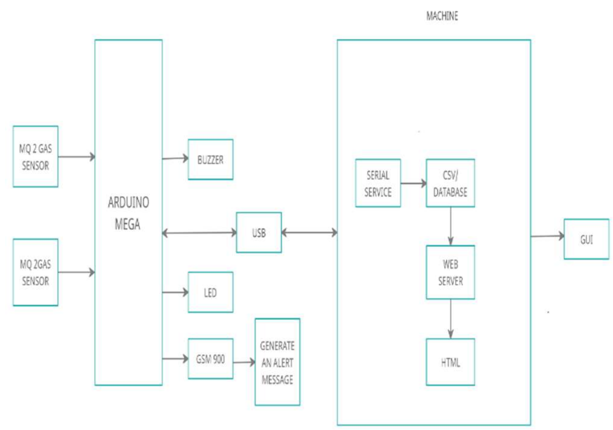

Fig. 1. Overall block diagram

The overall block diagram consists of gas sensors which is the MQ2 Gas Sensor. Those two gas sensors will collect the data from the surrounding environment which the collected data will then be transferred to the Arduino Mega to be read and interpreted to which will decide the next course of action to be taken. The Arduino Mega is also connected to a GSM 900 which helps to give out messages or calls to alert user in case of increment of the carbon monoxide gas. The GSM 900 is effective especially when WiFi is down. It provides a communication network that then allows a two-way communication between the system and user or any other party involve.

The output of the system will be a buzzer and led. Those two are vital components as it serves an audible alarm as well as a visual alarm to alert user to clear the area. The addition of a visual alarm is important to aid a person who has an impaired hearing. When the detected concentration of the carbon monoxide is high and is at dangerous levels, the buzzer and led will be activated and thus will alert user to exit. Arduino Mega is used as there are quite a bit of devices along with sensors that are used in this system hence the compatibility of the sensors along with the availability of the libraries available in Arduino makes it easier to us Arduino. A laptop or even a raspberry pi can be used as a machine. And this machine is connected to the Arduino Mega by a USB. Within this, a service serial or also commonly known as pyserial is a module for python and it is used to send and receive data from Arduino, thus all the data that is from Arduino will be sent to the pyserial.

The data from pyserial is then sent to the comma separated values or commonly known as csv or also the database. All the data from Arduino will be stored in here within the database. Moving on the data is then sent to Flask which is a microweb server. Basically, it is a web server and thus the data will be sent to the web server. From there, Flask will generate a HTML which will send the user to the web page to then be able to monitor and check on the concentrations of the Carbon Monoxide within the web server, the GUI is generated which then will be updated every time it receives new data as it is taking in real time data which will help the users to monitor the concentration of the Carbon Monoxide better.

B) Construction Details

MQ-2 sensor is a smoke and carbon monoxide sensor which is used by the microcontroller which in this case is the Arduino to extract the data in a digital output form. This sensor has the ability of anti-interference as well as able to give a high-level performance along with very high sensitivity to give accurate results. the voltage supplied to the sensor is set to be 5V as according to the datasheet. Fig 2. Shows Wiring diagram of carbon monoxide detection & monitoring system.

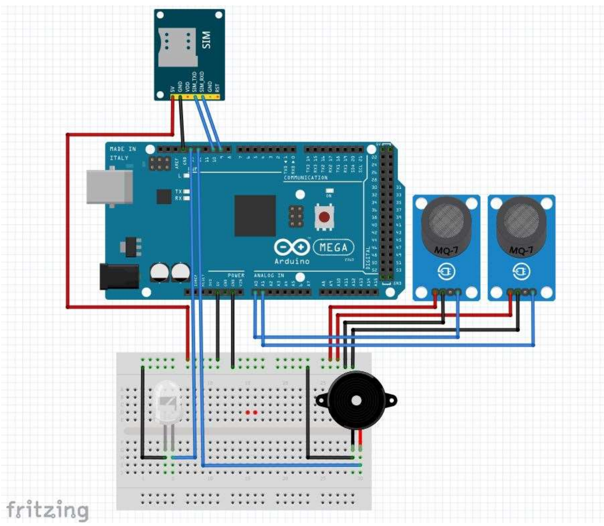

Fig. 2. Wiring diagram of carbon monoxide detection & monitoring system

The sensor has four pins namely as (VCC, Ground, Digital, Analog) however the sensor is connected with the VCC, ground and the analog output. The voltage supplied to the sensor is disseminated among the signal from the VCC and the ground. From the output signal of the data collected from the sensor, it is displayed in the serial monitor of the Arduino. There is no external power supply that is needed as the voltage supplied by the Arduino is sufficient to be spread across all the devices in use. GSM 900a is used in this project to broadcast alert messages to the user which is connected to the digital serial pin of the Arduino. The Tx and Rx from the GSM module are connected to the digital pin of the Arduino and the 5V supply and ground are too connected to the Arduino to power the module. It is sufficient as according to the datasheet of GSM 900a, the supply voltage of the module is in the range of 3,4V-4.5V. The buzzer and led are too connected to the system. The buzzer and led are extremely vital in this system as it is the output of the system. Both the buzzer and led are connected to the ground and connected to the digital pin of the Arduino to ensure that it is able to give out the output that is necessary as according to the system.

C) Working Principle

Fig 3. Shows 2 MQ-2 sensors, Arduino Mega, GSM module, Red LED and Buzzer. The MQ-2 sensor will take in the reading of the concentration of Carbon Monoxide in the surrounding environment. It will continuously monitor the gas level and the output data that is collected is sent to web server for purpose of monitoring the levels. The GSM module also connected to the system where it will constantly be connected and will trigger when the gas levels have crossed the threshold and will send out an alert message. The buzzer and led connected play a vital role in giving out the visual and audible alarm. All the data are shared over the USB and thus will be uploaded to the web server.

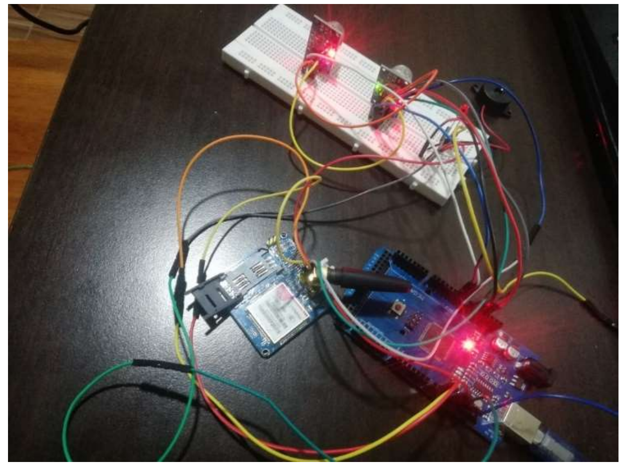

Fig. 3. Hardware of Carbon Monoxide Detector

Figure 4 shows the website that has been created to monitor the data in Real Time.

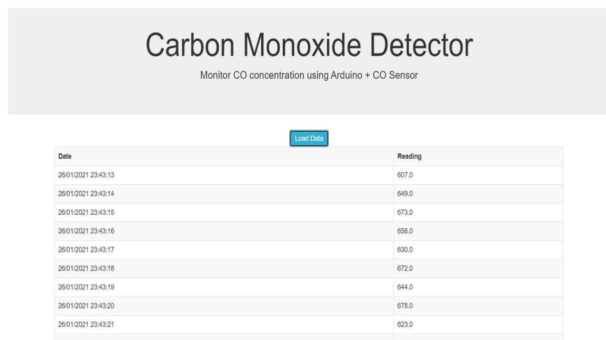

Fig. 4. Website main page

III. TESTING OF PROPOSED DESIGN

A) Gas Sensor Reading in Urban and Sub Urban Area

This testing was done to obtain sensor reaction in an urban and sub urban environment. The testing in an urban area was done in the Ayer Itam Forest Reserve, which is in Puchong, Selangor and the testing in sub urban area is done in Broga Hills which is located in Semenyih, Selangor. The aim of this testing is to detect the carbon monoxide gas reading in clean environment and the response of the system. he system uses an MQ-2 sensor which is gas sensor which is used to detect the different gases with their readings. The MQ-2 sensor has the ability to detect several different gases such liquid petroleum gas or commonly known as LPG, it is also able to detect smoke and most importantly it is able to detect carbon monoxide. Since this system is of a carbon monoxide monitoring system thus this sensor was used to only find the carbon monoxide. This sensor works on basis that it detects gas readings that are measured in its particle per million unit or PPM. The sensor produces output voltage which is used to indicate the gas level. Reading of the particle per million unit is calculated using quadratic equation.

$$Y - y1 = m (X - x1) \quad (1)$$

$$X= (y-y1)/m + x1$$

X= (Rs/Ro-y1)/m + x1

log X = (log (Rs/Ro) - y1)/m +x1

X =10^ ((log (Rs/Ro) - y1)/m +x1) (2)

Y= Rs/Ro (3)

Thus, the calculated reading can be obtained with respect to X which represents the PPM reading unit and Y indicates magnitude of sensor resistor over output resistor. These calculations are done within the Arduino IDE when the sensor is connected to the Arduino. The data collected from when the system ran was recorded from Arduino IDE. The data was taken in different samples as the time of transmission is fixed to send data every 5 seconds. This test is done is to check for the ambient amount of particle per million that is accepter. However, because Ayer Itam Forest Reserve is located in an urban area, it has more exposure to hazardous gas due to congested traffic which means heavy emission of the gasses released and coupled with the external signal of the lighter. It can be seen from the readings that Broga Hill has a better quality and lesser concentration of Carbon Monoxide. Thus, the reading from Broga Hill is deemed to be the ambient reading of the surrounding environment.

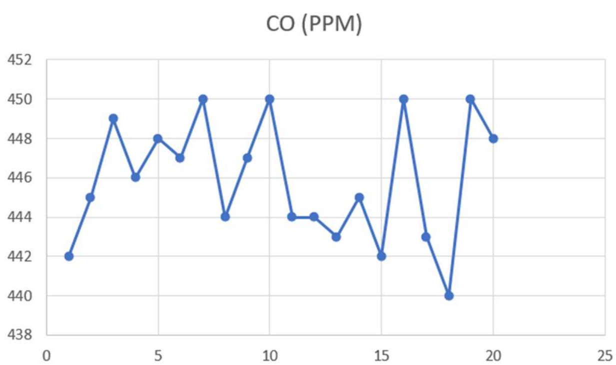

Fig. 5. Sample vs CO (collected data of the gas sensor in Ayer Itam Forest Reserve)

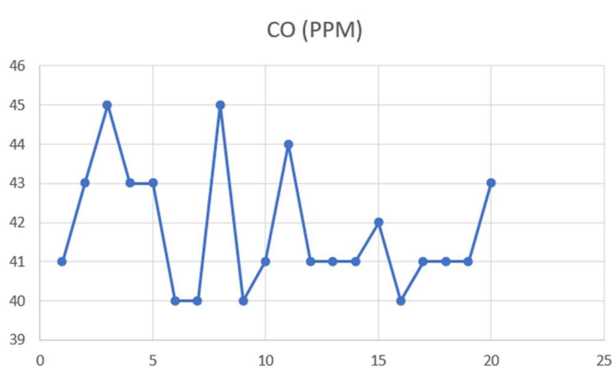

Fig. 6. Sample vs CO (collected data of gas sensor in Broga Hills)

As the graph shows in both Fig 5. and Fig 6., the peak of the response was different for each as it was exposed to different environment and its effects. Based from the plotted graphs, the ambient environment is of at Broga hills. The readings just vary between 40ppm to 45ppm which shows that the fluctuates as it should due to wind and other factors that come into play. Even the readings in Ayer Itam too fluctuates.

B) Gas Sensor Reaction to Exhaust System of a Vehicle

This experiment is developed to identify the hazardous level of carbon monoxide when it is directly exposed to an environment where there is high concentration of carbon monoxide. Exhaust fumes of vehicles have been used multiple times as a method of a suicide as it releases high level of Carbon Monoxide. Hence, devising this experiment is crucial to understand the high levels of Carbon Monoxide being emitted. The experimental setup for this testing is similar to the one done in the first testing. MQ-2 sensor is used in the system where this sensor is a gas sensor that has the ability to detect different gases such as liquid petroleum gas or known as LPG, detect smoke and as well as able to detect carbon monoxide gas. Since the system is of a carbon monoxide monitoring system therefore, the sensor was used to detect the carbon monoxide gas. The sensor works by detecting gas readings that measures in particle per million unit or PPM. The sensor produced output voltage that indicates the level of the gas and the reading of the particles per million unit is calculated by using the following quadratic equation.

Y - y1 = m (X - x1) (4)

X= (y-y1)/m + x1

X= (Rs/Ro-y1)/m + x1

log X = (log (Rs/Ro) - y1)/m +x1

X =10^ ((log (Rs/Ro) - y1)/m +x1) (5)

Y= Rs/Ro (6)

Therefore, the calculated reading is attained with respect to X which represents the reading of the PPM unit and the Y represents the magnitude of the sensor resistor over the output resistor. This was recorded by placing the sensor directly beneath the exhaust pipe of the vehicle however it is not directly connected to it by using a tube whatsoever. It is placed beneath with an open environment. Initially the sensor reading was 45 as the vehicle was not turned on.

But as soon as the vehicle started, the sensor begun to take the readings. The concentration or particle per million unit (ppm) of the carbon monoxide gas gradually increased and in a matter of seconds it crossed the threshold of hazardous and the levels of the carbon monoxide being emitted was critical. A person exposed to a high concentration of carbon monoxide can lead to a fatal death within minutes.

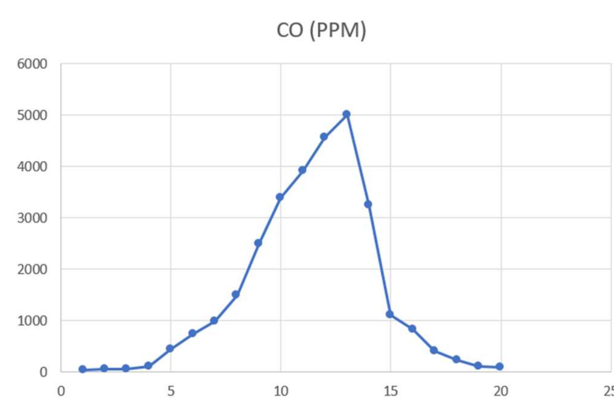

Fig. 7. Sample vs CO ppm (Collected Data of Gas Sensor Under Exhaust of a Vehicle)

Fig 7. shows the plotted graph of the sample time vs the concentration of the carbon monoxide gas in PPM. From the graph we can observe the steep rise in the concentration of the gas when it is exposed to the exhaust system of the vehicle. Thus, it shows that the concentration of carbon monoxide emitted by a vehicle is extremely high when exposed directly. When the vehicle was switched off, it still took some time for the carbon monoxide gas to dissipate, it was still within the air, thus even after the vehicle switched off the toxic gas was still present. And it gradually decreased over time.

C) Overall Testing of the Carbon Monoxide Detection System

This experiment is developed to test the integrated system of carbon monoxide detection system. The experiment will take place within a vehicle. When a vehicle is stationary for a long period of time, the internal combustion engine will then start producing carbon monoxide that will then be flowing within a vehicle. However, there is something called a catalytic converter which functions to reduce toxic gases and pollutants in exhaust gas that is generated from the internal combustion engine. To detect the carbon monoxide gas, MQ-2 gas sensor was used to detect the gases. The sensor detects gas readings and displays in particle per million (ppm) units and it produces an output voltage that indicates the gas level. The output voltage and reading of the particle per million unit was evaluated and calculated using the derivations from the quadratic equations shown below.

$$Y - y1 = m (X - x1) \quad (7)$$

$$X= (y-y1)/m + x1$$

$$X= (Rs/Ro-y1)/m + x1$$

$$\log X = (\log (Rs/Ro) - y1)/m +x1$$

$$X =10^{\wedge} ((\log (Rs/Ro) - y1)/m +x1) \quad (8)$$

$$Y= Rs/Ro \quad (9)$$

Therefore, the evaluated readings that accomplished with respect to X which represents the particle per million (ppm) unit and Y signifies the size of the sensor resistor over the output resistor. The experiment was conducted with respect to the MQ-2 sensor which is connected to the Arduino. This system also has the buzzer, alarm, GSM module attached as well.

The data collected from the Arduino had a transmitting time that was fixed to 1 minute apart which means the data was taken every one minute. The system was left running for 30 minutes inside a running vehicle. For the first 9 minutes, the reading of carbon monoxide gas was small. But after the 9th minute, the sensor started detecting a little more carbon monoxide gas and from then on, the concentration of the carbon monoxide gas kept increasing gradually over the period of 30 minutes. The plot of the increment of the concentration of carbon monoxide gas is best shown by using a plot that is shown in Fig 8.

Observing the plot in Figure 8, it is very clear of the gradual increase of carbon monoxide gas within a running vehicle that is stationary within a long period of time. Though it did not cross the threshold of hazardous particle per million (ppm) unit which was set to be 800, based on the plot, the increment of the gas was heading in that direction. Even an exposure of 200ppm of carbon monoxide gas is strong enough to cause serious illness to a person. So, from here, we can identify that the system works as per what has been programmed to function.

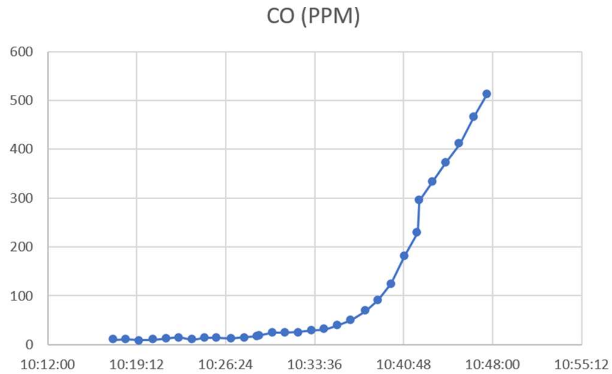

Fig. 8. Data collected of gas sensor inside a vehicle

IV. CONCLUSION

The sensor was calibrated and the calculations within the program was done to get the particle per million values. To ensure that the gas levels being detected by the sensor is accurate, the calibration and preheating of the sensor is done to get stable and accurate data.

The system when running, the data from the sensor that is running in Arduino, is uploaded to the web server through a serial service that is connected via USB. The data collected is in real time and will display the concentrations of the carbon monoxide gas. Buzzer and led was used as an audible and visual alarm. So, when the carbon monoxide concentration crosses its threshold, the buzzer and led will be triggered. Once the buzzer and led is triggered, then simultaneously the GSM module is triggered as well and will send out a text alert to the user.

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