Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 10, October-2023

The Environmental (EVE) Sleeve: A Tool to Monitor the Environment for Hazardous Gases

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***Abstract*—This paper provides a tool to monitor the environment for hazardous gases. Having gas sensors to detect these dangers is a solution since hazardous gases are invisible to the naked eye. Current multi-gas sensors are expensive. Thus, an affordable and portable device needs to be procured. The Environmental (EVE) Sleeve presents a rudimentary response to these problems by using low-cost sensors connected to an Arduino board with a user-friendly interface. This project utilizes the MQ series gas sensors to provide readings to the user. Each of these sensors can detect different gases to determine if hazardous gases are present in the air. Comparing the voltages each sensor gives off and the Parts Per Million (ppm) values the sensor codes reads, the EVE Sleeve notifies the user of the more common hazardous gases in the air thereby allowing the user to vacate the area. This project can be extended to emergency and commercial use.**

Keywords—Health/Safety; Hazardous Gases; Arduino; MQ Sensors

I. INTRODUCTION

With the rise of industrial companies around the world, one major health concern for humans is air quality. What if there is a way to quickly identify environmental air quality in emergency situations? For example, first-responders may be unaware of the type of gas present when responding to a gas-related incident such as gas leaks and mass unexplained sickness. Industrial employees working in chemical plants or areas also encounter hazardous gases. Measuring air quality is extremely important in an ever-changing atmosphere like the Earth's [1]. High concentrations of some gases can prove to be dangerous to human health and safety [2]. The Environmental (EVE) Sleeve is a valuable solution to these problems. The EVE Sleeve is a wearable arm device that allows for constant monitoring of an environment to detect harmful gases such as Liquid Petroleum Gas (LPG), Carbon Monoxide (CO), Methane (CH4), and Dihydrogen Gas (H2) [3].

The EVE Sleeve utilizes low-cost sensors and a wearable "sleeve" to allow for quick readings of the environment. While gas sensors exist, there is not a cost-effective mobile device that allows the user to consistently monitor the environment for hazardous gases. In addition, the EVE Sleeve aims to provide a user-friendly interface through a Human Machine Interface (HMI) touchscreen display with easy-to-read dials. No prior understanding of the chemistry and math involved in deriving the Parts Per Million (ppm) levels of these harmful gases is required.

The remainder of this paper will outline similar projects to detect hazardous gases, the related research to the EVE Sleeve project, the implementation of the project, the process of developing EVE, and finally the results and future work of the project.

II. RELATED WORK

There are many ways to detect gases that one would consider detrimental to human health. There are a multitude of sensors on the market, and how they sense the gases also varies.

The Volatile Organic Compounds (VOC) project develops a mobile device for the detection of gas leaks. It implements the MQ series sensors by utilizing an unmanned ground vehicle to detect gas hazards from afar [4]. This mobile robot is also fitted with a device to detect the distance from gases, giving it the ability to pinpoint the location of the gas. While this was an impressive display of their sensors' uses, the application of their work is limited due to the vehicle's inability to maneuver in ways that are common for a human. For example, suppose there is a staircase in an environment that the machine is probing. This impassable obstacle is easily eliminated by placing the sensors in the hands of a capable human.

The VOC work is a great source for pursuing knowledge in gas safety. The EVE Sleeve project provides an alternative solution to detect hazardous gases. It utilizes low-cost sensors and a wearable sleeve to allow for quick readings of harmful gases.

III. IMPLEMENTATION

The EVE Sleeve project uses the MQ series gas sensors alongside a Nextion HMI touchscreen display. These main pieces are interfaced with an Arduino Uno Rev3 board [5]. The microcontroller board effectively runs all the sensors as well as a display screen.

Multiple sensors are chosen in order to give the project variety and stability. The MQ6 sensor shown in Fig. 1 detects Liquid Petroleum Gas (LPG), Methane (CH4), and Dihydrogen Gas (H2). The MQ7 sensor shown in Fig. 2 detects Dihydrogen Gas (H2) and Carbon Monoxide (CO). After additional research is conducted, we realize these two sensors are difficult to use together. Gas sensors are not recommended to be used simultaneously since there are many factors that affect accuracy. Specifically, the types of gases detected interfere with one another.

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Fig. 1. MQ6 Sensor detects LPG and CH4 gases

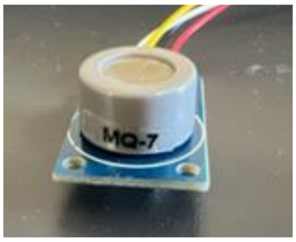

Fig. 2. MQ7 Sensor detects H2 and CO gases

It is worth noting that multiple sensors can detect the same types of gases. As seen in Fig. 3, the MQ6 sensor mainly detects LPG and CH4, but interferes with H2. The MQ7 sensor detects H2 and CO and does not interfere greatly with other gases. The MQ8 sensor (Fig. 4) detects H2 and does not interfere greatly with other gases. Finally, the MQ9 (Fig. 5) sensor detects CO and LPG but interferes with CH4. In order to use all of these sensors together, we need to decide on how to use these interferences rather than scraping the sensors altogether.

Gasses Detected and Sensor Interference

Sensor Name	MQ6	MQ7	MQ8	MQ9
Gasses Detected by the Sensor	LPG	H2	H2	CO
	CH4	CO		LPG
Gasses Which Interfere with the Sensor	H2			CH4
Gasses that Slightly Interfere with the Sensor	Alcohol, CO	LPG, CH4, Alcohol	Alcohol, LPG, CH4, CO	

Fig. 3. Analyzing the gases detected and sensor interference

Fig. 4. MQ8 Sensor detects H2 gas

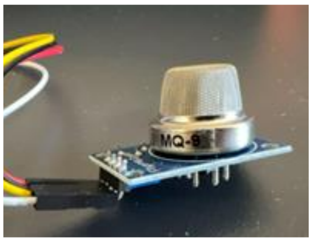

Fig. 5. MQ9 Sensor detects LPG and CO gases

The MQ series sensors are created with chemiresistor materials. Chemiresistors change based on a displacement in electrical resistance [6]. Molecules are absorbed on the surface, allowing for certain chemicals to be detected by the sensor. This is a common nanostructure for gas sensors [7]. The sensors measure resistance voltage, and that resistance changes based on the presence of specific gases.

Fig. 6, 7, 8, and 9 show the graphs provided by the gas sensor manufacturer, BONATECH. The X-axis describes the ppm levels of the target gas. The Y-axis describes the sensor resistance ratio (Rs/Ro), which is the Sensor Resistance (Rs) divided by the concentration of the gas at a certain ppm (Ro). The sensor resistance voltage is how the sensor is able to detect the presence of a harmful gas in the air. As the ppm level of the target gas increases, the Rs/Ro ratio decreases. The mathematical calculation of the Rs/Ro ratio is involved in producing an accurate reading from the sensors, even with the interference of other gases.

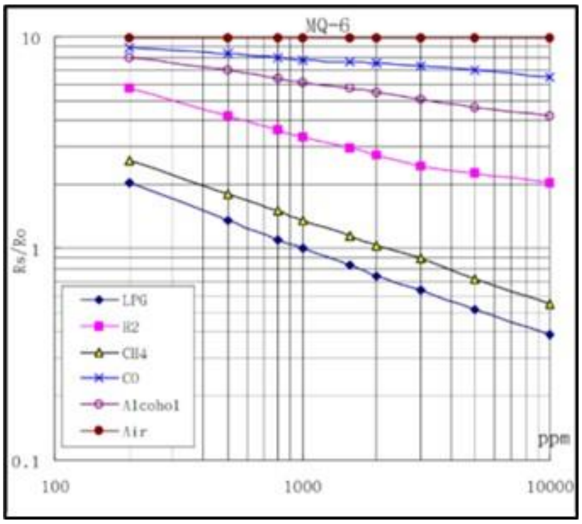

Fig. 6. MQ6 sensor graph provided by manufacturer

The curves closest to the bottom of each graph represent the gases that are most accurately detected by the sensor. The curves further up on the graph, separated from the bottom curves, represent the gases that interfere with the sensor. Every graph has an “air” curve that represents the Rs/Ro value of the sensor in clean air. MQ6 sensor detects LPG and CH4 more accurately than other gases from Fig. 6. Similarly, the remaining gas sensors are as follows: MQ7 for CO and H2, MQ8 for H2, and MQ9 for LPG and CO. Each graph also shows the detecting range of each of the sensors. For MQ6, the most accurate detecting range is 200 ppm to 10000 ppm. For MQ7, the most accurate detecting range is 50 ppm to 4000 ppm and for MQ8, 200 ppm to 10000 ppm. Finally, for MQ9, 200 ppm to 1000 ppm for CO, and 200 ppm to 10000 ppm for LPG and CH4 [4].

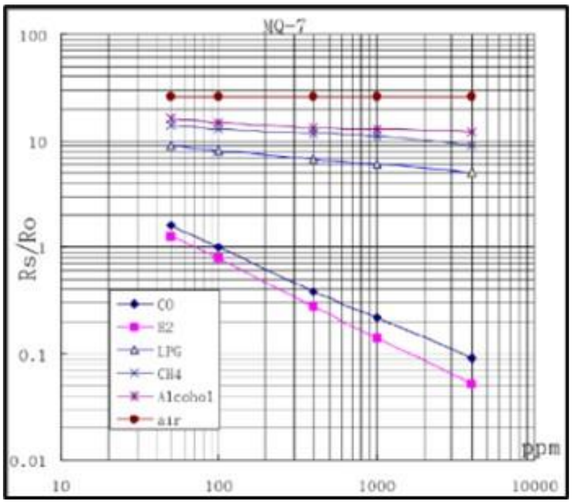

Fig. 7. MQ7 sensor graph provided by manufacturer

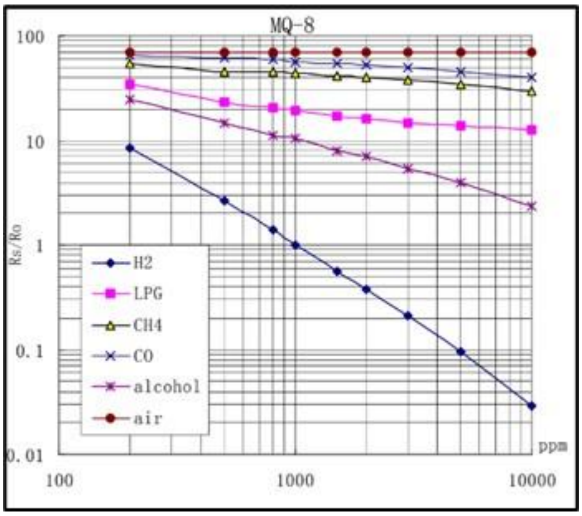

Fig. 8. MQ8 sensor graph provided by manufacturer

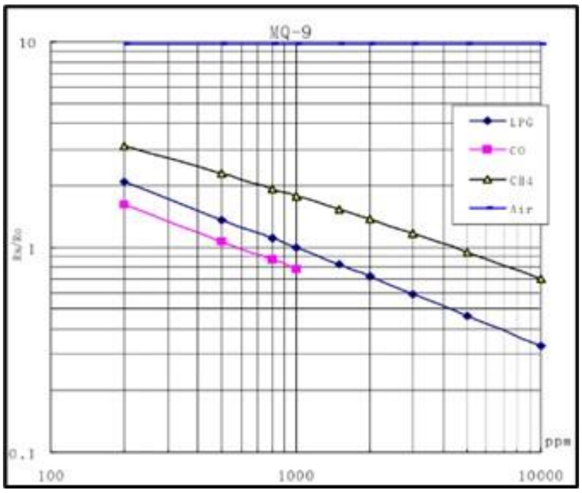

Fig. 9. MQ9 sensor graph provided by manufacturer

In order to deduce the accurate ppm values for each of the gases, the slope of the line given from the graphs must be calculated. In Fig. 10, the values read into the code are in the format: (log(x value), log(y value), slope of the approximate line). For example, the line for H2 must be deduced for Fig. 8. Two points on the curve are chosen and the log of those values is taken. Those values are then used to calculate the approximate slope of the line. This approximated line provides easier reading into the Arduino IDE software, allowing the EVE Sleeve to be interfaced with the Arduino board itself. The code reads in the approximate curve of the line and uses that to produce the ppm value based on the Rs/Ro ratio. For example, the three values for the H2 line for the MQ8 sensor are (3, 0, -1.5376). This is (log(1000), log(1), slope of the line deduced from two points on the graph). This same technique is used for the remaining three graphs. Approximate lines are created for each of the gases detected by each of the sensors.

Sensor	Gas	(x, y, slope)
MQ6	LPG	(3, 0, -0.4)
	CH4	(3.3, 0, -0.38)
	H2	(3, 0.518514, -0.252712)
MQ7	H2	(2, -0.09691, -0.757287)
	CO	(2, 0, -0.65276)
MQ8	H2	(3, 0, -1.5376)
MQ9	CO	(2.69897, 0.060698, -0.560087)
	LPG	(3, 0, -0.480273)
	CH4	(3, 0.255273, -0.110386)

Fig. 10. (x, y, slope) format for gases detected by each MQ sensor

It is important to acknowledge the difference between health and safety priorities. For some of the EVE Sleeve's sensors, health is the priority. Specifically, when measuring levels of LPG, CO, and CH4 shown in Fig. 11.

HAZARDOUS GASSES HEALTH AND SAFETY LEVELS (IN PPM)				
	SAFE	LOW	MED	HIGH
LPG	< 600 ppm	600 - 1000 ppm	1000-1500 ppm	> 1500 ppm
CO	< 30 ppm	30 - 50 ppm	50 - 100 ppm	> 100 ppm
H2	< 2050 ppm	2050 - 2870 ppm	2870 - 4100 ppm	> 4100 ppm
CH4	< 600 ppm	600 - 1000 ppm	1000-1500 ppm	> 1500 ppm

Fig. 11. Caution levels of Liquid Petroleum Gas (LPG), Carbon Monoxide (CO), Dihydrogen Gas (H2), and Methane (CH4) in parts per million (ppm)

For measuring H2, safety is the highest priority. The difference between health and safety in regard to the sensors is as follows: if human health is more negatively impacted by high concentrations of the gas, then health is the first priority. For example, when exposed to high concentrations of CO for an extended period of time, death is likely. While high concentrations of H_2 gas are also not ideal for human health, the threat to human safety supersedes the threat to human health. The lower explosive limit of H_2 in the air is 4100 ppm and greater. Weighing the difference in dangers to human health and safety proves to be vital for the production of the EVE Sleeve and understanding its purpose.

The sensors used for the EVE Sleeve are produced by a manufacturer and not created as part of the device's hardware, thereby necessitating the implementation of some of the setup code from an outside source, Circuits4You. The EVE Sleeve project implements five main functions: the MQ Calibration, the MQ Resistance Calculation, the MQ Resistance, the MQ Read, the MQ Get Gas Percentage, and the MQ Get PPM functions.

In order to yield the most accurate results, the sensors are required to calibrate individually, rather than taking a singular Ro value to use across the four sensors [8]. Ro value refers to the concentration of the gas at a certain ppm. To create replicable trials, EVE's calibration takes in 15 samples in 400 millisecond intervals. These 15 samples are then averaged to create the most accurate Ro value for each individual sensor. The MQ Calibration function brings in the Load Resistance (RL) value of each sensor, the analog pin that the sensor is plugged into, and the Ro value in clean air. The function effectively reads the raw value from the sensor through the analog pin of the Arduino board.

The equation to aid in finding the sensor's resistance (Rs value) is as follows:

$$Rs = RL(1023 - RA) / RA$$

Here, the Rs value refers to the sensor resistance. The RL refers to the load resistance of the sensor, which is $20k\Omega$ for MQ6, $10k\Omega$ for MQ7, $10k\Omega$ for MQ8, and $20k\Omega$ for MQ9. Both the MQ Resistance Calculation and the MQ Read functions work simultaneously to provide the Rs value. Like the MQ Calibration function, the MQ Resistance and MQ Read functions read in the raw Rs value from the sensor itself through the declared analog pin of the Arduino. The RA value refers to the raw Analog-to-digital conversion (ADC) value of the sensor when it is connected to a specific analog pin. The 1023 is derived from the 5V voltage of the sensor in clean air. This sets the base resistance of the sensor before it is exposed to hazardous gases.

The MQ Get Gas Percentage function works alongside the MQ Get PPM function to effectively obtain the ppm value of the gas that the sensor is detecting in the air [9]. The interferences between gases necessitates a way to cross reference the sensors to get the most accurate reading possible.

The final part of the coding process involves creating mathematical equations to allow the sensors to give valid readings. The equations to find the ppm values of LPG and CH_4 are similar to find the Rs value as follows:

$$\text{LPG ppm} = ((\text{MQ6 LPG} + \text{MQ9 LPG}) / 2) - (\text{MQ7 H2})$$

$$\text{CH4 ppm} = ((\text{MQ6 CH4} + \text{MQ9 CH4}) / 2) - (\text{MQ7 H2})$$

These equations are deduced by taking the average of the readings from both MQ6 and MQ9's LPG readings and subtracting the MQ7 reading of H_2, because the H_2 gas interferes with the ppm value of LPG. The next set of equations determines the ppm values of CO and H_2.

$$\text{CO ppm} = ((\text{MQ7 CO} + \text{MQ9 CO}) / 2) - ((\text{MQ6 LPG} + \text{MQ6 CH4}) / 2)$$

$$\text{H2 ppm} = ((\text{MQ7 H2} + \text{MQ8 H2}) / 2) - (\text{MQ9 CO})$$

Like finding LPG and CH_4 ppm values, the equations for CO and H_2 gases follow a similar procedure. The gas that interferes with the sensor is subtracted from the average ppm values of the target gas. This gives an accurate ppm value for each of the target gases.

In Fig. 12, the internal part of the EVE sleeve is interfaced with the Arduino UNO Rev3 shown in rightmost and the MQ series gas sensors shown in leftmost. These hardware components are connected using jumper cables.

Fig. 12. The internal part of the EVE Sleeve

In Fig. 13, The case was created using a 3D printer and the Nextion HMI touchscreen display.

Fig. 13. The top of the EVE Sleeve: Nextion HMI display and 3D printed case

The HMI touchscreen display that the EVE sleeve utilizes curates a simple and efficient manner of understanding the presence of harmful gases. The display essentially eliminates the need for prior knowledge of Occupational Safety and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 10, October-2023

Health Administration (OSHA) requirements for sustained exposure to harmful gases, since the dial has colors to indicate safe, slightly above average, above average, and dangerous levels of the detectable gases.

IV. EVALUATION

The Environmental (EVE) Sleeve presents a rudimentary tool to detect harmful gases by using low-cost sensors connected to an Arduino board with a user-friendly interface. With limited access to chemical materials to test the hazardous gases, the EVE could not effectively be tested in high concentrations of the gases it serves to detect. Unfortunately, to test the device in a manner that would (1) yield the desired results, (2) safely allow the participants of the project to interact with hazardous gases, and (3) be re-testable in the occurrence of later production, the EVE product team would need access to expensive and not readily available resources. A controlled environment with continuous air flow to create an artificial “clean air” environment would be needed. Then, a controlled environment containing a known ppm of LPG, CH_4, CO, and H_2 gases would need to be created. Access to a working gas sensor, which are extremely expensive, would need to be utilized [10]. Therefore, the accuracy of the sensors relies on the presumption that the manufacturer correctly produced their product [11]. However, there were some tests that were able to be performed to prove the accuracy of the gas sensors.

The gas sensors were tested in different locations to determine whether the ppm values were accurate. Readings were taken in four different locations, two of which were indoors and two of which were outdoors. The ppm fluctuated a reasonable amount and remained within a normal and safe range for each of the four gases being monitored.

V. CONCLUSION AND FUTURE WORK

The Environmental (EVE) Sleeve provides a wearable mobile device that allows for constant monitoring for hazardous gases in the air. The importance of a mobile gas sensor device lies in the ability for real-time updates in potentially dangerous situations regarding high concentrations of harmful gases. In the future iterations, the sensors will need to be upgraded. There are better sensors available that are more capable and align better with the goals of the EVE. Furthermore, interchangeable sensors would be a necessary feature for the EVE. Ideally, users will be able to switch out sensors based on situational relevance. Ultimately, as the EVE Sleeve progresses, its outreach could stretch from first responders and the public to companies interested in exploring space or unnavigated environments.

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