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Comprehensive Integration and Implementation of Air Quality Monitoring Technology for Respiratory Health in Cardiovascular and Asthmatic Individuals

[1]Jillella Sowmya,[2]Gajjala Venugopal Reddy,[3]Chavan Tharun,[4]heena Begum,[5]G.JoySangeethRaj,

[1,2,3,4] Student,Department of ECE,Narsimha Reddy Engineering College,Misammaguda(V),Kompally-500100,Telangana State,India.
[5] Assistant Professor,Department of ECE,Narsimha Reddy Engineering College,Misammaguda(V),Kompally-500100,Telangana State,India.

Abstract

Air pollution, which harms people's lungs and overall health, is a major problem in the modern world. Charcoal, methane, carbon dioxide, ammonia, and sulfur and nitrogen oxides are some of the dangerous gases emitted by inefficient combustion of agricultural waste and overuse of unconditioned cars. Humans are susceptible to respiratory and cardiovascular illnesses brought on by these contaminants. An IoT-based smart air pollution monitoring system was created to detect air quality and alert people when concentrations surpass safe limits, in accordance with the recommendations of credible sources, in order to tackle this problem. Microcontroller boards like Arduino Uno and ESP32 are used in this system, together with portable gas sensors (MQ2 for smoke and flammable gases like butane and methane, and MQ135 for ammonia, benzene, carbon dioxide, and other dangerous gases). An LCD shows the gas concentration, and data from the sensors is sent to a website using the ESP32 Wi-Fi module. When levels are too high, a bell goes out to let others know. Results from testing the proposed technology to determine gas concentrations in an indoor setting and the associated concentration values are detailed here. It is also possible to expand the system for use in mining and industrial regions with high levels of air pollution. The risk of hospitalization from cardiovascular disease increases by 0.96 percent for individuals over the age of 65 for every hour of exposure to carbon monoxide, according to A.L.N. Sri Datta of the Electronics and Communication Engineering department at Chaitanya Bharthi Institute of Technology in Hyderabad, India (dattaannavarapu9@gmail.com). There was a 6% spike in the hospitalization of non-elderly asthmatic persons when there was 3-7 ppm of carbon monoxide in the air. Individuals with cardiovascular disease or asthma greatly benefit from accurate gas level monitoring systems. Occupational Safety and Health Administration (OSHA) research indicates that at concentrations of 15,000 ppm of CO_2, a small number of persons may experience minor respiratory stimulation. Ammonia may aggravate respiratory issues in certain people and has an OSHA-specified maximum concentration threshold of 5 ppm; it also causes allergies similar to asthma. According to Cincinelli et al. in Indoor Air Quality and Health, there is a potential danger to IAQ due to the impact of outside pollution levels and penetration rates on the concentrations to which people are exposed while inside [1].

Keywords— Air quality monitoring, Gas detectors, parts per million(ppm), Respiratory Health, IoT (Internet of Things)

INTRODUCTION

To put it simply, human health and existence depend on air quality. Air pollution and the release of toxic chemicals into the environment have been steadily worsening air quality in recent years. Keeping the amounts of different gases in the air within acceptable ranges is critical, hence keeping an eye on their presence is essential. People with asthma and heart issues are particularly vulnerable to air pollution, but all living things are at risk when there are too many contaminants in the air. There has been a 1 ppm increase in the maximum daily concentration of pollutants discussed in relation to indoor air pollution in developing nations and acute lower respiratory infections in children. The risks of indoor air pollution appear to be particularly high in homes that use biomass fuels, likely as a result of the high concentrations of pollutants present in these settings and the fact that young children spend a lot of time with their mothers while they cook [2]. Using cloud platforms such as Think Speak and raspberry pi, Sivasankari B et al. [3] created an air quality system. Nonetheless, by keeping a homepage and interacting over several protocols, this system avoids the need of cloud-based platforms. Indoor air pollution may be responsible for almost 2 million preventable deaths in poor countries and 4 percent of the global disease rate, according to a 2000 study by Bruce, Perez et al. titled "Indoor air pollution in developing countries" [4].

It is now much simpler to keep tabs on the air quality around us because to the proliferation of sensors. By using the benefits of the Internet of Things, gas concentrations may be monitored and presented to the user in an intuitive manner. An accurate strategy for preventing and controlling pollution using data collected from telecom operators was developed by Chao et al., 2019. It offers a research on identifying and avoiding the sources of pollution and primarily addresses the issue of pollution control in China [5]. A "Survey on Air Pollution Monitoring, Challenges and Applications" [6] was created by Jiyal et al. in 2022. The main objective was to track urban air quality using sensors installed in streetlights. Instead than focusing on developing a product to improve respiratory health, this article aims to assist in monitoring environmental air quality so that appropriate measures may be taken. Using GSM wireless communication, Phala et al. (2016) developed a system to monitor air quality [7]. Individuals with respiratory issues are the target audience for this work, which employs serial communication protocols and Wi-Fi wireless connectivity for data transmission. An "IoT enabled environmental monitoring system for smart cities" [8] was created by Shah and Mishra in 2016. Mostly, it measures humidity, temperature, and carbon dioxide. A method for monitoring air pollution in major cities was created by Raipure and Mehetre in 2015 and is called "Wireless sensor network-based pollution monitoring system in metropolitan cities" [9]. A low-cost air pollution monitoring system based on the IEEE 1451 standard was developed by Sudantha Kularatna in 2008 [10]. Nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO) levels are also tracked by it. It does this by making use of many gas detectors. A study by Ramesh Bhat et al. [11] looked at the link between indoor air pollution and diseases of the lower respiratory tract. Research into these effects has progressed, and it is now possible to examine how different gases interact with one another. In contrast to the aforementioned works, this one describes an air quality monitoring system tailored specifically to the needs of people with cardiovascular disease and asthma. The simple design and manufacturing of this device make it very inexpensive when compared to other monitoring systems. The data is collected by the system's sensors and sent efficiently using serial communication protocols.

Methodological Strategy

Creating an inexpensive tool to monitor environmental quality is something that Tiele et al. have thought about [12]. When it comes to keeping tabs on air quality, this device really shines. Using inexpensive microcontroller boards and gas sensors like the MQ-2 and MQ-135, the system is put into action. There are four main components to the suggested air quality monitoring system: sensors, microcontroller boards, display, and user alert. In Figure 1 we can see the schematic of the planned system that would show how the air quality works.

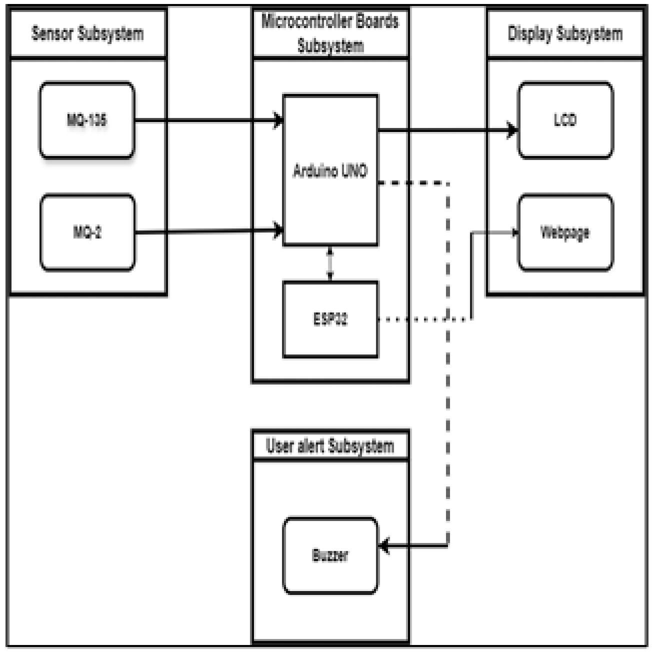

Fig. 1. A block diagram demonstrating the mechanism for monitoring air quality

Microcontroller Boards Subsystem

The ESP32 and Arduino UNO make up the microcontroller subsystem. One of the main components of the Arduino UNO board is the ATmega328P microprocessor. Because of its user-friendliness and durability, it finds widespread use. ESP32: Unlike the Arduino UNO, this inexpensive microcontroller board doesn't need an additional Wi-Fi module to function as a web server. B. Subsystem for Sensors The MQ135 and MQ2 gas sensors are part of the sensor subsystem. Smoke, ammonia (NH3), sulfur (S), benzene (C6H6), CO2, and other dangerous gases may be detected by the MQ135 gas detector. In this study, the quantities of ammonia (NH3) and carbon dioxide (CO2) are determined using MQ135. When it comes to air quality monitoring, this semiconductor air quality check sensor is perfect. Sensor for MQ2 Gas: Gas detectors like the MQ-2 can detect a wide variety of substances in the air, such as hydrogen, carbon monoxide, alcohol, smoke, propane, LPG, and methane. It works in a way that is comparable to MQ135. Using MQ2, the quantities of smoke, carbon monoxide, and methane were measured in this study. C. Subsystem for Display The liquid crystal display (LCD) and the web site hosted by the ESP32 make up the display subsystem. D. Warning System for Users The Buzzer is a part of the user alert subsystem; it rings if the gaseous concentrations go above what is safe for those with cardiovascular disease or asthma. The sensor subsystem's raw data is collected using an Arduino UNO. The data from the sensors is processed and converted to parts per Liquid Crystal Display (LCD) in the display subsystem from an acquired voltage level. Next, the data from the sensors is sent to the ESP32 over serial connection. A web site displaying the sensor data back to the end user is hosted by the ESP32, which is also serving as a webserver. Additionally, in the event that any of the measured gas concentrations above the threshold considered safe for patients with cardiovascular disease or asthma, the Arduino UNO will notify the user using the alert subsystem. The sensor subsystem was easily integrated using an Arduino Uno, while built-in Wi-Fi compatibility was implemented using an ESP32.

METHODOLOGY

Figure 2 shows the steps taken to put the suggested air quality monitoring system into action. It explains everything about the system's inner workings in detail.

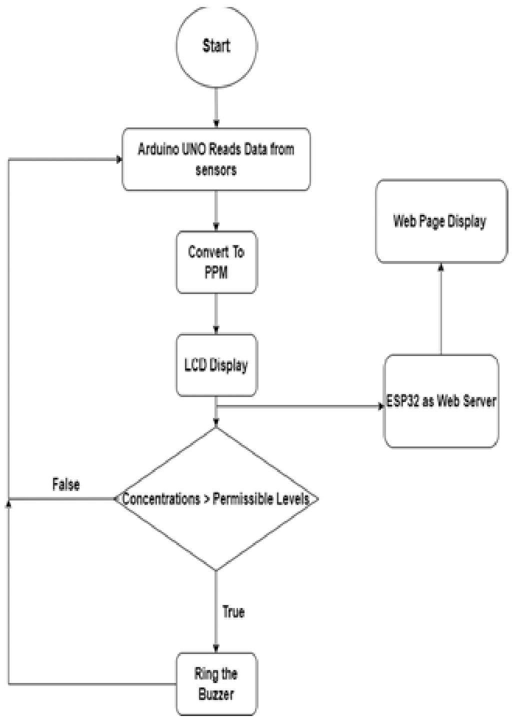

Fig. 2. Methodology for implementation of Air Quality Monitoring System

A link is established by supposing a linear relationship between the logarithmic scale of the ratio of resistances to concentrations in ppm as shown on the data sheet. Two resistors connected in series make up the circuitry of a MQ. The ppm value computation formula is

$$I = V_C/(R_S+R_L) \quad (1)$$

$$R_S = [(V_C*R_L)/V_{RL}]-R_L \quad (2)$$

$$R_S/R_0 = 4.4ppm \quad (3)$$

$$\log10(R_S/R_0) = m*\log(ppm)+b \quad (4)$$

$$ppm = 10\text{^}([\log10(R_S/R_0)-b]/m) \quad (5)$$

where,

V_C is the supply voltage in the internal diagram of sensor

R_S is the resistance of gas sensor in presence of specific gas

R_L is the external load resistance

V_{RL} is the voltage across the load resistance

R_0 is the resistance of sensor in clean air

b is intercept of the curve

m is slope of the curve

The Arduino UNO takes raw data from gas sensors and analyzes it to get parts per million. It has an LCD connection. The gas concentration data in parts per million are now shown on both the LCD panel and the Serial Monitor. From Arduino UNO, processed sensor data is sent to ESP32. The Serial Communication protocols are used for this purpose. Since there are only a few wires needed to link the two microcontroller boards in a serial communication setup, it takes up less room. The Soft Access Point (SAP) mode is used to run the ESP32. When operating in SAP mode, the ESP32 takes on the role of the network hub, connecting various external devices. Assigning IP addresses to clients is its primary function, much like a home router. Since ESP32 is the node at the heart of the network, running it in SAP mode guarantees that the website will continue to operate even if there is no external network. The front end development of websites makes use of Cascading Style Sheets (CSS), Vanilla JavaScript (JS), and Hyper Text Markup Language (HTML). As a web server, ESP32 is responsible for hosting this website. Additionally, the ESP32 constantly monitors the site and modifies its settings accordingly. When you reload the site, you can see the data from the sensors. The programmed action is for the ESP32 to compare the gas concentrations sent by the Arduino UNO with the acceptable values acquired from OSHA after the former has sent the data. In order to prevent respiratory issues, the amounts of the gases stated in Table-1 below are considered acceptable.

TABLE I.

Name of Gas	Permissible Concentration (ppm)
Carbon Dioxide (CO2)	12000 ppm
Carbon Monoxide (CO)	7 ppm
Ammonia (NH3)	5 ppm
Methane (CH4)	100 ppm

When any of the designated gases is detected in high concentrations, the programmed buzzer (Piezo Speaker) will sound an alarm, allowing the user to take the appropriate safety measures.

HARDWARE IMPLEMENTATION

To monitor the air quality within buildings in real time, Kim JY et al. [13] suggested an integrated sensor system. An interactive website has been created to showcase the results of a sensor-based system that has been put into place. The gas sensors, LCD, and buzzer connections are shown in Fig. 3, which also includes the microcontroller boards. The microcontroller subsystem's Arduino receives the analogue outputs from the two sensors, and the LCD is also linked to it. The serial connection pins on the ESP32 have been linked to the ones on the Arduino.

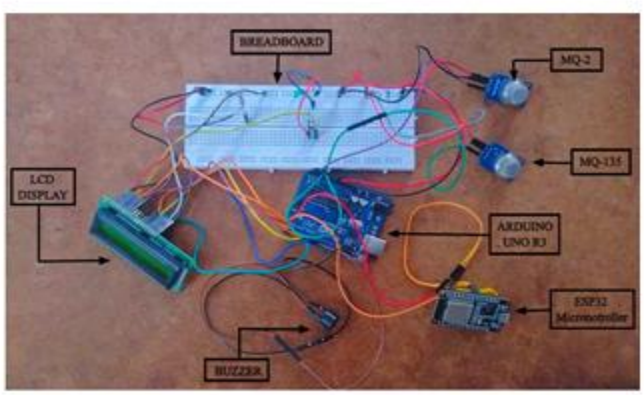

Fig. 3. Hardware Implementation

Following the two sensors' recommended pre-heating time—roughly equivalent to 24 hours—the data from the sensors is computed. The display subsystem then shows the measured gas concentrations within a room in a residential environment. The next part delves into the discussion of the collected outcomes of the aforementioned experiment.

RESULTS AND DISCUSSIONS

We compare the data obtained from the MQ135 and MQ2 sensors to the allowable gas concentrations. The data collected from the sensors is shown on the LCD screen first, and then exported to show on the website.

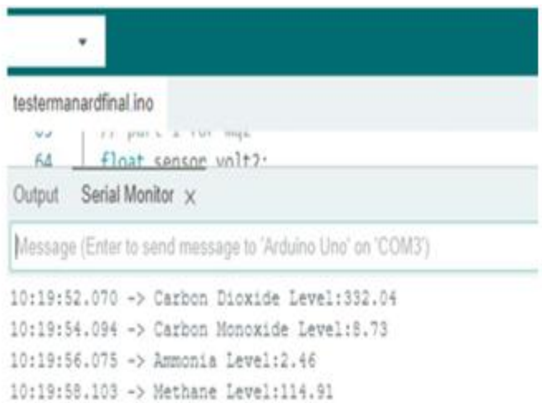

Fig. 4. Sensor data on Serial monitor

The serial monitor seen in Figure 4 displays the sensor data. The data is then exhibited on an LCD, as seen in Figures 5, 6, 7, and 8. You may access the serial monitor with the Arduino IDE. Indoors, we measured 332 ppm of CO2, which is much lower than the allowable values (see Fig. 5). The acceptable level of CO_2 is around 12,000 parts per million, as shown in Table 1. This proves that CO2 has no negative impact when used inside.

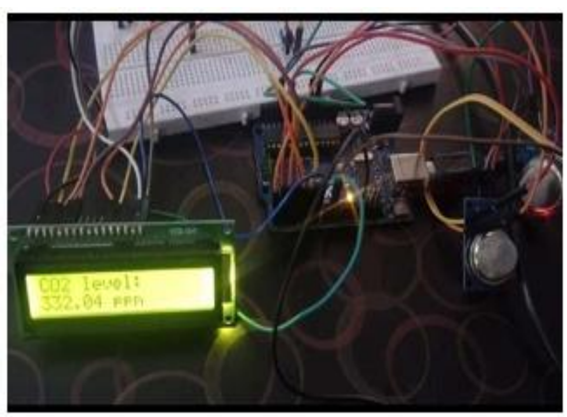

Figure 6 shows that an indoor environment had a concentration of 114 parts per million of methane (CH4). Table-1 indicated that the allowable quantity of methane should be approximately 100 ppm.

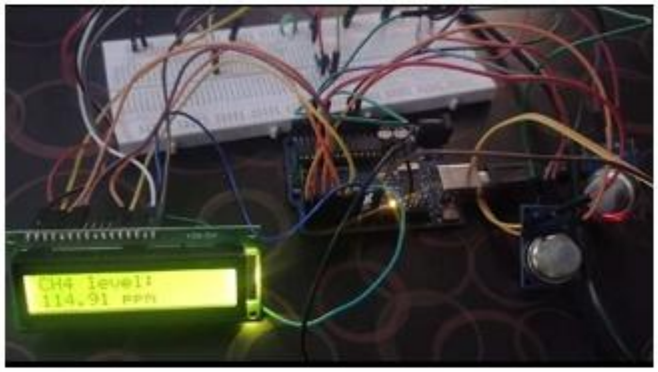

Fig. 6. Methane Concentration in indoor conditions

Indoor air pollution levels of 8.73 ppm of carbon monoxide have been found, which might be detrimental to people's respiratory health if they are exposed to it over an extended period of time. Carbon monoxide levels below 7 parts per million are not dangerous to humans, according to Table 1.

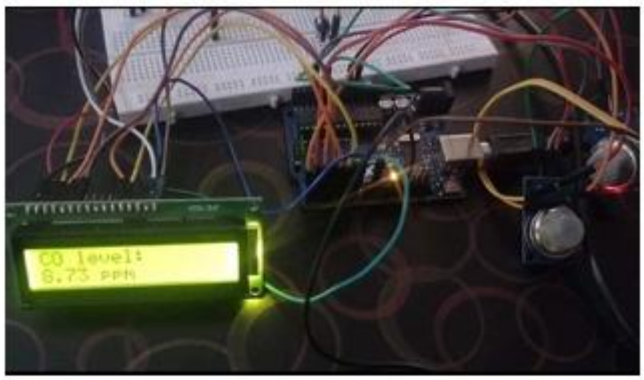

Fig. 7. CO Concentration in indoor conditions Ammonia (NH3):

The testing room contains levels of ammonia that may not harm an individual's respiratory health, as this system measured 2.46 ppm of ammonia. Table-1 shows that the optimal allowable amount of ammonia is close to 5 ppm.

Fig. 8. Ammonia Concentration in indoor environment

At the same time, these values are compared to atmospheric allowable gaseous concentrations to see if the observed readings would raise the risk of hospitalization for those with respiratory disorders. As shown in Figure 9, the data from the sensors is sent from the LCD to the ESP32 via serial connection and then exhibited on the website hosted by the latter.

CONCLUSIONS

In this article, we provide the results of an interior air quality test that we conducted using our custom-built Air Quality Monitoring System. We started by putting the system's gas sensors through their paces with CO2, CO, NH3, and CH4. We have also measured gas concentrations in a number of settings, such as parks and industrial sites, to determine the system's potential applications. We continued by bringing the setup inside to measure the levels of the aforementioned gasses. Based on our findings, the levels of carbon monoxide and methane in the living space exceed the recommended safe threshold, which is undesirable. Further improvements may be made by identifying the activities that impact indoor air quality in different rooms of a home and quantifying the resulting effects on each room, as described by Hegde et al. [14]. According to research by Graudenz GS et al., the system may be utilized to test its effects in both closed and open-ventilated buildings [15]. Better indoor air quality may be possible with the integration of this system with home automation systems, which might pave the way for the creation of automatic ventilation controls.

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