Application of MQ-Sensors to Indoor Air Quality Monitoring in Lab based on IoT

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Abstract— Air pollution levels have been rising around the world in recent years. Long-term pollution exposure causes a variety of ailments, including lung disease, heart disease, and eye irritation. The term "indoor air quality" refers to the building's residents' air quality. Physical variables, chemical or gaseous pollutants, and biological factors. Toxic gases are likely to be present in any laboratory where experiments or research are carried out. These contaminants can harm the health of the people that are working there, and the important work that is being done in this environment remains unaffected. A web-based system for indoor air quality monitoring in lab IAQML is presented in this study. The project was established to keep track of air quality metrics in the lab environment like carbon dioxide, carbon monoxide, alcohol, phenol, toluene, LPG, benzene, ammonia, and methane, if not properly maintained, this can have an impact on the inhabitants' comfort, health, and indoor working conditions. In general, the proposed method involves a selection of metal oxide MQ-sensors, and a Wi-Fi module connected to an Arduino microcontroller. The measured data from sensors is calculated in ppm units and then displayed on the Android device. Also, gas data is sent to the webpage through the ThingSpeak platform dashboard. The system has a notification function to alert students and workers in the laboratory when measurements of air quality are above or below specified thresholds. On the other hand, this allows for a well-controlled and maintained the quality standard for indoor air pollutants.

Keywords—MQ-Sensor, Indoor air quality, Arduino, IoT, Air pollutants

I. INTRODUCTION

Air quality plays a significant role in ecosystems, the climate and health [1, 2]. Air pollution can be defined as the presence of one or more biological, chemical, and physical contaminants in the air that might harm human and animal health, as well as disrupt aesthetics and comfort, or cause property damage. Indoor air pollution can affect human health as badly as air pollution in open spaces. Both human health and the environment are affected by air pollutants. When air pollutant concentrations increase, this world and the living things there can be fatal [2].

Air pollutants can be divided into two categories, namely, primary contaminants and secondary contaminants. Primary air contaminants are polluting elements directly generated by air contamination sources. Because it is produced by combustion, carbon monoxide (CO) is an example of a primary air pollutant. Secondary contaminants are created when main pollutants react in the atmosphere. Photochemical smog produces ozone, which is one example of secondary air contamination. [3].

The following are types of air pollutants (pollutants): Carbon Monoxide CO_2, Nitrogen Oxides NO_x, Sulfur dioxide SO_2, Ozone O_3, Hydrocarbons, Volatile Organic Compounds VOC and Suspended Particulates. These are some of the contaminants that have caused environmental disasters and diseases [4]. The term "indoor air quality" refers to the state of the air bad or good content inside a building (residence, hospital, lab) that can impact the occupants' health, comfort, performance, and physical reactions. Better indoor air quality is known as chemical (gaze) or biological (bacteria and fungi) or physical contaminants such as dust and the concentration of air pollutants in a building does not exceed the environmental threshold [5, 6].

The modern Internet of Things (IoT) technologies can access information about the availability of indoor air quality monitoring in a lab (IAQML) in real-time by using Wireless Sensor Networks (WSN)-based monitoring systems .

The proposed method includes the measurement of the IAQML content at the University of Baghdad-Environmental Engineering Laboratory for the detection and monitoring of pollutants. This measuring instrument uses reliable and cost-effective MQ sensors. The sensors used in our mathematical background were established while the raw data was converted into ppm units. The output from these sensors will be sent to the Arduino microcontroller to be processed and then used to control gases that have been set up remotely based on IoT that is transferred to the LCD reading, mobile app and air quality condition on a computer. Therefore, the method contributes to the safety of lab researchers and employers by warning them of gas release in the laboratory.

II. MATERIAL AND METHOD

A- Architecture of IAQML

The implementation device was conducted at the University of Baghdad, Environmental engineering laboratories, Iraq in March 2021. The proposed method involves MQ gas sensors that are used to monitor air quality. The sensors linked to the Arduino Uno board generate data continually in real-time while the Arduino microcontroller is powered on. The data, after processing by using a microcontroller, can send the concentration of each pollutant

in the ppm unit to an Android phone application and a message about the air quality level by using a Wi-Fi module connected to an Arduino for observing air quality in the lab. At the same time, the Wi-Fi unit will send the data to the ThingSpeak platform for drawing the data with time for each pollutant to know the maximum and minimum concentration of each of them in the laboratory. The system gives an alarm sound after the air quality exceeds a specific number by using an active buzzer module and running light according to the level of damage by using RGB led. To transfer gas value to the mobile application, using the Android mobile Wi-Fi network, the user would simply connect to our phone and the RemoteXY application to interface with the Arduino to transmit data. The data consists primarily of air pollution intensity concentration. Higher readings imply more contaminants in the air and vice versa. Fig. 1 depicts a block diagram of the entire system.
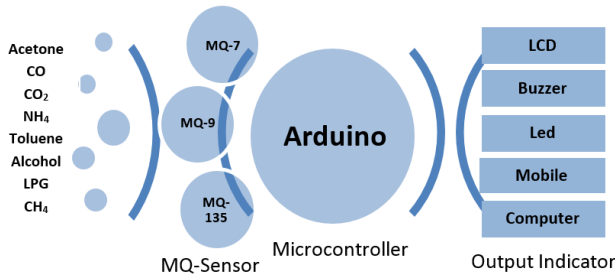

Fig. 1. The block diagram of IAQML.

The function of using an MQ- sensor connected with Arduino and display on the web and phone is that, nowadays, were easily accessible and inexpensive. It is affordable to anyone with a limited budget (less than $100). The sensors that have been employed are also highly convenient and changeable. Furthermore, all of the components were chosen because they are user-friendly and can be utilized and understood by people of all ages.

B- MQ gas sensors

A tiny AL_2O_3 ceramic tube serves as the structure and arrangement of the MQ sensors developed by Figaro Ltd. A plastic and stainless steel net crust hold the tin dioxide sensitive layer, measurement electrode, and heater. The heater creates the ideal environment for working on delicate components. The MQ gas sensors module has a digital pin that allows the sensor to work without a microcontroller, which is useful when simply trying to detect one type of gas. [7], to quantity the contaminant gas in ppm units, the analogue pin needs to be utilized. The analogue TTL is powered by 5 volts and may thus be utilized with the majority of microcontrollers [3]. The structure of the MQ sensor is shown in Fig. 2.
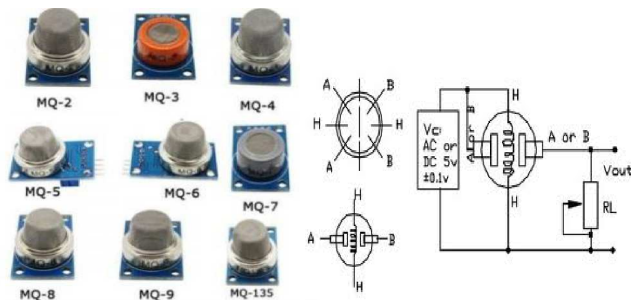

Fig. 2. MQ sensors type and structure [7]

In this proposed method in the IAQML system, three MQ sensors, MQ7, MQ9, and MQ135 are amongst the gas

sensors. They were used to measure and monitor the amount of gases and pollutants in the laboratory. Table 1 shows the specifications of each of the sensors used [8-10].

C- Components used and the hardware scheme

The device's hardware comprises of three sensors, including MQ-7, MQ-9, MQ-135, Wi-Fi module (ESP8266), graphic LCD, active buzzer, RGB led, and Arduino Uno board and micro USB charger module with a 2500 amp 3.7-volt battery. The device system detects contaminants in the air and creates real-time data that can be seen via the Wi-Fi module on a web browser or an Android mobile.

TABLE 1 MQ sensor specification used in IAQML [8- 10]

Sensor	Parameter	Technical Condition	Description
MQ-7	Circuit Voltage Heating Voltage	5V ± 0.1	AC or DC
	Load Resistance	Adjustable	
	Heater Resistance	33 Ω ± 5%	Room temperature
	Measuring Range	20-2000 ppm CO	
MQ-135	Circuit Voltage Heating Voltage	5V ± 0.1	AC or DC
	Load Resistance	Adjustable	
	Heater Resistance	33 Ω ± 5%	Room temperature
	Measuring Range	10-300 ppm NH_3 10-1000ppm of Benzene 10-300 ppm of Alcohol	
MQ-9	Circuit Voltage Heating Voltage	5V ± 0.1 5V ± 0.1	AC or DC High AC or DC Low
	Load Resistance	Adjustable	
	Heater Resistance	31 Ω ± 3Ω	Room temperature
	Measuring Range	10-1000ppm CO 100-10000ppm combustible gas	

The proposed method primary schematic is depicted below, with the interfaces among the main components shown in Fig. 3. The LCD was interfaced with the Microcontroller Uno board, and the output data pins of the specific MQ-sensors were linked up with the Microcontroller board's analogue input pins to deliver the analogue signals generated by the sensors as a result of the interaction of the emissions in the lab with the chemical layer, and then the data was sent to the ThingSpeak webpage using a Wi-Fi module. It also contains a buzzer that sounds when air quality levels exceed 200 parts per million [11]. With the use of a USB cable, the proposed device can be powered via a 9V DC power source. When the device turns on, it automatically senses and shows the output values of detected gases at a continuous time interval of 0.1 seconds.
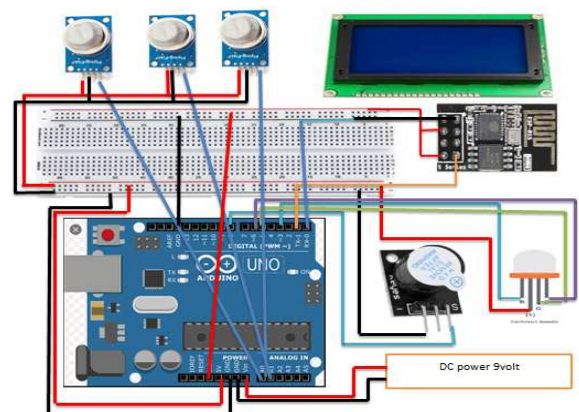

Fig. 3. System Architecture for IAQML

D- System Flowchart

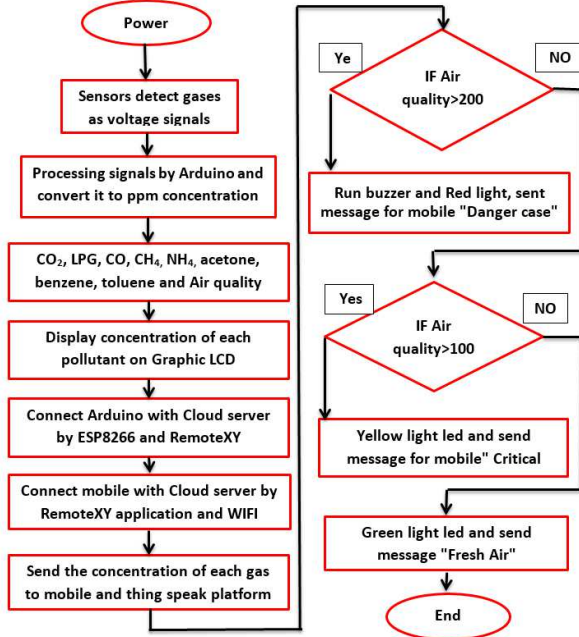The system will perform a continuous reading. The flowchart of the IAQML proposed method is shown in Fig. 4.

Fig. 4. The algorithm of the proposed method for IAQML

E- Implementation and IAQML procedure

When the system is turned on, the sensor will make continuous readings. If the sensor system detects the presence of gases at a certain value, the system will output and display the value on the graphic LCD and send the value to the android mobile and ThinkSpeak platform [12]. When the sensor detects a high air quality value that has passed the threshold value in the lab (greater than 200ppm) [13], the system sends a hazard case.

The Arduino board system sends a "danger case" to the Android mobile application. The buzzer will sound and the red light will activate. Otherwise, if the air quality has passed the critical value (greater than 100ppm), the system sends "Critical case" to the Android mobile application. The yellow light activates. When the sensor detects a low air quality value in the lab (lower than 100ppm), the condition is in a fresh case. The system sends a "fresh case" to the Android mobile application, and the green light activates. However, if the system status returns to a "danger case", the buzzer will be able to sound again.

Each sensor node must be calibrated separately to achieve acceptable accuracy. Because inexpensive sensors typically have substantial parameter tolerances, this calibration process is required. This explains why different samples with the same sensor type will have distinct gas response curves. As indicated in the datasheet of each sensor, all of the sensors to be employed are sensitive types, and their responses are almost linear in the log plot. Equation (1) can be used to compute the gas concentration [5, 14-16].

$$\log c = K_1 \log R_s + K_2 \qquad (1)$$

The gas concentration is denoted by C. Sensor resistance is denoted by Rs .The constants K_1 and K_2 are dependent on the MQ sensor type. The sensor gives only one reading at a time, so to convert it to multi concentration by using the logarithmic slope relation for every graph in the datasheet after choosing two points in the graph as shown in Fig. 5.
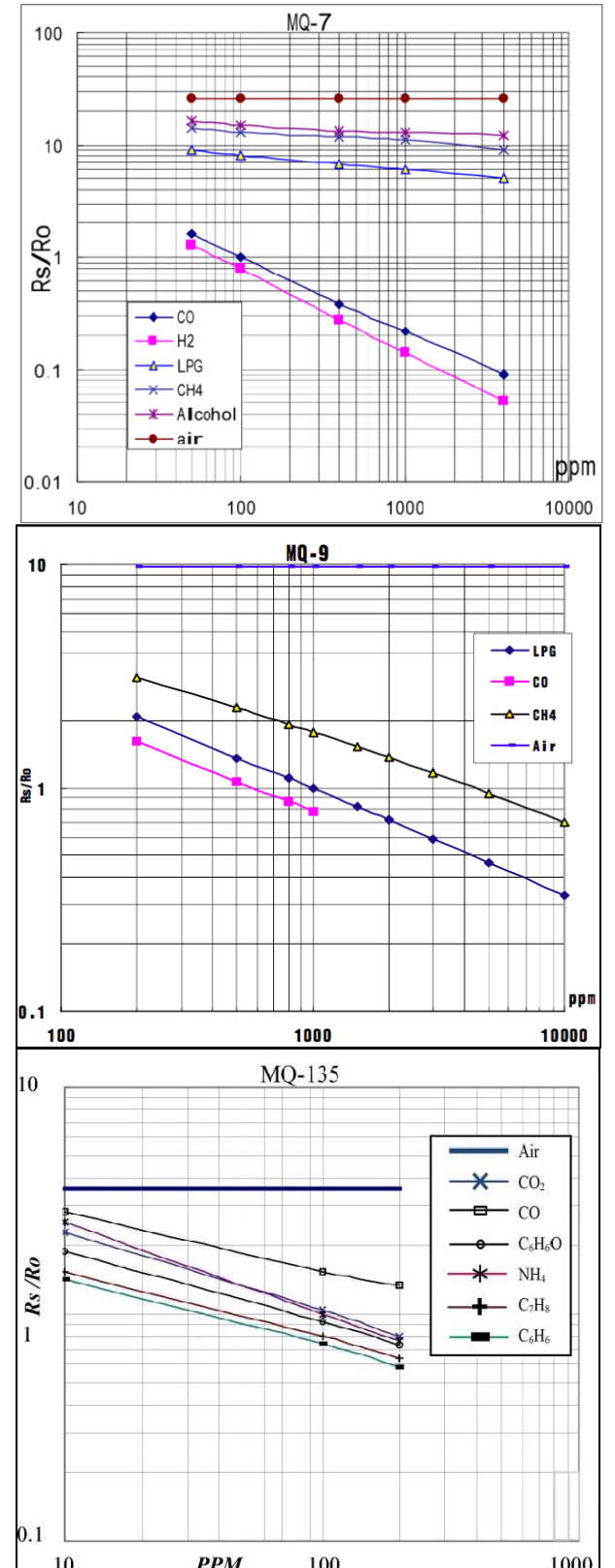

Fig. 5. MQ-sensor (MQ-7, MQ-9 and MQ-135) configuration chart for multi-gases detected [8-10]

As an example of calculating concentration equations as in (2) and (3) respectively.

$$Log (CO_2) = \frac{1.717 - log(ratio)}{0.366} \qquad (2)$$

$$Log (NH_4) = \frac{1.877 - log(ratio)}{0.4} \qquad (3)$$

III. RESULTS AND ANALYSIS

The proposed method of IAQML consists of MQ-sensors providing an alarm system that has been tested and successfully implemented in the Environmental Engineering research lab to collect gases and air quality data. As a testbed for the device, a research lab was used. This lab belongs to the University of Baghdad, which is located in the central region of Iraq. The results have been continuously monitored via the MQ sensors that can detect any of these polluted gases in an indoor atmosphere. As presented in Fig. 6, the output reading concentration of carbon dioxide (CO_2), carbon monoxide (CO_2), alcohol (C_2H_5OH), phenol (C_6H_6O), toluene (C_7H_8), LPG (C_3H_8), benzene (C_6H_6), ammonia (NH_4), methane (CH_4), and air quality that are present in the air of the lab are shown and displayed using the LCD output and the result sent to mobile using RemoteXY application for connecting between Arduino and Android mobile application.

Fig. 6. Display of IAQML output on LCD and mobile

Air pollution data was collected to analyze the test concentration trend of the implementation of the IAQML that was successfully obtained on the ThingSpeak platform API dashboard after the data had been preprocessed and was visible on the webpage. On the web page, ThingSpeak needs a 15-second refresh interval to push the data. Fig. 7 shows the field charts of sensors values for the lab where the experiment was conducted in ppm unit. It also shows the graphical graph for corresponding sensors collected with time stamping on the X-axis and air quality with ppm units on the Y-axis for carbon dioxide and carbon monoxide for every 100 seconds. Information about research lab gases that are being measured by the system can be read and viewed. For the user, this information is vital to be more aware of the air around them. This is especially true for the occupants, students, and researchers in the lab. In the event of a fire or a gas leak, it can also be helpful.

From the present test of the IAQML system, laboratory contaminant gas levels are below acceptable levels. Where the nodes are deployed, for example, CO_2 concentrations are in the range of 450–800 ppm. This is below the maximum exposure limit of 1000 ppm for a continuous eight-hour exposure [14]. Therefore, it is considered harmless for students or researchers to work in a lab. Besides these concentrations of CO_2, it is observed that the concentration of CO reached a maximum value of 51 ppm during the test, compared to the maximum exposure for an eight-hour workday specified by OSHA, 35 ppm [14], due to the use of furnaces in some experiments by workers and researchers in the competent.

Fig. 7. The ThinkSpeak output in the lab for real-time.

Also, it is observed that the concentration of air quality and contaminants gases is high in the environmental (chemical) lab compared to other rooms in the department due to many chemical compounds being vaporized in the lab area under normal environments. There are already gases and chemical sinks, where washes beakers of chemicals, and use furnaces, which result in a high concentration of contaminated gas in the air of the lab, as shown in Fig. 8 that represents the second variation of six gases observed during that test period.
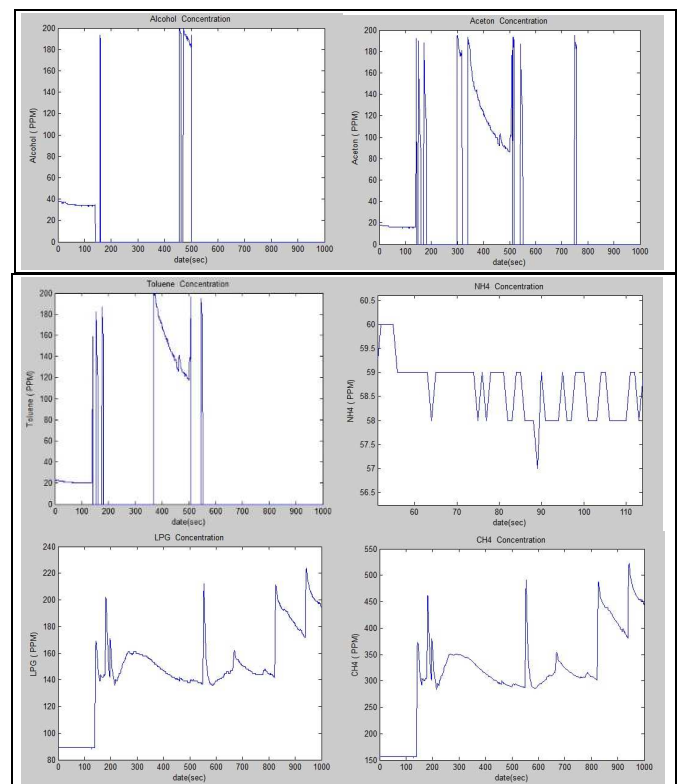

Fig. 8. The gases concentration measurement in the lab for real-time.

According to that were detected it is classified into three categories based on the ppm value obtained (Danger case, Critical case, and fresh air). When the air quality concentration in the ppm unit is less than 100, it is considered good air quality (fresh air). Alternatively, when air quality concentration rises to 200 ppm (Critical case), there are possible health problems such as migraines, languor, and torpidity. Eventually, the red light and buzzer are triggered, indicating the high levels of air quality exceeded the threshold limit of 200 ppm. That poses a serious health risk to those who are frequently subjected to such poor air quality (Danger case).

IV. CONCLUSION

Because of the enormous number of dangerous substances that cannot be smelled or seen, public awareness of the dangers of air pollution is low. In this article, a proposed method for IAQML to detect gases and monitor air quality in real-time has been developed based on data provided by cost-efficient MQ gas sensors and Arduino-Android has been presented and displays the values on an LCD with the help of IoT. Using the ThinkSpeak webpage, the user can monitor and access the gas concentration level. The preliminary test results obtained from the proposed method indicate the possibility of using MQ-sensors for monitoring air quality in laboratories. They also show that the concentration of gases in the lab is within the acceptable limit and indicate the possibility of using MQ type sensors to be capable of detecting various gases in laboratories, hospitals, factories, and any indoor building exposed to the release and impact of air pollution and providing alerts to the public. For future work, an IAQML system will be considered to recognize the health impact of harmful gases on the occupants of the structure. The system can be utilized in a hospital or an asthma patient's room, as well as in emergency conditions such as fire and smoke release.

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