The Making of an Air Quality Monitoring System with the use of Arduino Interface and Volatile Organic Compound Sensor

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Abstract: Air pollution has become an increasingly prominent issue in our world, specifically in problems towards ecological and public health. Thus, concerns in air quality have risen and a need for an accessible method to evaluate and assess it. The study made use of the experimental design and quantitative method to create an Air Quality Monitoring System with the use of Arduino Interface and Volatile Organic Compound Sensor. This device aims to address the problem of air pollution by providing a cost-effective but efficient way to determine the air quality in a space, yielding proper reports regarding whether or not the condition of the air is acceptable or not. The device was observed to be able to detect atmospheric particulate matter with a 98.29 percentage of accuracy, and exhibited minimal delay in displaying data on its liquid crystal display (LCD). Additionally, the response time of the buzzer after detecting an air pollutant had the slightest delay in response, with an average of 2.21 seconds. The Air Quality Monitoring System utilizes Arduino, an accessible and easy-to-use microcontroller software for compact devices, as well as a Volatile Organic Compound Sensor, which possesses the ability to detect volatile organic compounds in the area. The results of this study indicate that the Air Quality Monitoring System can detect atmospheric particulate matter accurately. The real-time speed in displaying the data and the response time of the buzzer both had little to no delay as well. Lastly, the Air Quality Monitoring System can be improved by implementing a larger visual display to show more extensive information and data to the user.

Keywords: *Air Quality Monitoring System; Arduino Interface; Volatile Organic Compound Sensor; Indoor Air Pollution.*

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I. INTRODUCTION

Air pollution has become one of the world's leading challenges towards ecological issues and public health. The problem continues to arise from the diverse set of contributing factors that not only impact but alter the quality of air that living beings utilize to survive. Indoor settings have been the target of new polluting fuels and technologies that negatively impact breathable air within indoor-based spaces. Disregarded indoor air pollution can result in occupants' exposure to illnesses such as respiratory and lung disease (Halder, 2024). Indoor air quality levels highly vary over time, depending on a range of internal factors that include the physical and chemical properties of pollutants; utilization of household products, such as cleaning products, cosmetics and insecticides, and appliances, such as stoves and gas cookers, and building and furnishing materials such as chemical flame retardants (Vardoulakis et al., 2020).

Air quality monitoring systems have become the standard in evaluating and verifying air quality and control. An air quality monitoring system refers to a device that provides continuous assessment of existing air pollutants to measure the degree of atmospheric quality (Saini et al., 2020). These devices can range from indoor and outdoor equipment that ensure the air is suitable for human respiration and environmental ventilation. In particular, indoor air quality monitors are often derived from sensor-based instruments that serve a primary function in detecting and identifying air contaminants such as particulate matter and harmful organic compounds in indoor

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environments. These types of air quality devices are purchasable but present a costly disadvantage to peoples' expenses. Majority of air quality monitoring devices require a significant budget in terms of satisfactory reliability and consistency (Zheng et al., 2016).

The implementation of open source software such as Arduino can be applied in the assembly and development of versatile devices and appliances at a reasonable price. Arduino refers to an open-source microcontroller interface that facilitates accessible programming capabilities for a variety of compact and surface-mounted devices (Louis, 2016). The arduino platform is often accompanied with sensors, actuators, and other modules that permit devices to be able to detect, receive, and transmit data. Furthermore, affordable sensor technologies such as volatile organic compound sensors possess the ability to recognize occurrences of volatile organic compounds that cause indoor pollution within the air (Shellaiah & Sun, 2021). These components serve as a strong foundation for the study's economical alternative to deliver atmospheric advantages for occupants within indoor environments. On top of that, designing an air quality monitoring system improves the awareness of inhabitants and enhances the criteria required for good respiratory health and chronic well-being. This study seeks to apply ingenuity and a cost effective approach towards facing the concern of air quality. A concern that necessitates the utilization of new innovations in air monitoring systems.

Various issues can occur with poor air quality affecting health, living experience, and safety. Breathing in air pollution, even at low concentrations, can seriously harm one's respiratory system, leading to lung cancer, asthma attacks, and other respiratory health issues (Maio et al., 2023). People with respiratory medical conditions are at most risk as poor air quality can worsen their condition. As compared to healthy people, those with respiratory allergies are more susceptible to or less tolerant to lower indoor air quality caused by occupants during instantaneous exposure (Zhang et al., 2021). Poor air quality also affects living conditions such as sleep quality. Accumulation of pollutants in the bedroom due to decreased air exchange rate can contribute to respiratory symptoms which can affect sleep. Furthermore, gas leaks and chemical leaks affect the safety of people. Leaks of chemicals and gasses can affect human beings in different ways. Toxic substance exposure can cause both chronic morbidity and immediate disease or death (Horiguchi & Numazawa, 2023).

The air quality monitor that has been created has addressed some of the gaps from the previous models. Some models of the air quality monitoring system such as the device created by Kelechi et al., 2022, lacked humidity and temperature readings, two factors which are important in measuring the quality of air. The sense of air quality is greatly influenced by temperature and humidity, with greater temperatures and humidity levels resulting in less acceptable air (Wei et al., 2018). Humidity and temperature should be checked in order for the air quality monitoring system to provide proper reports as to the condition of the air, if the air is acceptable for people or not.

This study utilized Arduino Interface and Volatile Organic Compound Sensor. Arduino is an easy to use interface consisting of both hardware and software that is used to help create electronic devices and projects. Arduino is an open-source platform that assists circuit developers create electronic projects (Kondaveeti et al., 2021). The hardware part of arduino focuses on programmable circuit boards, while the software includes an application called Arduino Integrated Development Environment (AIDE) which is used to program the circuit boards to perform various tasks accordingly. It has made hardware projects featuring intricate programmable electronics accessible to everyone and was successfully utilized and programmed in creating Air Ionizer-Purifier and Ion Generators (Tudela & Marín, 2023; Real, 2023). Due to Arduino being relatively inexpensive, it is widely available which encourages many to use this interface.

A Volatile Organic Compound Sensor is a type of sensor that detects the chemicals in the air. It is optimized to both monitor and measure atmospheric concentrations linked to bad air quality (Kuncoro et al., 2024). These types of devices play a critical role in different applications such as indoor air quality analysis, industrial emissions tracking, and environmental monitoring. A volatile organic compound (VOC) sensor has the capability to identify the so-called volatile organic compounds that are present within interior and indoor environments. Indoor products such as paint, cleaning supplies, and cooking gas are instances of common volatile organic compounds that can be detected and discerned by the presence of an active sensor. Furthermore, substantial evaluation of volatile organic compounds can indicate the need to diminish poor air quality and necessitate improvements within the indoor setting (Hanif, 2021).

An Air Quality Monitoring System is a tool used to check the contents and the quality of air. Temperature, humidity, air pressure, fine particulate matter, carbon monoxide, and carbon dioxide are examples of parameters measured by an air quality monitoring system (Kumar et al., 2017). The air quality monitoring allows measurement and analysis of air conditions in real time by measuring the parameters of air quality as well as identifying multiple air pollutants in order to make the right judgments in a timely manner. This will mitigate the harmful effects of bad air quality caused by pollution such as damaged human health, especially worsening respiratory conditions.

This study can be used by future researchers when they conduct their research on air quality monitoring systems. They can use this study to verify the accuracy of previous studies conducted in the same field. This research will help them with their investigations and develop better quality systems by reducing issues and using similar components and procedures.

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II. RESEARCH QUESTIONS

A. Research Questions

The objective of this study is to create an Air Quality Monitoring System with the use of Arduino interface and volatile organic compound sensor. Specifically, it answers the following questions:

- What is the accuracy of the Air Quality Monitoring System in detecting air pollutants?.
- What is the real-time speed of detection of the Air Quality Monitoring System?
- What is the response time of the buzzer of the Air Quality Monitoring System?

B. Hypothesis

H1: It is feasible to make an air quality monitoring system with the use of Arduino interface and volatile organic compound sensor.

III. METHODOLOGY

This study utilized the experimental design of research. Experimental research is where the researcher will maintain control over all the factors to determine or predict the result of an experiment (Zubair, 2023). In this study, the use of Arduino interface and volatile organic compound sensor are the independent variables while the air quality monitoring system is the dependent variable. The quantitative method was used to ensure that the experiment is properly organized and to make sure that the correct type of data is obtained to be able to answer the research questions as accurately and as efficiently as possible. It is crucial to use this type of research method as it gives a high level of control over the variables that display an outcome and have an advantage in finding accurate results.

A. Research Locale

This research study was conducted in Doha, State of Qatar. It is selected as it is the most accessible to the researchers and provides the facilities needed for the completion of the study.

B. Data Gathering Procedure

The procedure shows the step-by-step process that shows and instructs how to make an air quality monitoring system with Arduino interface and volatile organic compound sensor.

Below is the procedure in ensuring protection and maintaining safety.

- Wear protective apparel such as safety gloves, safety goggles, and a laboratory coat before carrying out the procedures below to avoid any hazardous conditions.

Below is the procedure in creating the circuit.

- Place all the necessary components on their designated terminals on the breadboard.
- Attach all the components' Voltage at the Common Collector (VCC) pins to the positive terminals of the breadboard.
- Attach all the components' Ground (GND) pins to the negative terminals of the breadboard.
- Connect the MQ-135 Sensor's data pin to the Arduino Uno board in the analog input A0.
- Connect the DHT11 Sensor's data pin to the Arduino Uno board in the digital pin 3.
- Make the first connection of the Organic Light-Emitting Diode (OLED) display to the Arduino Uno board by attaching the Serial CLock Line (SCL) pin to analog input A5.
- Make the second connection of the OLED display to the Arduino Uno board by attaching the Serial Data line (SDA) pin to analog input A4.

Below is the procedure in programming the codes.

- Install Arduino IDE.
- Open the Arduino Software.
- Input the codes for each component.
- Install the necessary libraries for every component.
- Verify the commands and upload them to the Arduino Uno circuit board.

Below is the procedure in calibrating the components.

- Run through the codes uploaded to the Arduino Uno.
- Let the components run for 24 hours to calibrate properly.

Below is the procedure in setting up the exterior.

- Reuse a cardboard box.
- Cut it into six rectangular sections big enough to hold the breadboard along with the attached components.
- Glue five of the sections together with the use of a glue gun creating an open box leaving the front side open.
- Cut out the necessary pieces on the front section for the components to be placed.
- Secure the components to their slots on the front cover with the use of electrical tape.
- Glue the front cover with the components, closing off the box.

In order to determine the effectiveness of the Air Quality Monitoring System, its accuracy and response time were compared to an Air Quality Meter in terms of percentage and delay in seconds respectively. The percentage of accuracy was calculated by dividing the observed value from the OLED display by the true value from an Air Quality Meter and multiplying the quotient by 100. With the use of a stopwatch, the real-time delay was calculated by subtracting the time it takes for the OLED display of the air quality monitoring system to display the data from that of the Air Quality Meter indicator.

Furthermore, to determine the response time of the buzzer, a stopwatch was utilized to help measure how fast the buzzer could notify. Once the Air Quality Monitoring System detected an air pollutant, the time of response was recorded using a stopwatch. For reliable results, each test had three trials and the average was calculated by dividing the sum of all values by the number of trials.

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IV. RESULTS

This study is aimed at creating an Air Quality Monitoring System with the use of Arduino Interface and Volatile Organic Compound Sensor. The section below brings about the results and interpretation of data that were collected from assembling and testing the device, wherein three main research questions were created to be answered, such as accuracy of the device, real-time speed of the device, and the response time of the buzzer.

- *The accuracy of the Air Quality Monitoring System in detecting air pollutants*

Table 1 Accuracy of the Air Quality Monitoring System

Trial	1st	2nd	3rd	Average
Observed Value (in micrograms per cubic meter)	76 µg/m³	76 µg/m³	78 µg/m³	
True Value (in micrograms per cubic meter)	77 µg/m³	78 µg/m³	78 µg/m³	
Accuracy (in percentage)	98.71%	97.44%	98.71%	98.29%

Table 1 shows the accuracy of the Air Quality Monitoring System, in comparison with one sold commercially, in terms of percentage. The percentage of accuracy was calculated by dividing the observed value from the air quality indicator by the true value from an Air Quality Meter and multiplying the quotient by 100. For reliable results, a total of three trials were conducted and the average was taken by dividing the summation of percentages by three. In the first trial, the Air Quality Monitoring System detected 76 µg/m3, while the commercial one detected 77 µg/m3, meaning the Air Quality Monitoring System was 98.71% accurate. In the second trial, the Air Quality Monitoring System detected 76 µg/m3, whereas the commercial one detected 78 µg/m3, making it 97.44% accurate. In the third trial, the Air Quality Monitoring System detected 78 µg/m3, while the commercial one detected 79 µg/m3, exhibiting 98.71% accuracy.

Analyzing the results, the Air Quality Monitoring System was 98.29% accurate on average. The trials show that the Air Quality Monitoring System can detect atmospheric particulate matter accurately, in comparison to those sold commercially, with little to no error. Other studies report similar results, whereby low-cost indoor air quality monitoring systems utilizing open-ended technologies have been tested and demonstrated to deliver reliable and accurate data on par with commercially sold devices (Taştan, 2022).

- *Real-Time Speed of the Air Quality Monitoring System*

Table 2 Real-Time Speed of the Air Quality Monitoring System

Trial	1st	2nd	3rd	Average
Delay (in seconds)	0.39s	0.49s	0.05s	0.31s

Table 2 illustrates the real-time speed of detection of the Air Quality Monitoring System based on its time of delay in seconds. The delay in real-time speed was calculated by subtracting the time it takes for the LCD of the Air Quality Monitoring System to display the data from that of the commercialized air quality monitor. For consistency, three trials were conducted and the average was computed by adding the results of each trial and dividing it by three. In trial 1, the Air Quality Monitoring System took 1.35 seconds to display the data, while the commercial one only took 0.93 seconds, resulting in a delay time of 0.39 seconds. In trial 2, the Air Quality Monitoring System took 1.45 seconds to display the data, whereas the commercialized one only took 0.96 seconds, having a delay time of 0.49 seconds. In trial 3, the air quality indicator took 0.98 seconds to display the data, while the commercialized one displayed the data in 0.93 seconds, only exhibiting a delay time of 0.05 seconds.

Evaluating the results of the trials, the average delay time of the Air Quality Monitoring System compared to one sold commercially was 0.31 seconds. The results show that the air quality indicator had a minimal delay in comparison to a commercial-grade air quality monitor. This can be beneficial and can be utilized advantageously as these minimal delay speeds of the sensors can help produce accurate data at a higher rate and sampling frequency (Concas et al., 2021).

- *Real-Time Speed of the Air Quality Monitoring System*

Table 3 Response Time of the Buzzer

Trial	1st	2nd	3rd	Average
Delay (in seconds)	0.39s	0.49s	0.05s	0.31s

Table 3 displays the response time of the buzzer of the Air Quality Monitoring System in seconds. Once the Air Quality Monitoring System detected an air pollutant, the delay in response time was recorded using a stopwatch. Three trials were conducted for the credibility of data and the average was taken by dividing the summation of all values by three. In the first trial, it took 2.24 seconds for the buzzer to respond. In the second trial, it took 2.30 seconds for the buzzer to respond. In the third trial, it took 2.10 seconds for the buzzer to respond.

Analyzing the results, it took an average of 2.21 seconds for the buzzer to activate after the sensor was

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exposed to an air pollutant. The trials indicate that the buzzer of the Air Quality Monitoring System has the slightest delay in response. Having a fast response time means there is less time for a negative outcome to occur (McRacken et al., 2021). Similar findings are found in other investigations, various performances of air quality monitoring systems are observed which have been found to have varying response times (deSouza, 2022).

V. DISCUSSION

This research aimed to gauge the effectiveness of the Air Quality Monitoring System in terms of accuracy in detecting particulate matter, the real-time speed of detection, and how long it took for the buzzer to activate after the sensor had been exposed to an air pollutant. The monitoring system accurately detected atmospheric particulate matter, and performed exceptionally in comparison to those commercially available. The reliability of the device in identifying atmospheric particulate matter proved a very high success rate from the first to the third trial. Trials 1 and 3 measured a percentage of accuracy of 98.71%, and trial 2 measured a percentage of accuracy of 97.44%, averaging at 98.29% accurate. Despite being low-cost, these sensors proved to be effective in precisely detecting air pollutants nearly equivalent to that of standard equipment (Nguyen et al., 2021). Moreover, the Air Quality Monitoring System showed minimal delay in terms of the real-time speed in displaying the data pertaining to indoor air quality status on the OLED display, with the fastest time being 0.98 seconds, with a minimal delay of 0.05 seconds. Fast display of real-time data is significant as it creates less room for possible harm to take place and early decisions can be made due to swift readings (Devarakonda, et al., 2013). Lastly, the device exhibited a fast response time in initiating the coded buzzer system, the fastest time recorded being 2.10 seconds after the sensor was exposed to an air pollutant. Quick-responding notifying systems in air quality monitors provide immediate alerts about harmful pollution levels, enabling timely protective actions for health and safety (Baicoianu et al., 2020). Living a day to day life with poor air quality can lead to various health issues and may become detrimental to a person’s health. Poor air quality can lead to lung cancer and respiratory conditions including asthma and chronic obstructive pulmonary disease (COPD) (Behinaein et al., 2023). But possessing an air quality monitoring system can help mitigate the issue of bad air quality. Since an air quality monitor gives real-time data on contaminants including PM, CO, and O3, it is essential for controlling poor air quality. Communities can use this information to spot patterns and pollution sources and take preventative action to enhance the quality of the air (Prince & Mtende, 2024). Despite the fact that the air quality monitoring system can detect air pollutants and thus can help deal with air quality, one of the main reasons why many people lack an air quality monitoring system is due to the high costs of obtaining the device (Theresa et al., 2023). The monitoring system proved to be functional by exhibiting successful results in all of the given trials. Although the tests have shown great results, there are still limitations that can be further improved. The device lacks the use of additional sensors that can help detect specific gases in the air in order to give greater detail of readings of the surrounding air quality which would be beneficial in identifying the cause of possible poor indoor air. The device is also limited in notifying as it only makes use of a buzzer and a light indicator that can only be heard and seen within a certain distance.

VI. CONCLUSION

This study helps prove the development of a low-cost and feasible air quality monitoring system utilizing the Arduino interface, coupling it with a volatile organic compound sensor and making an innovative device feasible for communities and households that could otherwise not afford expensive commercial monitoring devices. The device's validity rests in its ability to give real-time and accurate data regarding air quality, ensuring mitigating risks from prolonged exposure to conditions caused by poor air quality.

Based on the findings, it is recommended that future researchers may use this study as a guide towards the creation of new projects with related functions and components. Future researchers may incorporate more sensors to make a more effective Air Quality Monitoring System in detecting more pollutants with greater accuracy. The researchers suggest employing a larger visual display to provide more extensive data and information that can suitably inform and notify users of the device. The researchers also suggest the addition of a Wi-Fi module that can be connected to a mobile application that will display the readings of the data collected by the sensors and notify the user in detection of bad air quality.

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