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Development of Particulate Matter Detection and Air Monitoring System by Using Ardunio

Sahazati Md Rozali[1], Nurul Syuhada Mohd Shari[1], Eliyana Ruslan[2], Rosnaini Ramli[1], Mohd Fuaa'd Rahmat[3]
[1]Faculty of Electrical Technology and Engineering, Universiti Teknikal Malaysia Melaka, [2]Faculty of Electronic and Computer Technology and Engineering, Universiti Teknikal Malaysia Melaka, [3]Faculty of Electrical Engineering, Universiti Teknologi Malaysia
Corresponding Author Email: sahazati@utem.edu.my

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Abstract
Air pollution poses a significant threat to both human health and the environment. Among its various pollutants, particulate matter stands out as a major concern. A key indicator of air quality is the amount of particulate matter 2.5 (PM2.5) in the air. Monitoring and detecting the concentration of PM in the air are crucial for assessing air quality and implementing effective pollution control measures. Most studies indicate PM2.5 at or below $12\mu g/m^3$ is considered healthy with little to no risk from exposure. If the level goes to or above 35 $\mu g/m^3$ during a 24- hour period, the air is considered unhealthy and can cause problems for people with existing breathing issues such as asthma. This research developed PM2.5 detection and monitoring system by using Arduino. Dust sensor is used to detect and measure the concentration of PM2.5 in the surrounding air. The sensor employs an infrared LED and a photodetector to analyse the scattering of light caused by the particles. A gas sensor MQ-2 is incorporated to provide support in areas where pollutants like Carbon Monoxide and LPG are present. Arduino functions as main controller to collect data from dust and gas sensor. The data is displayed on LCD screen. This provide information on the air quality and prompt action can be taken earlier.
Keywords: Air Pollution, Particulate Matter, Air Monitoring, Arduino, Sensor

Introduction

Air quality refers to the condition of the air within our surroundings, specifically in relation to the presence of pollutants and other substances that may affect human health and the environment. It is measured by various parameters including levels of pollutants such as particulate matter (PM), nitrogen dioxide (NO2), sulphur dioxide (SO2), ozone (O3), carbon monoxide (CO), and volatile organic compounds (VOCs). Air pollution refers to the presence of harmful substances in the atmosphere that can have adverse effects on human health, ecosystems, and the climate. It arises from both natural sources, such as wildfires and volcanic eruptions, and human activities, such as industrial processes, vehicle emissions, and burning fossil fuels. Air pollution is characterized by the presence of detrimental substances or pollutants in the Earth's atmosphere. These pollutants encompass gases, particles and biological materials which contaminate the air and engender potential hazards to human health, ecosystems, and the overall environment. Particular Matter (PM) such as PM2.5 and PM10 which can penetrate deep into the respiratory system, Nitrogen Dioxide (NO_2) which is produced from burning fossil fuels and Sulfur Dioxide (SO_2) which is emitted from burning coal and coil and contribute to respiratory problems and acid rain are among the common pollutants found in the air. A colorless, odorless gas from incomplete combustion of fossil fuels, which can be harmful in high concentrations which is called Carbon Monoxide (CO) and Ozone 3(O_3) are another type of pollutants which affect the air quality. The main source of air pollution are emissions from transportation, agriculture, domestic activities from residential and commercial and natural sources such as wildfires, dust storm and volcanic eruptions. An exposure to high levels of air pollutants can cause respiratory issues, cardiovascular problems, and aggravated asthma. Even chronic diseases, such as lung cancer, heart disease, and premature death also could be happened because of long term exposure to air pollution. Air pollution also contributes to climate change by increasing greenhouse gas concentrations in the atmosphere while harming wildlife, damaging forests, and affecting bodies of water. Poor air quality can have significant impacts on human health, ranging from respiratory and cardiovascular diseases to more severe conditions such as lung cancer. It is also affecting the environment, contributing to issues like acid rain, ozone depletion, and climate change. Among the various pollutants, particulate matter (PM) emerges as a significant contributor, comprising small particles of dust, smoke, and other substances that when inhaled, can lead to respiratory and cardiovascular diseases. According to the World Health Organization (WHO), outdoor air pollution is responsible for 4.2 million premature deaths annually with PM2.5 being a prominent cause of air pollution- related fatalities. PM2.5 refers to fine particles with a diameter of less than 2.5 micrometres, capable of deeply penetrating the lungs and entering the bloodstream.

Ramírez et al. (2023), presents a review of air quality studies regarding chemical pollutants carried out in university campus during the last 10 years using bibliometric tools and descriptive approaches whereas (Gupta et al., 2024) aims to improve people's productivity and wellbeing in indoor environments by filling the current void in educational institutions' air quality monitoring. The suggested system helps to increase awareness of the significance of indoor air quality among staff, instructors, and students, in addition to acting as a real-time monitoring tool. A literature review on IoT architectures for air quality monitoring using LoRa communication technology is presented in (Vicente et al., 2020). The study aims to support future research initiates on the application of air quality monitoring system using LoRa and presents an overview on sensors, power source, communication, data storage, processing, and visualization technologies used. The study focuses on analysing and predicting air quality using data from two distinct areas Victoria and Rabindra in Kolkata is presented in (Imam et al., 2024). It offers valuable insights into the effectiveness of machine learning algorithms for air quality prediction, with the novelty of the study lying in the focus on hyper-parameter tuning to achieve the highest accuracy.

Yang et al. (2017), proposed a new air quality monitoring and early warning system, including an assessment module and forecasting module. Fuzzy comprehensive evaluation is used to determine the main pollutants and evaluate the degree of air pollution in the first module while in the next module, a novel hybridization model combining complementary ensemble empirical mode decomposition, a modified cuckoo search and differential evolution algorithm, and an Elman neural network, is proposed to improve the forecasting accuracy of six main air pollutant concentrations. (Waworundeng et al., 2021) build the prototype of an air quality monitoring and detection system which used the air quality sensor, temperature and humidity sensor, carbon-monoxide sensor, dust sensor, multiplexer and microcontroller and is implemented in the vehicle cabin. The prototype device is connected to IoT platforms Blynk Apps and Thing Speak. In another research, air quality parameters are monitored using drones in and around solid waste dump yards. This is presented in (Rani Hemamalini et al., 2022) by designing Smart Drone to monitor 9 different pollutants present in the air of Metropolitan City. This method deploys smart drones to monitor air quality and a deep learning model to forecast it will aid in urban sustainable planning and development. AIRO, a decentralised IoT-based air quality monitoring solution proposed to calculate the Air Quality Index (AQI) in real time and notify the users of dangerous AQI levels (Kumar et al., 2023). This portable system can easily be integrated into everyday items for computing real-time air quality at any given place. Another research briefs various state of art methods such as SVM, RF, ANN, RNN and FL in predicting air quality using machine learning (Livingston et al., 2023). The results show that it can be deployed in various cost-effective hardware platforms for household and commercial purposes. The proposed model used eight parameters like NO2, CO, O3, PM2.5, PM10, SO2, TEMP, PRES, DEWP, RAIN, WD, WSPM of Beijing dataset to predict AQI and it is tested with regional dataset.

The main problem of indoor air quality monitoring systems are unreasonable layout of monitoring points and inaccurate data processing. Thus, it is difficult to effectively cope with complex indoor environments. Therefore, (Liu et al., 2024) proposes an intelligent monitoring system for indoor air quality in sports venues based on an improved cohesive hierarchical clustering algorithm to address these issues. The system optimizes the layout of monitoring points, combines real-time data collection on the Android platform, and accurately processes non smooth data using an improved cohesive hierarchical clustering algorithm. With the gradual enhancement of awareness of environmental protection, air quality index forecasting is a key point of environment management. Thus, an innovative forecasting system combining data pre-processing technique, kernel fuzzy *c*-means (KFCM) clustering algorithm and fuzzy time series is successfully developed for air quality index forecasting (H. Yang et al., 2024). The effect of PM2.5 was believed to have caused more adverse effect on human health than PM10. In this study, the concentration of PM10 and PM2.5 during haze and non-haze period was measured. This was followed by the correlation evaluation of the concentration of the two particulate matters with the meteorological factors such as temperature and humidity. An air quality monitoring system utilizing a scalable, low power wide area network, centralized system, and low-cost sensors is proposed (Castor et al., 2024). The nodes gather data on air pollutants and environmental factors. Data conversion, storage, and calculation of air quality indices were processed on the central subsystem and visualization through IoT cloud. Another research presents a system of smart air quality monitoring for urban city area by using IoT Technology (Yusof et al., 2022). Its main purpose is to minimize, improvise, use low-cost configuration, and able to perform as industrial sensor capability, as required by the IEEE 1451 Sensor Standard. This enables the usage of this system in range of 20 meters for the WIFI module. In addition, an effective Internet of Things

(IOT) implementation is employed to monitor air pollution (Singh et al., 2023) which provides a monitoring system for air quality, allowing for real time monitoring. This data is continually transmitted by the system, which employs air sensors for detecting pollutants and carbon dioxide in the air. (Cho et al., 2022) also proposed a smart air quality monitoring and purifying system for the school environment. The developed system consists of an outdoor air quality monitoring system, indoor air purifiers, and a server program running on PC. It allows teachers and students to choose the usage of air purifier or natural ventilation by comparing outdoor air quality and indoor air quality. In addition, the proposed air purifier system includes an intelligent operation that controls the speed of the fan and blower to make sure it does not generate noise that interferes with students in class.

The design of IoT based-air quality monitoring system is proposed in (Rochadiani et al., 2022) by using LoRaWAN for human settlement. It uses WisBlock Kit 4 produced by RAKWireless and the Bosch BME680 based sensor modules to measure air quality index, temperature, humidity, and barometric pressure. The design was evaluated by measuring coverage of LoRa network and the response time of monitoring website to display the air quality data. An air quality monitoring system is also designed in (Nasution et al., 2020) by using ESP32 as a controller and several sensors to measure air quality. The system can monitor temperature and humidity, dust particles and polluting gases (H_2S, NH_3, CO, NO_2, and SO_2).(Hussain et al., 2020) presents a design of real-time Air Quality Monitoring System (AQMS) which incorporates again Internet of Things (IoT) and cloud computing. It utilizes solar panel and battery pack for independent and autonomous operation, thus making it self-powered and sustainable. The system is based on AVR Microcontroller (Atmega32) and GSM modem (Sim900) with low cost and scalable so that around 50nos of such systems can be installed on roundabouts of marketplaces, residential and industrial areas.(Zafra-Pérez et al., 2024) is another work that presents a system to measure air quality by using a wireless sensor network composed of a distributed sensor network linked to a cloud system. The proposed system can efficiently measure air quality as it is cost-effective, small-sized, and consumes little power. The main objective of (Malik et al., 2023) is to develop an economical method of monitoring and alerting of outside air quality in real time. The system uses an ESP8266 Nuttyfi WiFi board as the slave device for internet access and an ATmega328 board as the master controller. To ensure the accuracy of air quality measurements, the device integrates with MQ135 Oxygen air quality sensor, which can identify gases like ammonia, benzene, alcohol, and CO_2. The monitoring capabilities are improved by the DHT11 humidity and temperature sensor, which also records environmental data.

Based on these literatures, it can be concluded that there are various methods for monitoring indoor and outdoor air quality which is based on the usage of internet and cloud database. These methods enable real-time data collection, analysis, and reporting, facilitating more effective and comprehensive air quality management. By integrating sensors, data analytics, and cloud- based platforms, these approaches offer enhanced accuracy and accessibility, allowing for timely responses to air quality issues and better-informed decision-making for public health and environmental protection. This work also aims to design and implement an air quality monitoring system specifically to detect PM2.5 pollutants. According to the World Health. Organization (WHO), outdoor air pollution is responsible for 4.2 million premature deaths annually with PM2.5 being a prominent cause of air pollution-related fatalities.

Monitoring PM concentrations in the air is vital for assessing air quality and safeguarding public health. However, current commercial PM detection and monitoring devices often prove costly, complex, and inaccessible to individuals and communities. Therefore, it is crucial to adopt low-cost and user-friendly monitoring devices to track PM concentrations effectively. In recent years, the utilization of Arduino microcontrollers has gained popularity for developing such devices due to their affordability, versatility, and ease of use. Arduino, an open-source microcontroller board, enables programming to control sensors and interact with the physical world. It finds extensive applications including environmental monitoring. Additionally, the open-source nature of the Arduino platform allows for the freedom to modify and customize its hardware and software. (Abraham et al., 2014) present a low-cost indoor air quality monitoring wireless sensor network system which can collect six air quality parameters from different locations simultaneously. It is developed by using Arduino, XBee modules, and micro gas sensors. The research also constructs a linear least square estimation-based method for sensor calibration and measurement data conversion. A low cost, mobile Air Pollutant Index (API) Monitoring System, which consists of Sharp GP2Y1010AU0F optical dust detector as a sensor for dust, Arduino Uno and LCD Keypad Shield is developed in (Norhafizah, 2018). The system is applied in industrial areas around Parit Raja, Johor. In this research, a signal conditioner has been used to amplify and extend the range of the sensor reading to obtain accurate result. The readings from the sensor have been compared with reference data from the Department of Environment, Malaysia to ensure the results validity of the developed system. Another system for indoor air quality monitoring has been developed in (Rudavskyi et al., 2023). It is created based on the Raspberry Pi 4 microcomputer and the Arduino hardware- programming platform. Information fusion algorithm was used to analyse the measured parameters. In (Kosim et al., 2022), air quality is monitored by using Matlab. This work studies the real-time communication between Arduino UNO and Matlab. The main component used are Arduino UNO, MQ7 carbon monoxide sensor, and MQ135 air quality sensor. Another system that used Arduino Uno integrated with sensors is proposed in (Ho et al., 2024). It employs Optical dust sensor and MQ-135 sensor to monitor dust, pollen, and smoke levels in the atmosphere. The collected data is utilized to analyse and calculate the Air Quality Index (AQI), which is then displayed on the LCD screen.

Monitoring and improving air quality involve both regulatory efforts and individual actions, such as reducing emissions from vehicles and industries, promoting clean energy sources, and planting trees. Public awareness and policy interventions play crucial roles in safeguarding air quality and mitigating its adverse effects. Monitoring PM concentrations in the air is vital for assessing air quality and safeguarding public health. However, current commercial PM detection and monitoring devices often prove costly, complex, and inaccessible to individuals and communities. Therefore, it is crucial to adopt low-cost and user-friendly monitoring devices to track PM concentrations effectively. In recent years, the utilization of Arduino microcontrollers has gained popularity for developing such devices due to their affordability, versatility, and ease of use. Arduino, an open-source microcontroller board, enables programming to control sensors and interact with the physical world. It finds extensive applications including environmental monitoring. Additionally, the open-source nature of the Arduino platform allows for the freedom to modify and customize its hardware and software. Typically, Arduino-based PM detection and monitoring systems employ sensors capable of detecting PM in the air. These sensors can be connected to the Arduino board which processes the collected data and presents the PM concentration on an LCD screen or other output devices. Arduino-based systems are often characterized by their low-cost, user-friendly nature and flexibility to cater to specific user requirements. Individuals, communities, and organizations can utilize these systems to monitor air quality and adopt appropriate measures to mitigate the health risks associated with air pollution.

The current system which utilizing Arduino has limited accessibility to detect and monitor particulate matter 2.5 (PM2.5) concentration in the air. In addition, the price is quite high for domestic usage in our community. Therefore, this research proposed prototype development of the low cost and user friendly PM2.5 detection and monitoring system by using Arduino. The designed system displays the reading of PM2.5 concentration on LCD screen such that the information can be used as indicator for level of environmental cleanliness. This low cost and user-friendly system are targeted to monitor air quality and corrective action can be taken immediately if there are unusual readings on the air quality system. The robustness of the prototype is tested in different environment and conditions.

Methodology

The main components that are involved in this research are MQ2 dust sensor, LoRa module, Arduino Uno R3, Node MCUV3 ESP8266 and LCD display. The system's operation starts by activating both sensor nodes, serving as the transmitters and receiver. When the sensor node is ON, the calibration of the gas sensor MQ-2 and GP2Y1010AU0f dust sensor takes place. Subsequently, the sensor node proceeds to continuously measure the gas concentration level and transmit the corresponding measured values in parts per million (ppm) to the gateway every 30 seconds. Upon receiving the data, the gateway processes it to extract pertinent information. The processed data, representing the gas concentration level in ppm is then display on LCD display and updated on the Telegram application. Additionally, the Telegram Bot sends a notification to the responsible individual through the Telegram application. This entire sequence of operations is reiterated until the system is powered OFF. The operation of the developed system is represented by Figure 1.

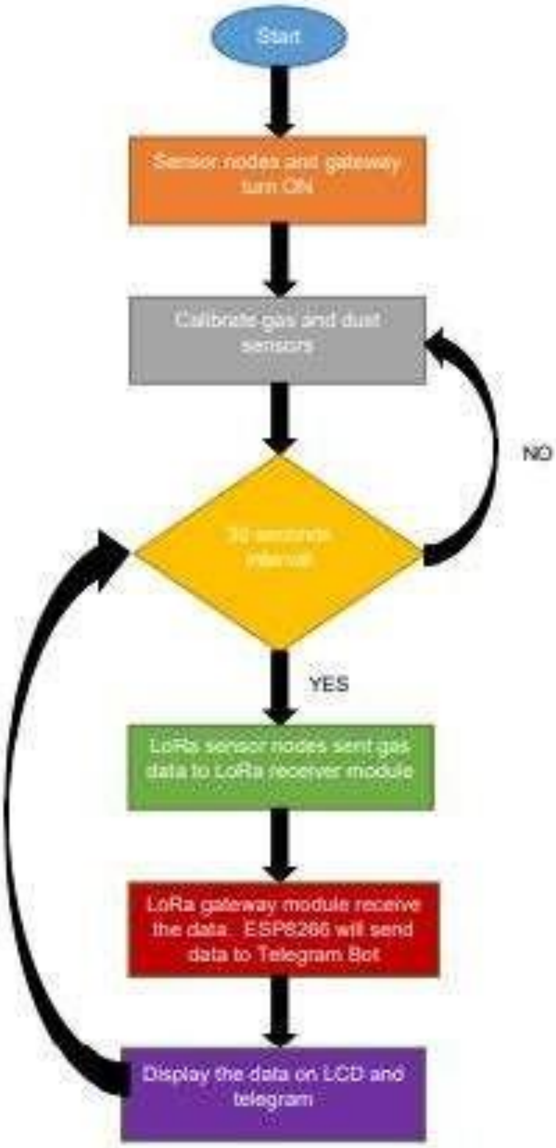

Figure 1: Flowchart of the Project

Figure 2 illustrates the input output relation between each component of the system. The proposed system comprises two parts: transmitter and receiver. The controller for both the transmitter and receiver is implemented using Arduino Uno R3. In this study, the transmitter corresponds to the sensor nodes situated in the monitored area. These sensor nodes are equipped with two gas sensors, namely the MQ-2 sensor and GP2Y1010AU0f dust sensor. The MQ-2 sensor enables the measurement of various gases such as Liquefied Petroleum Gas (LPG) and Carbon Monoxide (CO). On the other hand, the GP2Y1010AU0f dust sensor detects PM2.5 and counts particles. MQ-2 sensor able to detect gas concentrations ranging from 300 to 10,000 parts per million (ppm) which allows us to address the presence of Particulate Matter in polluted areas. The receiver, on the other hand, corresponds to the gateway responsible for aggregating all the monitored data. The gateway is equipped with an LCD display and aNodeMCU V3 ESP8266. Therefore, once the gateway receives the monitored data, ESP8266 will process the data and upload the processed data to the Telegram Bot. Then, Telegram Bot will send a notification to the in-charge person.

Furthermore, the processed data is uploaded to the LCD for display. As discussed earlier, the LoRa module is being used in this project because the communication medium between the transmitter (sensor node) and the receiver (gateway) due to its long-range communication capabilities and low power consumption.

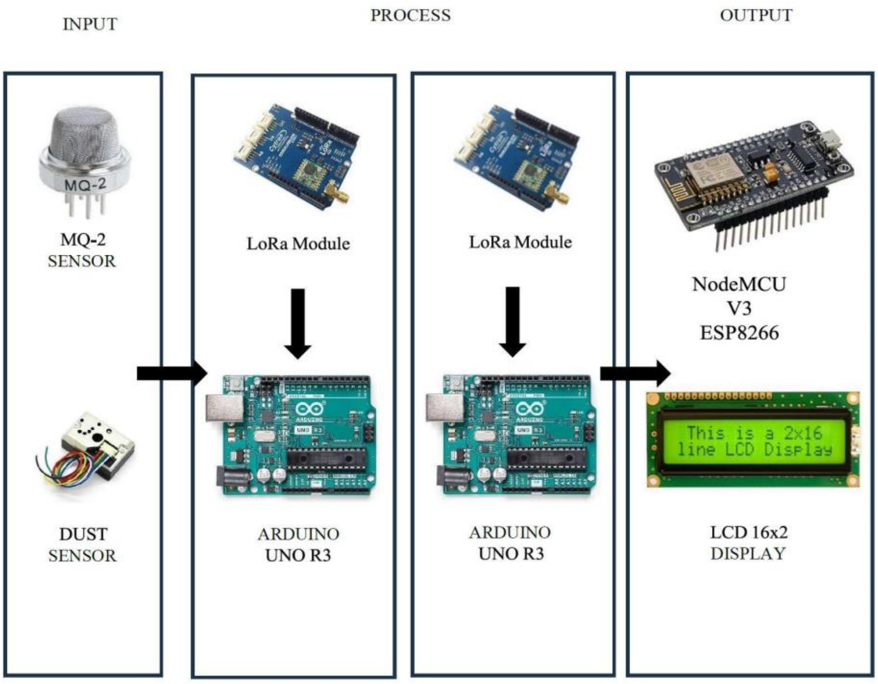

Figure 2 : Input output relation between each component of the system
The connection between LoRA and Arduino Uno is shown in Figure 3.

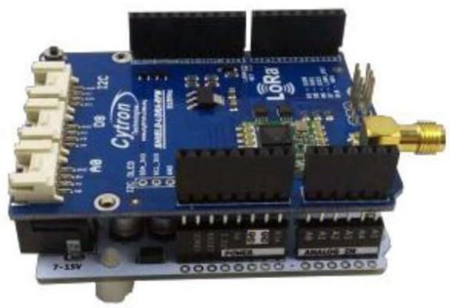

Figure 3: Arduino Uno R3 and LoRa Cytron RFM Shield Pin Layout

The LoRa Cytron RFM Shield is typically designed to work with Arduino Uno R3 boards. It has a pin layout compatible with the Arduino Uno in terms of its physical dimensions and connectivity. The LoRa module is specifically designed to be placed on top of an Arduino Uno, aligning with the standard pin layout to ensure compatibility. The transmitter schematic diagram is illustrated in Figure 4 while the receiver circuit diagram is shown in Figure 5.

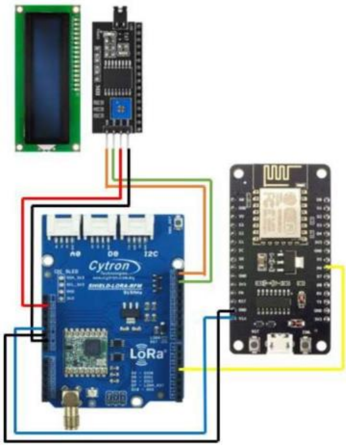

Figure 4. Wiring Schematic Diagram for Transmitter

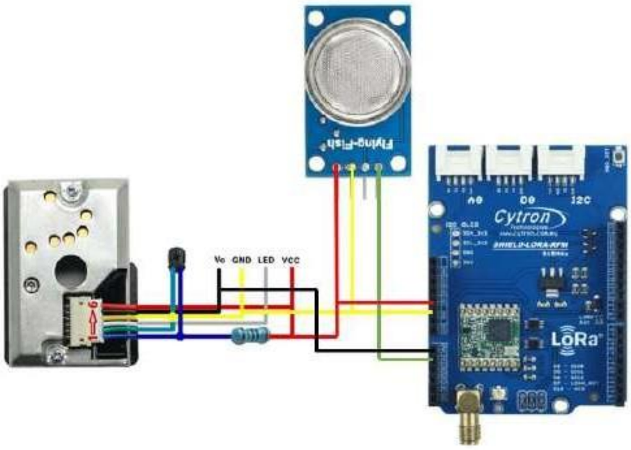

Figure 5: Wiring Schematic Diagram for Receiver

The hardware configuration of the project transmitter and receiver are illustrated in Figure 6 and Figure 7 respectively.

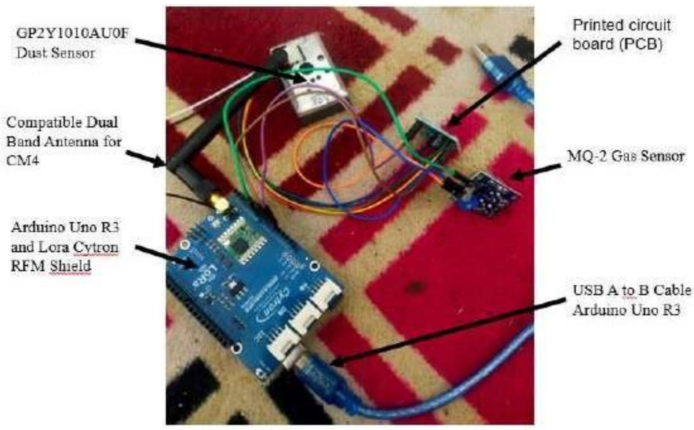

Figure 6: Hardware configuration of the project transmitter

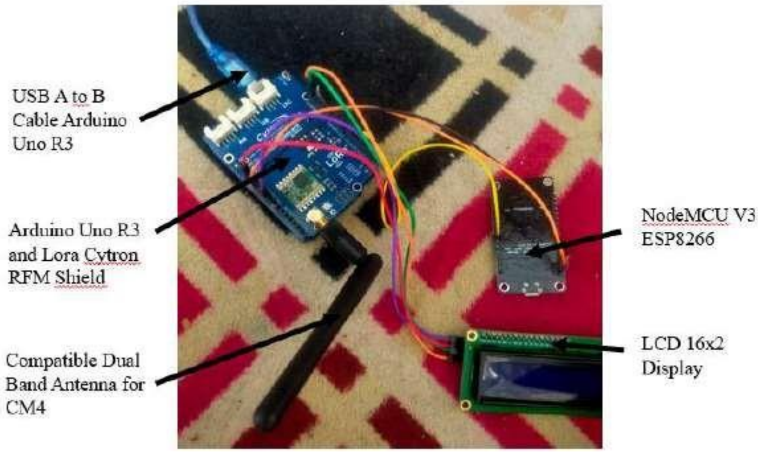

Figure 7 : Hardware configuration of the project receiver

Data is displayed in telegram message as shown in telegram interface in Figure 8.

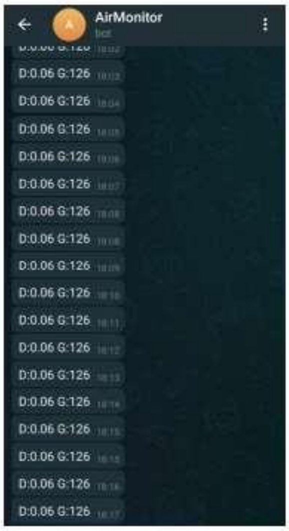

Figure 8:Telegram Interface

Figure 8 shows the project Telegram Bot message on Mobile Application using Telegram. In this project, Telegram Bot is utilised to display values obtained from the input sensors and notify users when it becomes clear that it is air pollution. Telegram can communicate with what we programmed in Arduino IDE by using an authentication token that is suited only for one device. Once the Telegram is connected, the value from sensors is collected and immediately displayed to Telegram application. In addition to displaying the value of sensors that are being utilized for this project, this Telegram interface is equipped with two values for dust and gas sensor. This is shown in Figure 9.

Telegram Bot Messages	Function
D:0.25	Display dust density to user for monitor. The unit for dust density is Microgram per Cubic Meter µg/m3
G:174	Display gas to user for monitor. The unit for gas is Parts-Per-Million (PPM)

Figure 9: Telegram Bot Messages on Telegram Application

The result in Telegram Bot messages show the same value with the value that appear in LCD screen. D in Telegram Bot messages and at LCD screen stand for dust density while G in Telegram Bot messages and at LCD screen stand for gas.

Results and Discussion

Figure 10 and Figure 11 show the telegram and LCD screen when the dust is not detected, and dust is detected, respectively.

Figure 10: The telegram and LCD screen when dust is not detected

Figure 11: The telegram and LCD screen when dust is detected

Smoke from matchstick flow through GP2y1010AU0F dust sensor to supply PM2.5 dust particles. When the dust sensor detects dust particles from smoke, the dust values will increase. Telegram bot messages notification show the same value with the value that appear in LCD screen. Note that, D in Telegram bot message and at LCD screen stand for dust density.

Figure 12 and Figure 13 shows the demonstration of how the MQ-2 gas sensor works with LCD screen and Telegram Bot. Gas from lighter work as gas supplier. When the gas sensor detects gas from lighter, the gas values will increase. Telegram Bot messages notification show the same value with the value that appear in LCD screen. G in Telegram Bot message and at LCD screen stand for gas.

Figure 12: LCD screen and Telegram notification when gas no detected

Figure 13: LCD screen and Telegram notification when gas is detected

The designed prototype is located around the area of Scientex Durian Tunggal Melaka. The data is recorded within three days from 6th January 2024 until 8th January 2024. The prototype captured data on Carbon Monoxide (CO) and PM2.5 around the testing area. Figure 14 until Figure 16 illustrated the reading of CO within these three days while Figure shows PM2.5 within the same days.

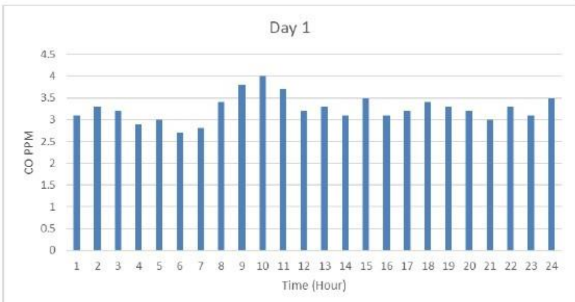

Figure 14: CO Concentration on 6th January 2024(Saturday)

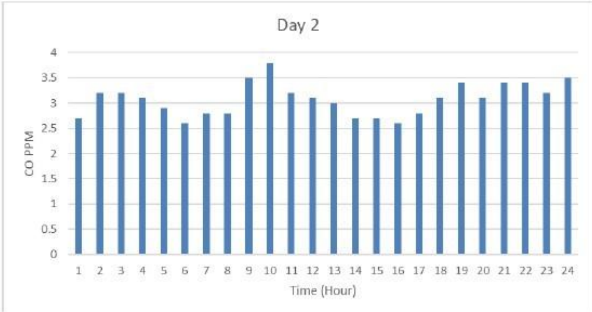

Figure 15: CO Concentration on 7th January 2024(Sunday)

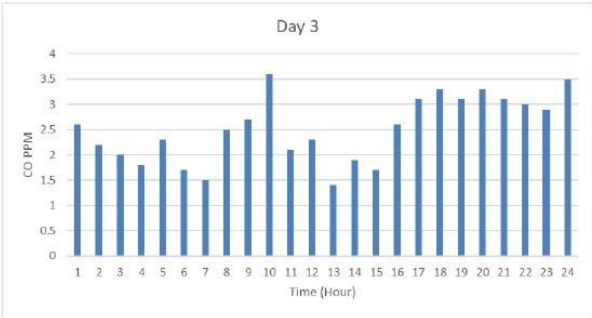

Figure 16: CO Concentration on 8th January 2024(Monday)

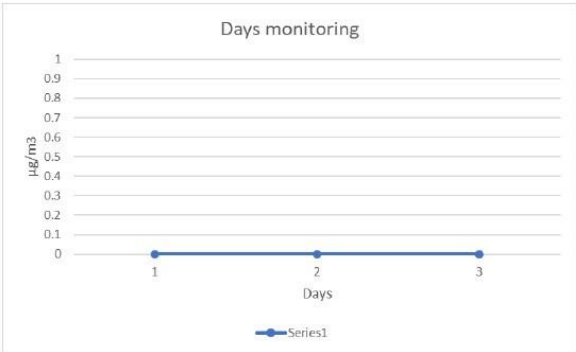

Figure 17: PM2.5 Dust Particles within 3 Days

Based on the three readings on the graphs of CO concentration, the patterns of the graphs within these three days almost similar. The reading is lower in the early of the morning and start increasing or decreasing until reach the peak value at 10 am. The CO concentration is higher within 9 am to 11 am on every day. This might be happening because the frequency of activities and number of people in this area is increase during this period. This reading is start reducing and climbing again and get to the maximum value at around 6 pm. The situation occurred since it is the peak time of activities in that area. Graph in Figure 17 indicates that zero PM2.5 is detected within that area since the industrial activities in the area might be lower.

The prototype testing is continued by locate it in the industrial area in Ayer Keroh with variety types of factories around it. Beside smoke, the dust sensor also detects the presence of PM2.5. Table 1 list down the reading of smoke and PM2.5 detected by the system.

Table 1
The reading of smoke and PM2.5 detected by the system

Time	**Component Detection**	**Component Value**
1	**PM2.5 (µg/m3)**	**0**
	Smoke (PPM)	126
2	**PM2.5 (µg/m3)**	**0.13**
	Smoke (PPM)	140
3	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	138
4	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	135
5	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	128
6	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	128
7	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	128
8	**PM2.5 (µg/m3)**	**0.11**
	Smoke (PPM)	123
9	**PM2.5 (µg/m3)**	**0.12**
	Smoke (PPM)	121
10	**PM2.5 (µg/m3)**	**0.11**
	Smoke (PPM)	124
11	**PM2.5 (µg/m3)**	**0.07**
	Smoke (PPM)	126
12	**PM2.5 (µg/m3)**	**0.07**
	Smoke (PPM)	230
13	**PM2.5 (µg/m3)**	**0.19**
	Smoke (PPM)	168
14	**PM2.5 (µg/m3)**	**0.25**
	Smoke (PPM)	159
15	**PM2.5 (µg/m3)**	**0.32**
	Smoke (PPM)	150

Referring to Table 1, PM2.5 reading is detected with the increment of smoke and time. The smoke produced from the industrial activities around the area contribute to this reading. The reading is recorded within one hour between 8 pm to 9 pm. These reading is displayed in telegram bot as shown in Figure 18.

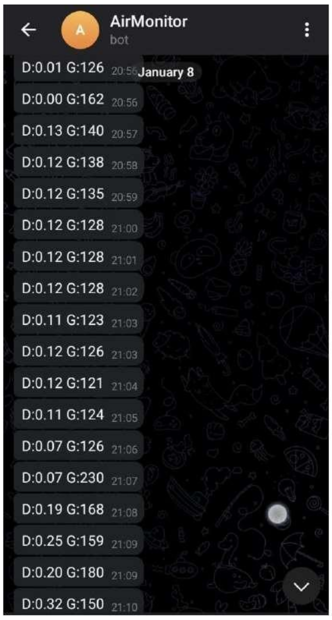

Figure 18: Telegram bot display for PM2.5 and smoke detected by dust sensor

In addition to Ayer Keroh industrial area, the monitoring and recording is also documented around several other areas; Taman Scientex Durian Tunggal, UTeM Archway, Zoo Melaka, and Hospital Pantai Ayer Keroh. Taman Scientex is chosen since this area is densely populated. The transmitter is in this area and several transmitters are distributed in these four places.

UTeM archway is chosen since it is full of the movement of crowd while Zoo Melaka area is also chosen because the routes is being used by vehicles entering and exiting Melaka. Hospital Pantai Ayer Keroh is also among the busy route in Ayer Keroh since it is located on the fourth junction of traffic light and near to the food stalls and schools. Table 2 shows data recorded in these areas.

Table 2
Data Recorded in Four Different Areas

Transmitter Location	**Receiver Location**	**Component detection**	**Component value**
Taman Scientex	Taman Scientex	**PM2.5 (µg/m3)**	0.5
		Smoke (PPM)	126
Taman Scientex	UTeM Archway	**PM2.5 (µg/m3)**	0.13
		Smoke (PPM)	140
Taman Scientex	Zoo Melaka	**PM2.5 (µg/m3)**	0.12
		Smoke (PPM)	138
Taman Scientex	Hospital Pantai Ayer Keroh	**PM2.5 (µg/m3)**	0.12
		Smoke (PPM)	135

The table demonstrates the reading of PM2.5 and smoke levels at various receiver locations from the transmitter in Taman Scientex. At Taman Scientex, PM2.5 value detected is the lowest at 0.5 µg/m^3, and smoke levels are 126 PPM. UTeM Archway shows the increment value of PM2.5 to 0.13 µg/m^3 and smoke levels increase to 140 PPM. This might be happened because the movement of crowd in the university campus which involved variety of vehicles. Zoo Melaka and Hospital Pantai Ayer Keroh also illustrates the similar trends of PM2.5 levels which remain at 0.12 µg/m^3, and smoke levels hover between 135 and 138 PPM. Though these two areas are the main and busy routes, the reading of PM2.5 at these areas is almost similar with the UTeM Archway since these two locations cover wide areas therefore the distribution of smoke is wider compared to the UTeM area. Besides, the distance between the transmitter and receiver also influenced the reading of dust sensor since Zoo Melaka and Hospital Pantai are quite far from Taman Scientex, the location of transmitter.

Based on the table also, the mean PM2.5 concentration is 0.18 µg/m3, with a median value of 0.12 µg/m3. This suggests that the PM2.5 concentrations are generally low, with a slight skew towards higher values. On the other hand, the mean Smoke concentration is 134.75 PPM, with a median value of 135 PPM which indicates that the Smoke concentrations are relatively consistent across locations. The highest value of PM2.5 is recorded at Taman Scientex (Transmitter) - Taman Scientex (Receiver) while the highest value of smoke concentration is recorded at Taman Scientex (Transmitter) - UTeM Archway (Receiver). Therefore, in addition to the distance, the reading of the prototype's sensor is also influenced by the environment, surrounding weather and light.

Conclusion

In conclusion, the development of a particulate matter detection and monitoring system in air pollution using Arduino is a crucial step towards creating a more sustainable and environmentally friendly future. The system's ability to detect and monitor PM2.5 concentrations in real-time provides valuable insights into air quality, enabling individuals and authorities to get the information of the effects of air pollution. The proposed system's advantages, including its low cost, ease of use, and real-time monitoring capabilities, make it an attractive solution for air quality monitoring in various settings, including urban and rural areas, industrial zones, and residential neighborhoods. Thus, the public can be educated about the importance and risk of air quality such that the proactive action can be taken to reduce the long exposure to the poor air quality. As the system is scalable and adaptable, it can be replicated and customized to suit various applications, making it a valuable contribution to the field of environmental monitoring and sustainability.

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