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An Internet of Things-based Air Pollution Detection System

Nurul Aida Mat Saari[1], Hazalila Kamaludin[1*], Noor Zuraidin Mohd Safa[1], Isredza Rahmi Abd.Hamid[1]

[1]Faculty of Computer Science and Information Technology,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, MALAYSIA

*Corresponding Author

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Abstract: The Internet of Things (IoT)-based air pollution detection system using gas sensors is a system that is developed to detect air pollution using IoT technology. Air pollution is a condition where there is a mixture of harmful chemicals in the air we inhale that can cause damage to humans and the surroundings. The issue of polluted air nowadays has made people become more aware of the air quality they inhale. The system has been developed using MQ2 and MQ9 gas sensors to detect the air pollution level. The system involved two features in helping users read the air pollution level and notify the reading through a mobile app. Users also get notified of the reading through a pop-up notification. The mobile application development uses Android Studio, while Google Firebase is used as the database for the system. This IoT-based air pollution detection system is successfully developed and notified users about the air pollution reading to be more aware of their surroundings.

Keywords: Air pollution, gas sensors, internet of things, mobile application

1. Introduction

The central concept of IoT is connecting daily use devices to the internet so that they can collect and share data over the internet without the intervention of humans. These objects are connected by adding a sensor enabling them to communicate in real-time. The objects used for IoT can be anything from the smallest to the biggest things that exist.

Air pollution happens when there is a mixture of harmful chemicals in the air that will cause damage to humans and the surroundings. Its effects can vary from a higher risk of diseases to rising temperatures [1]. Since the water and air pollution incident in Johor in 2019, people have become more aware of the quality of the air they inhale [2]. Therefore, a system is developed to detect air pollution with gas sensors using IoT technology and display the reading in a mobile application [3], [4].

The result of the project is that the system can detect and generate air pollution reading using a gas sensor and Arduino, display and inform users about air pollution reading with a mobile application, and produce a graph of air pollution reading [5].

2. Related Work

Three existing systems are analyzed and compared as they have similar features to the proposed system, which is to detect air pollution. The systems are IoT Based Air Quality system [6], Centralized Air Pollution Detection and Monitoring: A Review [7], and Air Pollution Detection System Using Edge Computing [8]. The comparison is made to analyze the existing system's weaknesses studied and apply the improvement opportunity to the proposed system. The

**Corresponding author: hazalila@uthm.edu.my*

existing system has a few weaknesses: they did not have a mobile application display and a pop-up notification to notify users about the reading. Users need to access the website to view the reading. Therefore, there will be a mobile application in the proposed system to display the air pollution reading to ease users as they can directly access the application on their mobile device. A notification feature also will be included in the mobile application to notify a user about the reading. All systems compared and proposed systems need an internet connection to work. Table 1 below shows the comparison of the three systems with the proposed system.

Table 1 - Comparison of existing systems with the proposed system

Features	IoT based Air Quality Monitoring	Centralized Air Pollution Detection and Monitoring: A Review	Air Pollution Detection System using Edge Computing	Proposed system
Display in a mobile application	No	No	No	Yes
Pop-up notification	No	No	No	Yes
Sensors used	MQ2 gas sensor, MQ9 gas sensor, ZH03A Dust sensor	MQ2 gas sensor, MQ4 gas sensor	Grove dust sensor, Grove air quality sensor	MQ2 gas sensor, MQ9 gas sensor
Cloud computing usage	Yes	Yes	No	Yes
Microcontroller used	Arduino	Arduino	Raspberry Pi	Arduino
Sensitivity	High	High	High	High
Internet usage	Yes	Yes	Yes	Yes

3. Methods and Materials

The methodology approach chosen for this research is illustrated in this section. The phase included in this methodology is analysis, design, implementation, testing, and maintenance. The methods are chosen because of their relevance based on the review of the related work.

3.1 Air Pollution Detection

Various types of chemical substances can be found in polluted air. Six harmful air pollutants have been defined by the Environment Protection Agency [3], which are considered harmful due to their effects on health and surrounding. The pollutants are ozone (O3), particulates (PM), carbon monoxide (CO), nitrogen dioxide (NO2), Sulphur dioxide (SO2), and lead (Pb). The consequences of air pollution can be towards both humans and the surroundings. It can affect health by causing diseases such as asthma, cough, and lung disorders. An air pollution detection system is built to detect the air's current condition, whether it is polluted with harmful substances or not. Many studies have been done to detect air pollution and monitor air quality with the hope to reduce the air pollution level. There are several methods used to detect air pollution. However, the common method used is by using sensors. There are various kinds of sensors, such as gas sensors, particle sensors, and dust sensors. All research systems have drawbacks. Some of them can only detect a few types of substances, some do not have an alert notification system to alert people about the reading, and some are not mobile [4]. The significance of an air pollution detection system is to detect the concentration of harmful chemical substances in the air and come up with a solution to reduce it.

3.2 Gas Sensors

All Gas sensors are electronic devices used to detect and identify various types of gasses in the air. They are commonly used to measure gas concentration and detect toxic and harmful gasses. They vary in size, range, sensing ability, and sensitivity towards certain substances. Their physical appearances and sensing process differ based on their intended environment and functions [5]. There are several types of gas sensors. The sensors used in this project are MQ2 and MQ9 sensors, as shown in fig. 1.

(a) (b)

Fig. 1 - (a) MQ2 gas sensor; (b) MQ9 gas sensor

3.3 The System Development

The analysis phase is where this project's user and system requirements are defined and analyzed. The method used for user requirements and system requirements is by doing research. Existing systems are analyzed and studied to develop improvement opportunities for that system. Three current systems are analyzed and compared during the analysis phase. The systems are IoT Based Air Quality system [6], Centralized Air Pollution Detection and Monitoring: A Review [7], and Air Pollution Detection System Using Edge Computing [8]. The user requirements required are to view air pollution reading, view air pollution reading graph, and receive a notification alert. Functional requirements are system requirements or system features that are compulsory for developers to develop and fulfill user requirements so that users can use the system smoothly. Applicable requirements characterize the system behavior. Table 2 shows the functional requirements for the system.

The design phase is where the information collected from the previous phase is used to design the system. Using all of the information gathered, ideas for the project are generated, such as the interface design and the applicable technology. The planning for the system is also carried out during this phase. During the planning, every aspect is considered, such as the programming language used, the cost for the project components, the project objective, and the scope. System architecture and user interface are designed during this phase. User interface design needs to be user-friendly so that users can use the application with ease. User interface design considers all application functionalities such as buttons, images, and content display design.

When users access the mobile application, there are two options: view air pollution reading and view air pollution reading graph. Fig. 2 illustrates the sequence diagram for the use case view air pollution reading. The reading will be produced from MQ2 and MQ9 gas sensors.

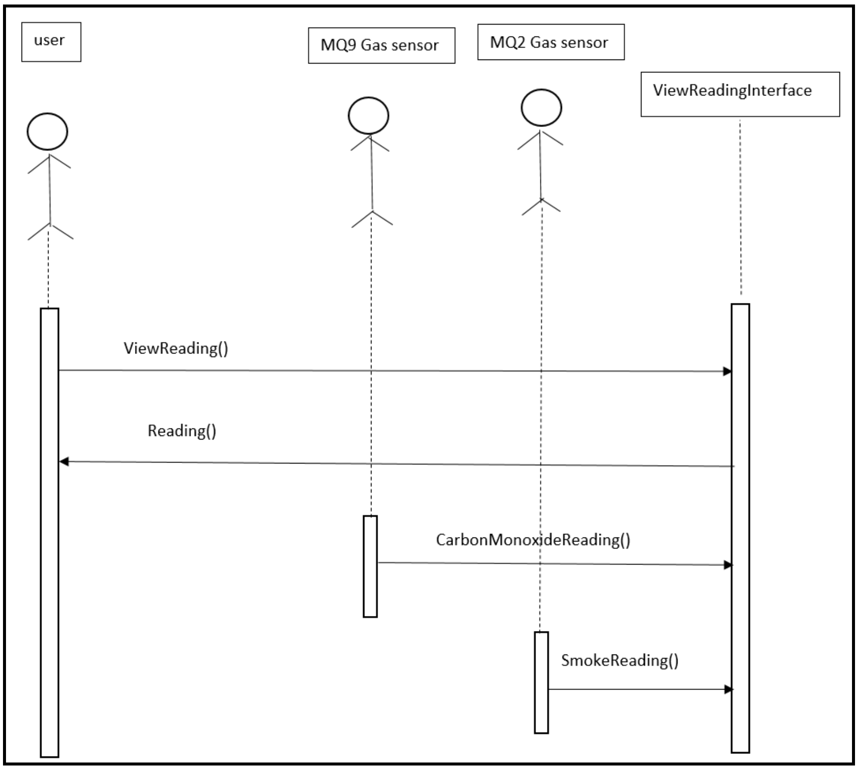


Fig. 2 - Sequence diagram for use case view air pollution reading

Fig. 3 illustrates the system architecture design for the proposed system. The MQ2 and MQ9 sensors detect and send the air pollution reading to the Arduino Uno board. The Arduino Uno will then send the reading to the Wi-Fi module ESP2866 that connects the system to the Wi-Fi so that the data can be sent to Google Firebase, which acts as the database and ThingSpeak website to produce the graph for the air pollution reading. The data from Google firebase will also be sent to the mobile application.

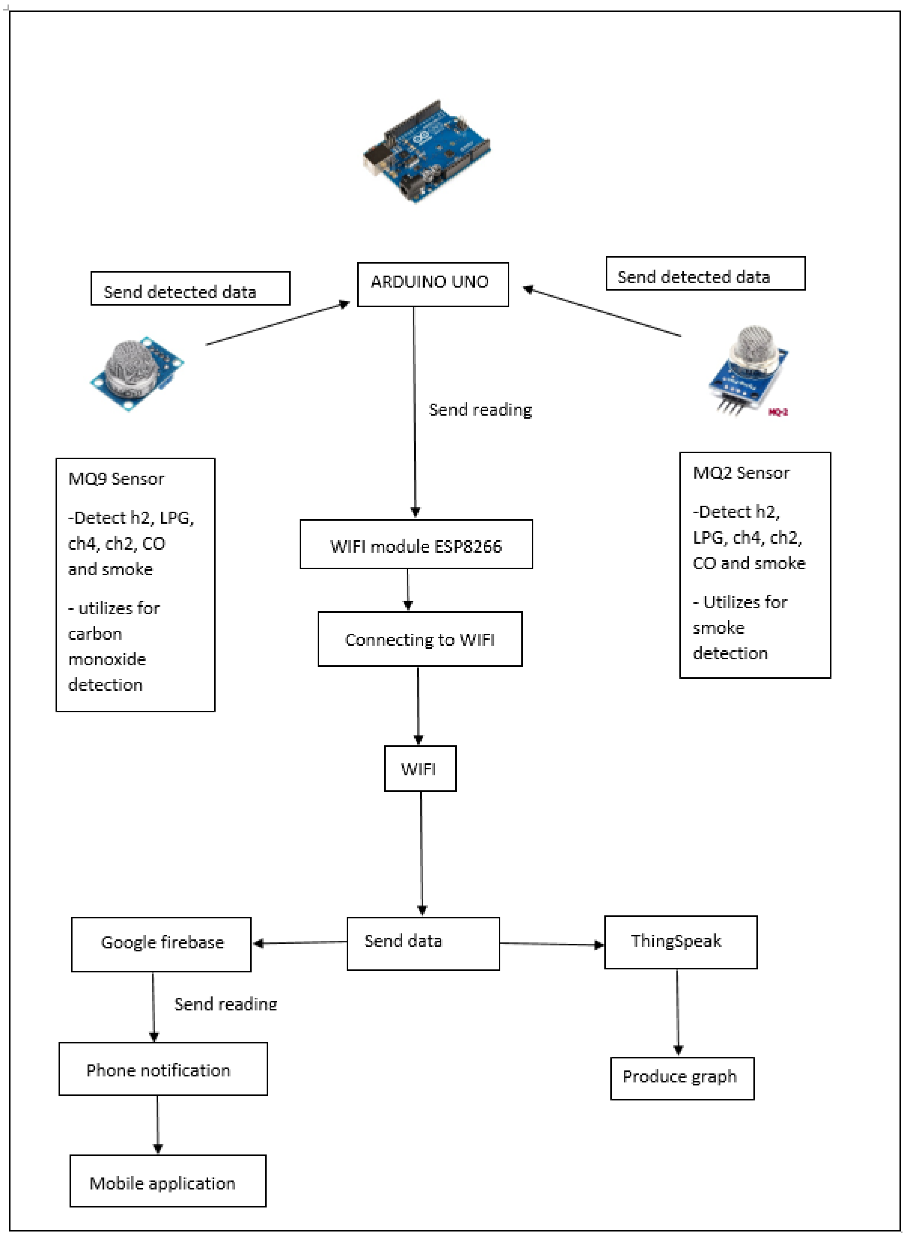


Fig. 3 - System architecture design

All information and design from the previous phase are translated into the actual system during the implementation phase. There are two types of implementation done during this p: the tare development of the system and the application and the development of the database. The components for the system are installed and programmed along with the database. The software used for the system development is Arduino IDE. Google Firebase is used as the database for the mobile application. The software used for the application development is Android Studio and the programming language is Java. Fig. 4 below shows the schematic diagram for the circuit connection. The components used are node MCU ESP8266 as the Wi-Fi module, Arduino Uno as the microcontroller, MQ2 and MQ9 gas sensor, resistor, and buzzer.

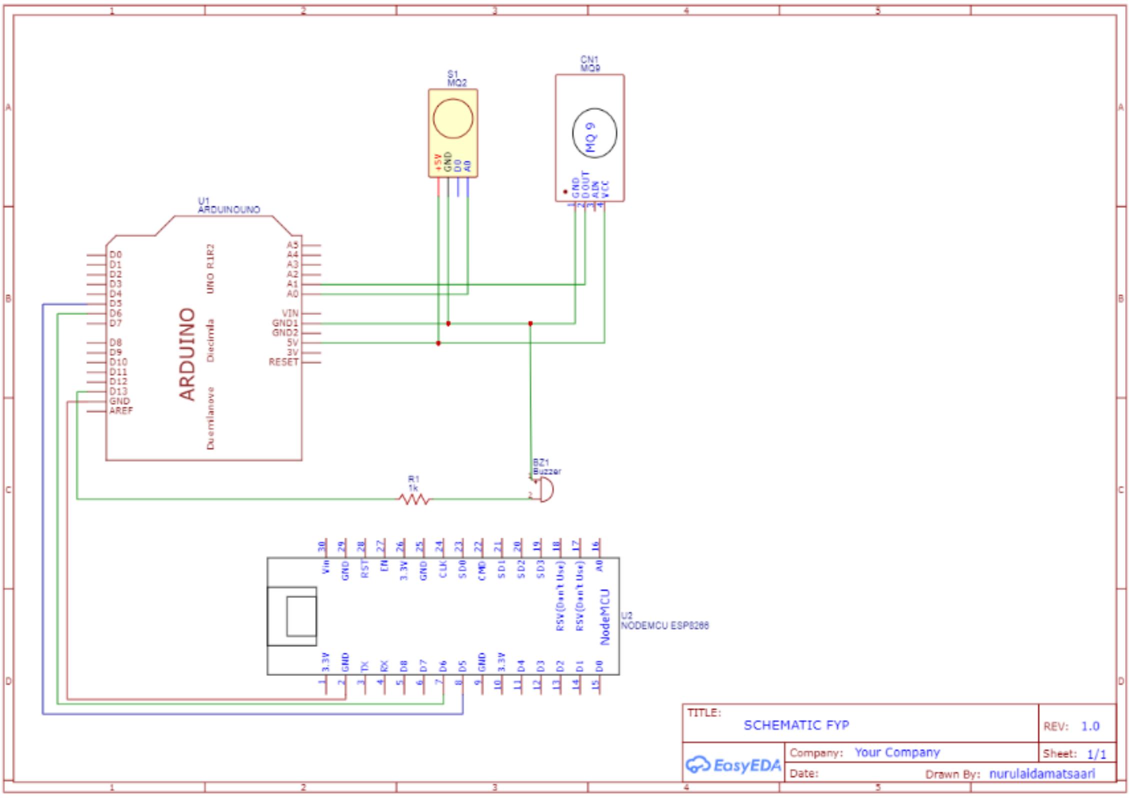
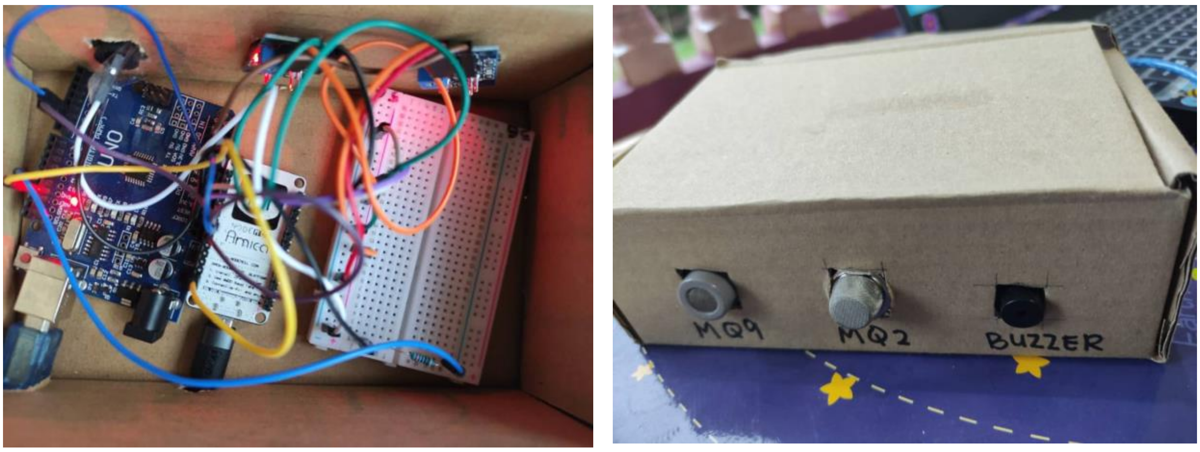


Fig. 4 - Schematic diagram of the system hardware

Fig. 5 shows the system circuit connection and the outer part of the box where the circuit is placed, respectively. The system testing is done by lighting a cigarette and a mosquito repellent and letting the smoke comes from it near the sensor.



(a) (b)

Fig. 5 - The system hardware (a) circuit connection; (b) sensor box

Fig. 6 shows the mobile application's main interface. Users can choose from two menus "Reading" and "Graph." When users click on the "Reading" button, they will be directed to the reading page where the reading for smoke and carbon monoxide will be displayed. There is also a reading guide at the bottom of the page to show the meaning of the reading and whether the air quality is in good condition or not. Next, when users click on the "Graph" button on the homepage, they will be directed to the page where two graphs is displayed. The graph is for smoke and carbon monoxide readings, respectively. Lastly, when the reading exceeds a certain level, a notification alert will be generated to alert the user.

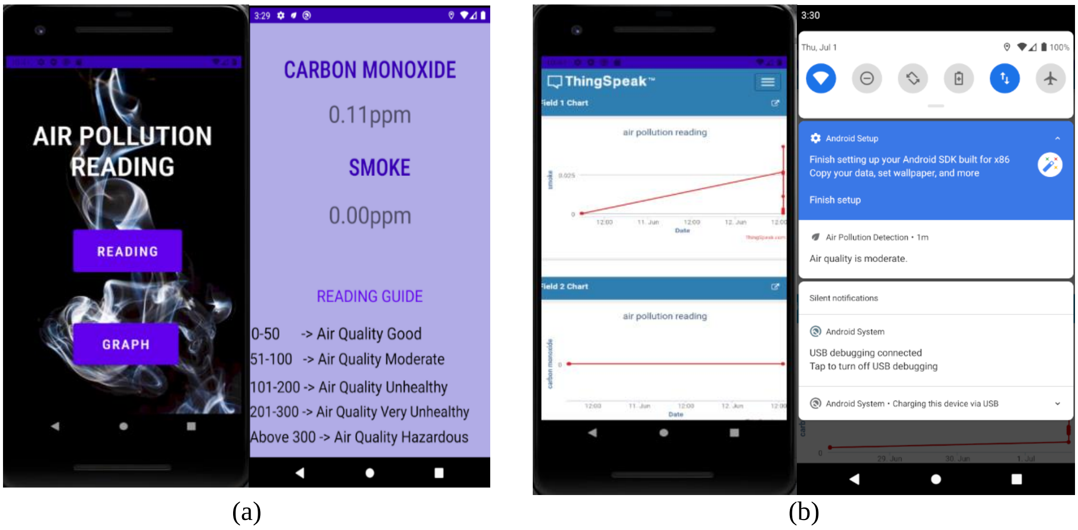


Fig. 6 - The system software (a) air pollution reading options; (b) notification alert interface

The test plan is compulsory to ensure that the system can run smoothly. During the testing phase, all codes are deployed, and the system is tested to make sure it can run smoothly. The application is also tested. For testing, test cases are determined for the testing process. The testing process will be executed according to test cases.

Table 2 - Testing steps

Test category	Description	Expected results	Actual results
1	Store sensor data: I. Store sensor data to firebase	II. Sensor output is stored in the firebase database	Pass / Fail
2	View air pollution reading: I. View current air pollution reading II. View air pollution reading graph for smoke and carbon monoxide	I. Current air pollution reading II. Air pollution reading graphs are displayed	Pass / Fail
3	Notification alert: I. Receive notification alert	I. Notification alert appears for the user if the reading exceeds a certain level	Pass / Fail

Smoke can affect human health in terms of breathing [9]. When we inhale too much smoke, we will have difficulty in breathing. Inhaling too much smoke also increases the risk of respiratory infection. According to the Air Pollution Index Management System(APIMS) website from the Ministry of Environment and Water, there are five levels of air pollution quality status [10]. Table 3 shows the level of air pollution.

Table 3 - Air pollution level

Reading	Status
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very unhealthy
Above 300	Hazardous

All changes and corrections will be made during the maintenance phase to ensure the system can run smoothly without any problem and meet the project objective. The system is made sure to support the system's users along with changes and corrections discovered during the testing phase. Any improvement opportunities found during the testing phase also are implied during the maintenance phase.

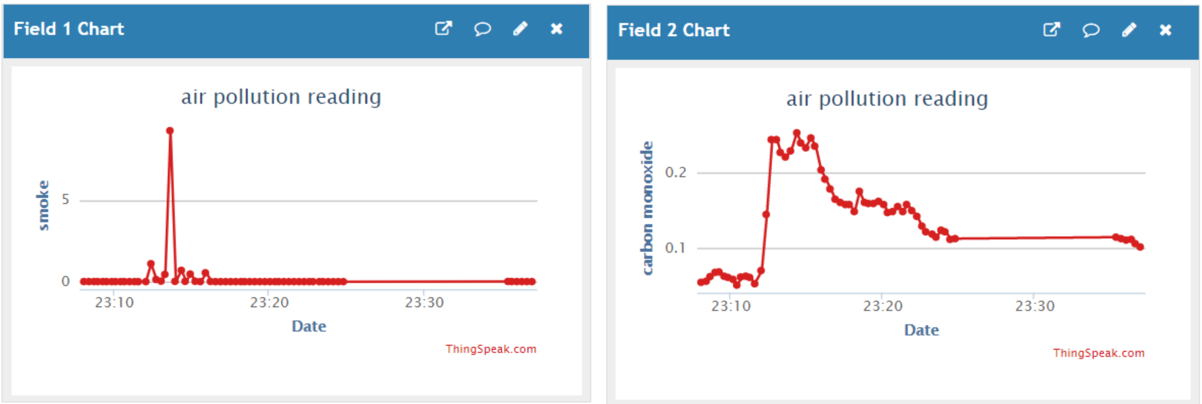
4. Results and Discussion

The system testing uses smoke from cigarettes and mosquito repellent to detect smoke and carbon monoxide. The data from the sensor reading are displayed in a graph in the ThingSpeak channel and also sent to the firebase. If there are upwards changes to the red line in the charts, it means that there are some concentrations of the gases in the air. Table 4 shows the result of the testing.

Table 4 - Testing results

Source of Smoke	Smoke reading	Carbon monoxide reading
Cigarette	9.56 ppm	1.17ppm
Mosquito repellent	1.02ppm	0.08ppm

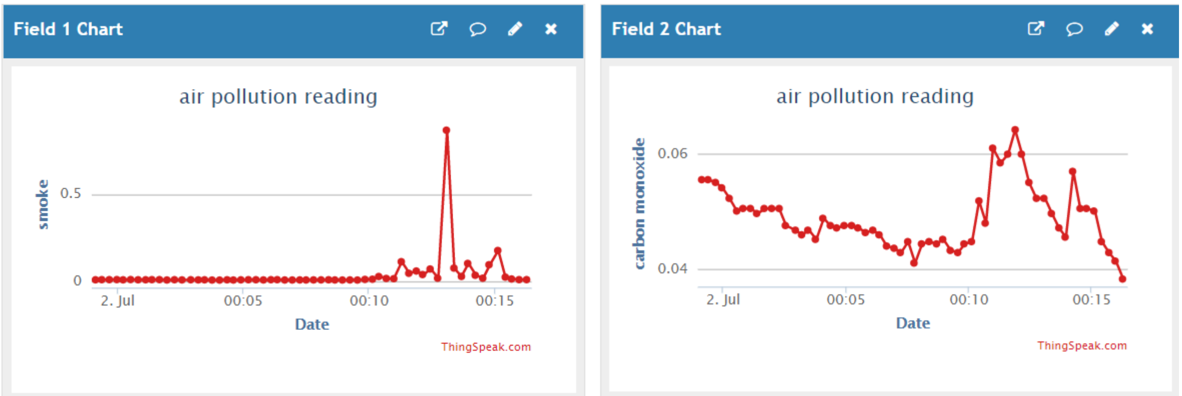
Fig. 7 shows the graph of smoke and carbon monoxide first reading respectively from the ThingSpeak website for testing using cigarettes. The reading rises and decreases immediately from cigarette smoke causing the chart to also increase and decrease downward immediately.



(a) (b)

Fig. 7 - First Reading of (a) smoke reading; (b) carbon monoxide reading

Fig. 8 shows the graph of smoke and carbon monoxide second reading, respectively from the ThingSpeak website for testing using mosquito repellent.



(a) (b)

Fig. 8 - Second reading of (a) smoke reading; (b) carbon monoxide reading

The testing result shows that cigarettes produce more smoke and carbon monoxide than mosquito repellent. This implies that cigarette smoke causes more air pollution compared to mosquito repellent. Cigarette also contains a lot of carbon monoxide, a hazardous gas for the human body if inhaled too much. Carbon monoxide has many severe effects, especially on human health. It is not safe for a human to consume too many carbon monoxides. Based on the graphs, we can see that there is a lot of smoke and low carbon monoxide from the cigarette.

5. Conclusion

In conclusion, air pollution is a vital issue as it keeps increasing into a concerning state. An air pollution detection system can help in the hope of detecting the air quality index as more people become aware of this situation. This air pollution detection system is based on IoT and uses two types of gas sensors which are MQ2 and MQ9 sensors. The system testing is done by using a cigarette to detect the presence of smoke and carbon monoxide. Several improvements can be applied to the system. The suggestion for modifications to be involved in future work is to include time along with the real-time sensor data as well as to display the reading in color according to the Air Quality (AQI) levels.

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