Development of Arduino based air quality monitoring systems for measuring gas sensor

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Abstract: - There has been an increase in the number of hazardous gases emitted in the environment due to rapid industrialization. It is becoming very important to monitor the quality of air around so as to take adequate steps in protecting ourselves. This work proposes a mobile air quality monitoring system that is portable enough to be carried around. This system is designed to give real time update on the air quality around. The system contains an air quality sensor, which measures the air quality. The system also contains an LCD screen which displays alerts, warnings and the air quality, in parts per million (ppm), on the screen. A buzzer is also implemented in the system which is triggered when the air quality, is above a certain value. The air quality in different venues in Covenant University were obtained, analysed, and compared with one another. The gases tested in this study include CO_2, ammonia, and alcohol. Another experiment was conducted to check the effect that distance has on how the sensor senses the gas. Due to the unavailability of another indoor air quality measuring device for comparison, several data from different locations were taken during the course of this project in order to make comparisons. A significant observation that was made was that increase in temperature is directly proportional to poor air quality. The values of the air quality in H213 in CST ranged from 250 ppm to 275 ppm which shows that the air quality in H213 is good and the environment is conducive. The values of the air quality CST Buttery ranged from 330 ppm to 380 ppm which shows that the air quality in the Buttery is not so good and the environment is not so conducive. When the gas was placed 0 cm to 1.2 cm away from the sensor, the air quality ranged from 1000 ppm to 4500 ppm and when the gas was placed more than 1.2 cm away from the sensor, the air quality ranged from 200 ppm to 500 ppm. This shows that the sensor is more sensitive when the gas is placed close to it.

Key-Words: - Air quality, MQ135 sensor, air pollution, Arduino Uno, data logger

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1 Introduction

Air pollution is one of the significant environmental problems in this century. In Africa, Nigeria has the leading cause of death by air pollution [1] Several factors contributed to this, such as fumes from generator, industries, as well as smoke from car exhausts which releases carbon monoxide (CO) into the air, which is very dangerous to the health. Another factor is that 50% of Nigerians still cook with firewood and stoves [2]. Refuse burning is also a huge factor that contributes to air pollution. The air pollution problem is concerned with the undesirable effects that are produced by excessive atmospheric pollutants. It is becoming rather imperative for the air quality to be monitored and to keep it under control in order to live a healthy and better life. Conventionally, air quality is usually measured using expensive and complicated devices placed in one location [3-5]. This approach measures air quality in parts per million (ppm), giving accurate and precise air quality data. While this approach gives accurate results, it is expensive. One shortcoming to this approach is that it is not readily available, it is a costly approach, it can only be placed at a fixed location and the data gotten from the device are few and far between.

Air is the most sensitive aspect of the environment and it is contaminated by the elements released into it regularly [6]. Air pollution has been in existence since the beginning of time. However, the first recorded lethal occurrence was in Donora, Pennsylvania in 1942, which lasted for over five days, where over 40 deaths were recorded and over 7000 people developed respiratory diseases [7]. A similar situation happened in London, England, four years later in 1952, that killed about 4000 people [8]. The air quality monitoring system came to be because the quality of air had to be measured to prevent any form of lethal re-occurrence. The Air Pollution control act was introduced in 1955 in the United States of America, while the British introduced the Clean Air Act in 1956 in response to the event in 1952 [9].

The United States Environmental Pollution Agency (EPA), was introduced in 1970 by President Richard Nixon to enforce the clean air act [10]. Four other air quality regulatory bodies were the NAAQS, SIP, NSPS and NESHAPs. The Clean Air Act was then amended in 1977 to include vehicle emissions requirements[11]. Other amendments were made in 1990 [9]. In their air quality monitoring studies, [12] discovered elevated concentrations of motor-vehicle released compounds including CO, NO_2, PM 10, PM 2.5, PM1, Black Carbon, polycyclic aromatic hydrocarbons and benzenes in air pollution monitoring. To better understand harmful gases and their consequences, industrial air quality control system was introduced in 2008. Inexpensive air quality systems were considered because the sensors were quite expensive. The use of wireless sensors, GPRS and pollution dynamic monitoring systems have then been introduced to detect pollution and monitor air quality.

At ambient temperature, carbon dioxide is a colourless, odourless, faintly acidic-tasting, non-combustible gas. It is a byproduct of normal cell function and is expelled from the body through the lungs in the air breathed out. It is also emitted during the burning of fossil fuels. Exposure to carbon dioxide can result in a range of health effects like excessive sweating, headaches, edginess, fatigue, light-headedness, difficulty breathing, and increased heart rate. According to computer climate modelling, a branch of science that has recently been showing substantial strides in knowledge although it still in its infancy, significant increases in surface and lower atmospheric temperatures are hypothesized to be due to increases in minor greenhouse gases (GHGs). An array of computer simulations have been used to study their probable climatological effects, from complex 3-dimensional to simple 1-dimensional models to coupled ocean-atmosphere general circulation models (GCMs), rests on the authenticity of the models significantly determine the reliability of the calculations. The models can only be evaluated by comparing existing climate information with their predictions of current and past conditions and outlining the consistencies or inconsistencies with significant, observed climate factors, which ideally should be precisely measured. Although the models fundamentally have experimental power, that fact does not ensure that that the measurements are accurately predicted. As a result, it is vital to test the hypothesis that significantly increased atmospheric CO_2 results in the significant rising of the average temperature of earth's climate system or global warming [13]. Table 1, shows potential health problems depending on the concentration of carbon dioxide in the environment [3].

Table **Σφάλμα! Δεν υπάρχει κείμενο καθορισμένου στυλ στο έγγραφο.**: Toxicity Levels of Carbon dioxide on Humans [3].

250-350ppm	Standard concentration in the outdoor atmosphere.
350-1,000ppm	Concentrations in indoor spaces with proper cross ventilation resulting in adequate air exchange.
1,000-2,000ppm	Potentially dangerous concentration wherein exposure could result in drowsiness.
2,000-5,000 ppm	Dangerous concentration, where continuous exposure leads to headaches, lethargy, stuffy stale air, abnormal heart rate and slight nausea.
5,000ppm	Concentration Limit for exposure in an industrial work environment (as 8-hour TWA) in most districts.
>40,000 ppm	Hazardous concentration, and exposure potentially leads to severe oxygen deprivation which can cause respiratory failure, brain damage, suffocation, coma, even death.

This proposed system is a wireless sensor network that operates primarily to track emissions in order to assess the level of air quality. It is a low-cost monitoring device with an inexpensive but powerful sensor. In order to understand variations in air quality, versatile and complex techniques are needed as the pressure on air quality increases [5]. The use of a new mobile air quality monitoring system allows an intensive description of air quality instead of depending on static sites to provide a representative image of air quality. Mobile air quality monitoring systems allow proper air assessment in a region, using temporary spots that can be moved around various locations. A mobile air quality device can cover more locations faster and cheaper than deploying a static site [11]. There is always variation in air quality, and a mobile monitoring device allows a swift response to these changes. Another advantage that this device has over deploying a static site is that it does not require as much power. It also utilises an LCD screen to display the output to the user.

2. Methodology

The MQ135 gas sensor senses ammonia (NH_3), NO_x, alcohol, benzene, smoke and CO_2. The MQ135 sensor will then be connected to the Arduino Uno board and then sense the gases. The pollution level will be gotten in parts per million (PPM). The output gotten from the gas sensor is in the form of voltage levels, and it will need to be converted to parts per million (ppm) using a library for the sensor. For this device, the safe value is less than 400 ppm, and hazardous air is about 1000 ppm. Figure 1 shows the hardware block diagram of the project.

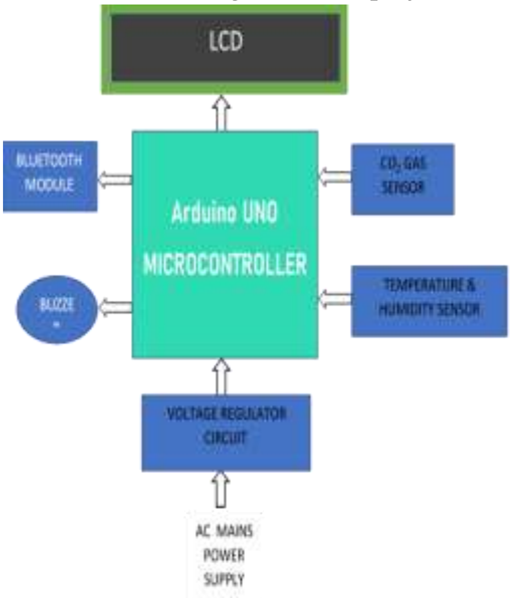

Fig. 1: Block Diagram of the Proposed System

2.1 Hardware

This section outlines the process by which the various components are assembled. It is divided into three sections; the power supply, the analogue-digital conversion (the Arduino), sensor interface. An analogue can take any number or value as opposed to a digital signal which can only take two (2) values: HIGH and LOW or 0 and 1. The Arduino Uno microcontroller board has an analogue-digital converter (ADC) to convert analogue values to digital values. However, the Arduino board does not have a digital-analogue converter (DAC) built-in. However, it can do pulse-width modulation (PWM).

A USB connection or an external power supply can be used to power the Arduino board. The external power supply can either be acquired from a battery or an AC-DC adapter. The adapter can be connected by plugging a 2.1 mm centre-positive plug into the board's power jack. The Arduino Uno board can operate on a recommended external power supply from 7 volts to 12 volts. A USB connection will be used in the construction of this device. The USB will be connected to the USB port of a laptop or computer system. The Arduino IDE is used in programming the microcontroller. While programming the Arduino, the analogue signal's value can be obtained using the function analogRead (pin). If the pulse-width modulation (PWM) output is to be gotten, the function analogWrite (pin, value) will be used.

2.2 Software Module

The MQ135 sensor is an inexpensive sensor used in the monitoring of air quality. This gas sensor acts like a variable resistor whose resistance depends on the gasses surrounding it. The sensor has four (4) pins named the VCC, Ground, Digital out (DO) and the Analog Out (AO). The VCC (voltage at the common collector) pin, which is the regulated supply voltage required to operate it, is used to power the sensor, and it requires 5 volts for operation. The ground pin is used to connect the sensor to the ground of the system. The digital out (DO) pin is used to get digital output from this sensor. The analogue out (AO) pin outputs 0volts to 5volts analogue voltage depending on the intensity of the gas. When the code has been uploaded to the device and it is connected to a power source, the MQ135 gas sensor gets the air quality from the environment and sends to the Arduino. If the value is between 0 and 400, “Fresh Air” is printed on the LCD screen. If the value is between 400 and 1000, “Poor Air” is printed on the LCD screen and if the Value is above 1000, “Hazardous air” is printed on the LCD screen. Figure 3.5 is the flowchart showing the working principle of project.

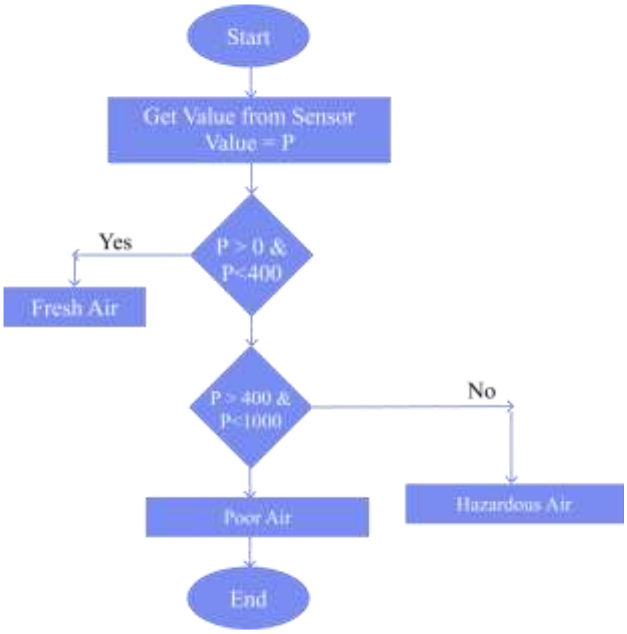

Fig. 2: Flowchart showing working principle

3 Problem Solution

The device developed was used to collate two sets of results. The first set of results is used to ensure that the device shows some level of being accurate and reliable. This was achieved by comparing the results from the device with those of standard results.

3.1. Test of accuracy

The device was tested in different locations with different quality of air. It was tested in environments with fresh air, high amount of alcohol, high amount of ammonia, high amounts of CO and well as other congested areas. During the course of constructing and testing this project, all the objectives were met and the device gave expected results In Figure 3.

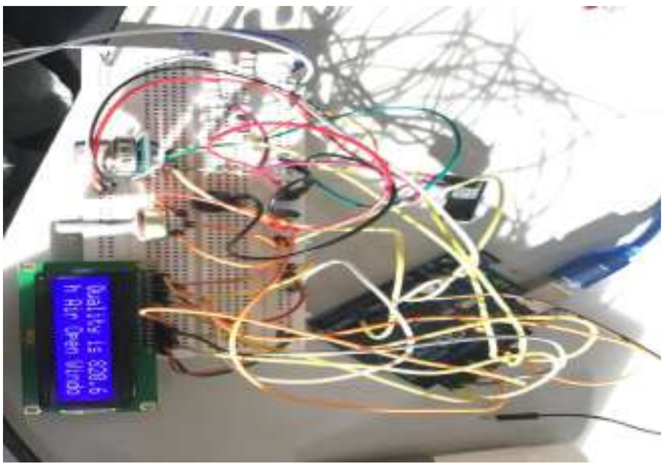

Fig. 3: Constructed device on a breadboard

3.2. Air Quality Monitoring in Hall 213 Lab

Data was collected in Hall 213 in CST, which is the final year Physics laboratory, biochemistry laboratory, and CST buttery. Table 2 shows the categories of AQI levels in this study. The data collection from H213 lasted for 3 days. On the first day, the data collection from H213 started by 10:00 am. Classes are usually held on this day from 10:00 am to 14:00 pm. From 10:00 am to 14:00 pm, there were general classes. Figure 4 shows that the increase in the value of the air quality from 10:00 am. The increase in the value of the air quality is caused by an increase in the amount of CO_2. The air quality was a bit better from 14:00 pm because few people left the venue. Since the value is below 400 ppm, the air quality for that day was considered to be good. On the second day, the data collection started by 8:00 am. Classes start in H213 by 10:00 am.

The class that held from 10:00 am to 12:00 pm was an elective course so there weren't a lot of students present. The class that held from 12:00 pm to 14:00 pm was a general class so a lot more people were present in H213 within that time frame. The increase in the value of the air quality in Figure 5, was caused by increase in CO_2. The value of the air quality reduced significantly from 14:00 pm to 15:00 pm because a lot of people already left the venue by that time. Since the air quality values are less than 400 ppm, the air quality for that day is considered good. Figure 5 shows the air quality in H213 on the second day. The data collection for the third day started by 8:00 am. On this day, there was a significant increase in the value of the air quality by 16:00 pm which was when a lot of students were present in the venue. This increase in the value of the air quality was caused by an increase in the levels of CO_2 in the venue. The lowest values were recorded when there weren't a lot of people at the venue. Figure 6 shows the analysis of the air quality in H213 on Thursday, 8th of July, 2021. The values of the air quality on this day were below 400 ppm which means that the air quality was good.

Table 2: Categories of the Air Quality index (AQI) levels in this study.

Air Quality Status	Air Quality index (ppm)	Air Quality index Colour
Fresh Air	0-400	Green
Poor Air	400-1000	Orange
Hazardous Air	>1000	Red

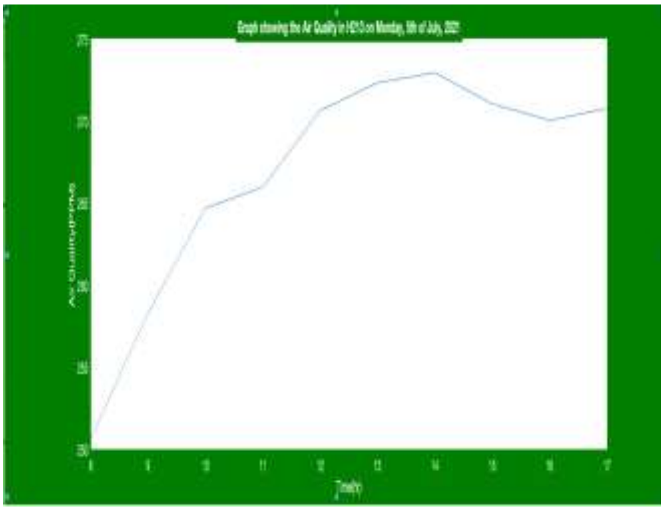

Fig. 4: Air quality in H213 Lab at CST on Monday, July 5, 2021.

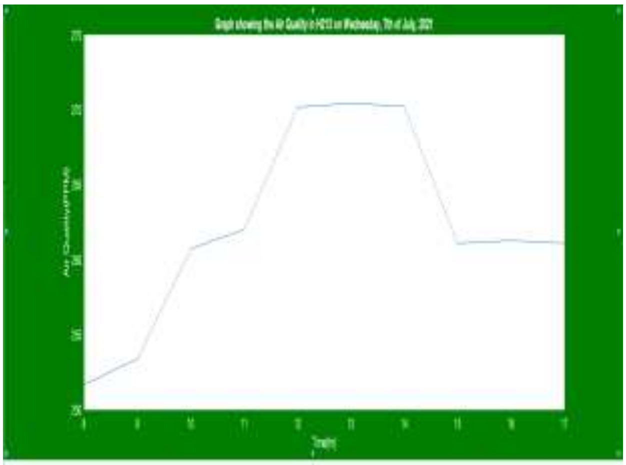

Fig. 5: Air quality in H213 Lab at CST on Wednesday, July 7, 2021.

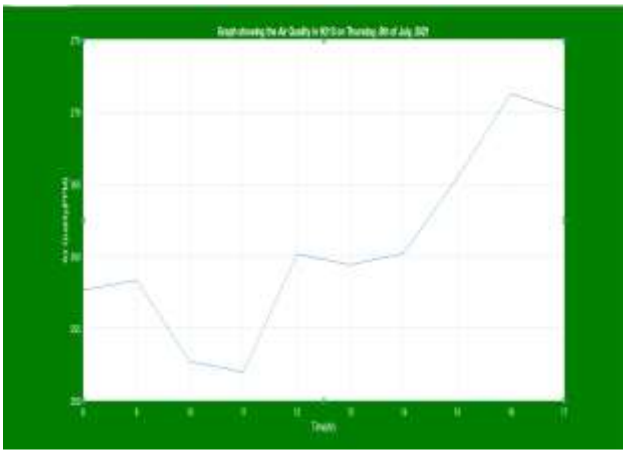

Fig. 6: Air quality in H213 Lab at CST on Thursday, July 8, 2021.

3.3. Air Quality Monitoring in Biochemistry lab

The data collection for this day started by 8:00 am. According to the graph in Figure 7, there was a significant increase in the value of air quality by 10:00 am which was when the classes started for the day. From Figure 7, it is shown that the time when the air quality was very poor was by 14:00 pm which was when the number of activities in the laboratory heightened. The reason for the level of pollution of the lab was the amount of carbon monoxide, ammonia and CO_2 present in the laboratory due to the experiments that were being carried out. The values of the air quality in the Biochemistry lab on the selected day ranged from 304 ppm to 312 ppm. These values are classified under “Fresh Air” but they are closer to the maximum value for “Fresh Air”. Since the values are below 400 ppm, the air quality for the selected day is considered good. Although, some precautions have to be taken to make the air quality better. Figure 7 shows the air quality in Biochemistry Laboratory.

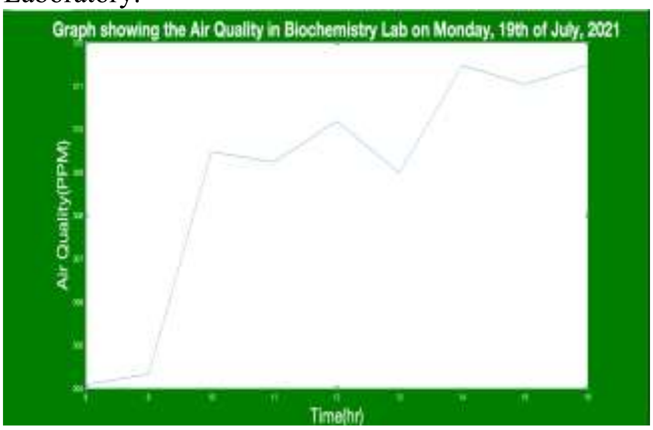

Fig. 7: Air quality in Biochemistry Lab at CST on Monday, July 19, 2021.

3.4. Air Quality Monitoring in CST Buttery

The data collection for this day started by 8:00 am. From Figure 8 it was shown that there was a spike in the value of the air quality by 14:00 pm which is when students are on break. By this time, there is an increase in the activities in the Buttery. A lot of activities that result in the release of carbon monoxide and other harmful gases begin to take place. Another factor that causes the poor air quality in the buttery around this time is an increase in the number of students present in the Buttery. This increase in students cause an increase in the amount of CO_2. From Figure 8, it was shown that the air quality values range from 330 ppm to 380 ppm which falls in the "Fresh Air" category. But due to the closeness of the gotten value to the "Poor Air" category, a lot has to be done to make the CST Buttery more conducive. Figure 8 shows the air quality in CST buttery.

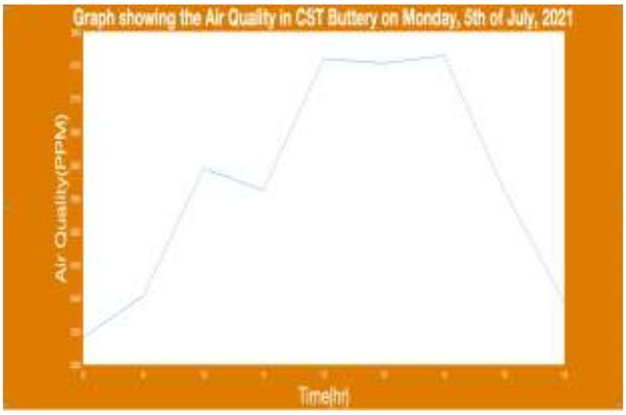

Fig. 8: Air quality in CST buttery on Monday, July 5, 2021.

3.5 Data Analysis of the Effect of Distance on the MQ135 Sensor

This experiment was conducted to measure the impact distance has on the sensitivity of the air quality sensor. While conducting the experiment, a hand sanitizer which contains alcohol, a gas that can be sensed by the air quality sensor, was places at different distances from the sensor to check the sensitivity of the sensor when it is far away from the gas it should measure. The distance ranged from 0 cm to 5 cm. From the experiment, Figure 9 shows that the farther the gas is from the sensor, the lower the ability of the sensor to detect the gas. When the gas was placed 0 cm away from the sensor, the air quality was 4500 ppm and when the gas was placed 5 cm away from the sensor, the air quality was 600 ppm. Figure 9 shows the effect that distance has on the ability of the MQ135 gas sensor to detect the gases.

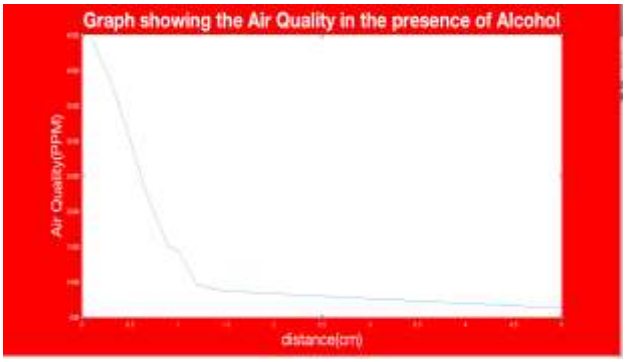

Fig. 9: Graph showing the effect of distance on the MQ134 gas sensor

4 Conclusion

The use of an air quality monitoring system has helped in the real time monitoring of the quality of air around us. This project has shown how to construct a cheaper, real-time, portable and efficient air quality monitoring system. The project contains an air quality sensor that measures the air quality, sends the air quality in parts per million (ppm) to the Arduino microcontroller board into which some set of code and commands has been sent using the Arduino integrated Development Environment (IDE). This code has been written in such a way that the air quality and the air quality status can be displayed on the LCD screen. This code also triggers the buzzer to sound an alarm when the air quality goes above 400 ppm. The detection and monitoring of harmful gases is treated seriously and relevant precautions have been considered in the form of a warning message and a buzzer so that appropriate action can be taken. Because it is a centralized system with a complete monitoring function, it is expected to have a high market adoption. In case of future or further research, this project can be improved by implementing a temperature and humidity sensor which can be used to sense the temperature and humidity. A wireless network card can be added to this monitoring system to save values from sensors connected to the microcontroller. Another feature of particle matter measurement can be added to make it more advanced.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Aimudo O. S carried out the data acquisition, analysis and evaluation.

Usikalu M. R supervision of research activity and mentorship.

Ayara W. A implemented the Algorithm used in the MatLab programming language.

Akinwumi S. A has organized and executed the experiments of Section 3 and 4.

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Conflicts of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.