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Designing and Implementing a System to Monitor the Air Quality of Abbottabad City

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ABSTRACT

This research investigates air quality and environmental conditions at COMSATS University Islamabad Abbottabad Campus and Missile Chock using IoT-based sensors. Sensors were deployed at both sites to monitor PM 2.5 levels, AQI, temperature, humidity, and gas concentrations. Data was collected over specific intervals and analyzed to identify trends and differences. The methodology involved using IoT-based sensors to capture real-time data on environmental parameters and air quality indicators at both locations, i.e., COMSATS University and Missile Chowk. At COMSATS University, PM 2.5 levels consistently fell within the "Good" category, with readings ranging from 11 to 35 μg/m^3. AQI values improved over time, dropping from 91 to 2, indicating effective air quality management. Temperature and humidity remained stable, ranging from 19°C to 21.4°C and 57% to 63%, respectively. The MQ-2 sensor said that the gas levels were between 2550 and 3776 parts per million. On the other hand, Missile Chock had higher PM 2.5 levels, which varied from "Moderate" to "Poor," with values between 11 and 139 μg/m^3. Initially, the AQI measurements revealed "Moderate" pollution, but with time, they became better and reached "Good." The humidity was between 18% and 20%, while the temperature was between 30°C and 31.5°C. The MQ-2 sensor results showed that the gas levels were generally high, between 3887 and 4159 ppm. The survey shows that major cities like Missile Chock have greater pollution because of people and automobiles. On the other hand, green locations like COMSATS University have cleaner air. We need to always be aware of air pollution and do something about it so that the air quality in cities improves and the health hazards that come with it decrease.

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1. Introduction

Air pollution is a big problem that hurts people's health and the environment all around the world. People have become more anxious about air quality in cities in recent years because of how quickly cities have grown, how quickly industries have grown, and how quickly populations have grown. This issue isn't only in Abbottabad, which is in Pakistan's Khyber Pakhtunkhwa province. Over the past 10 years, Abbottabad has changed a lot in terms of how land is used and how rapidly it is built (Naz & Sheeba Afsar, 2024). This is because it is a popular place for tourists to go and study. Individuals are anxious about how these changes could influence the health of individuals who reside there and the quality of the air. It's crucial to have a reliable means to keep an eye on air quality so that people in Abbottabad city don't have to worry as much, and the city is a nicer place to live. This sort of equipment would tell you about significant pollutants, including particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), as well as the temperature and humidity levels in real time. Policymakers, researchers, and average people may learn a lot about the air quality in different regions of Abbottabad city by keeping a watch on these things all the time. When planning an air quality monitoring system for Abbottabad city, there are a number of elements to keep in mind. First of all, it should have sensors that are reliable and can accurately monitor how much pollution is in the air surrounding it. It is vital to pick these sensors carefully based on how sensitive, precise, and quick they are, as well as how well they perform in the area where they will be used (Ali, Raza, Saghir, & Khan, 2021). Second, the system needs a good way to collect information so that it can keep an eye on all the different parts of Abbottabad city. You may achieve this by establishing monitoring stations in different parts of the city in a way that makes sense so you can see how the air quality changes from one area to another. There also has to be a strong communication network so that this monitoring equipment can deliver data to a central database or online platform in real time. People who care about the problem may look at the data that was collected, determine where pollution levels are high, and figure out the best way to clean up the air. It should also be able to display information in a style that is simple to read and understand. This will let both average people and politicians know how clean the air is in Abbottabad. If Abbottabad city had a mechanism to check the air quality, good things may happen. It can help people understand how important it is to have clean air and get them to act. It can also help policymakers make choices based on facts about how to clean up the air and make it safer for people's health. Lastly, it's extremely vital to put up a whole system to keep an eye on the air quality in Abbottabad city to preserve people's health and deal with environmental problems. Our system can help make Abbottabad city a healthier place to live by using reliable sensors, setting up an effective way to collect data, making sure communication networks work smoothly, and giving people access to tools that let them see the data in a way that makes sense (Ali et al., 2021; Kuncoro, Mellyanawaty, Sambas, Maulana, & Mamat, 2020; Mehmood, Bao, Petropoulos, Abbas, Abrar, Mustafa, & Fahad, 2021; Nakamitsu, 2019; Raza, Raja, Raza, & Lindgren, 2012; Ullah, Usama, Abbas, & Muhammad, 2024; Usama, Gardezi, Jalal, Rehman, Javed, Janjua, & Iqbal, 2023).

1.1. Sensors in Measuring Air Quality

Different sensors are used to identify the quality of air and make a secure and safe environment for public health. Different types of sensors are given below which are used widely and have a great accuracy impact.

1.1.1. Arduino works as micro controller measuring air quality

Arduino is an outdoor air quality monitoring cost efficient device. This device can monitor real time data and can count the total number of number of pollutants the air and transfer this directly to the wirelessly server. The Arduino system is integrated with SCADA, yet its utilization has been confined to the exclusive monitoring of CO_2 levels (Azim, 2022; Khalid, 2024). It works as a microcontroller in which data is recorded without using any wirelessly materials and automatically captures the data of air quality. All the data in this are recorded through ZigBee mesh network. This gadget uses Arduino Uno as the brain because it's cheaper than alternatives like Raspberry Pi and Beagle Bone. Arduino Uno is the most cost-efficient device in all types of Arduinos. Arduino Uno has 14 digital input/output total pins and contains 6 analog input pins; it has LCD display of 16 x 2 and also contain an SD card to keep track of data. Arduino Uno is the fundamental and widely used board among all the Arduino boards (Al Ahasan, Roy, Saim, Akter, & Hossain, 2018; Kelechi, Alsharif , Agbaetuo, Ubadike ,Aligbe, Uthansakul, & Aly, 2022; Kuncoro et al., 2020). It has an automatic monitoring system; it sends data to the cloud system using a wireless module. Next to write code for Arduino Uno, we use Arduino IDE, which is a tool for creating programs for Arduino (data reading sensor microcontroller), now to read the data we create a channel on ThingSpeak to gather the measurement data sent by the Arduino (Marques, Ferreira, & Pitarma, 2019).

1.1.2. DHT11 Sensor for sensing temperature and humidity.

The DHT11, a temperature and humidity sensor, features four pins - VCC, GND, Data Pin, and an unconnected pin. Communication with the microcontroller involves a pull-up resistor ranging from 5k to 10k ohms. The sensor incorporates a capacitive humidity sensing element and a thermistor for temperature measurement. With two electrodes within the humidity sensing capacitor and a moisture-holding substrate as a dielectric, changes in humidity levels alter capacitance values. The integrated circuit (IC) processes these changes in resistance, converting them into a digital format. Using a Negative Temperature Coefficient thermistor, the sensor's resistance decreases with rising temperature. The DHT11 is a suitable choice since it is cheap, reliable, reads rapidly, and can prevent interference. Because it is small and can send signals up to 20 meters, it may be utilized in a number of different scenarios. Digital signal calibration makes sure that the sensor gives you the right information regarding temperature and humidity. People know it for being stable, working with ATmega8 microcontrollers, and keeping calibration coefficients in OTP program memory. The DHT11 is an excellent way to keep an eye on the humidity in the air. This can change how quickly electrical equipment rusts and other things. People remark that the sensor is correct, simple to use with Raspberry Pi, and a good way to find out how humid it is in different places. Gunawan, Munir, Kartiwi, and Mansor (2018); Nasution, Muchtar, and Simon (2019).

Fig. 1 DHT-11 sensor (Ali et al., 2021)

1.1.3. MQ-135 Gas Sensor Detecting Harmful.

The MQ-135 Gas Sensor can find dangerous gases, including ammonia (NH3), sulfur (S), benzene (C6H6), CO2, smoking, acetone, thinner, and formaldehyde. The sensor needs 5VDC of power and 0 to 20mA of current to work. It can function in temperatures between -10°C and 70°C. The MQ-135 can locate a lot of different gases in a lot of different places since it can measure amounts from 20 to 2000 ppm. It is a useful tool for keeping an eye on and finding certain gases when safety and the environment are very important (Kuria, Robinson, & Gabriel, 2020). The MQ135 is attached to an Arduino Uno board as shown in the figure below.

Fig. 2 MQ-135 Gas Sensor

It gives us a reading called AQI (air quality index). We keep an eye on the data coming from the Gas Sensor in terms of AQI. If it goes higher than 150, a buzzer makes a sound. All this information is sent to the Things board API cloud. The cloud stores all the data that the microcontroller sends through the Wi-Fi module, keeping it updated on the internet. You can check out the data on a webpage we created (Novelan & Amin, 2020).

2. Literature Review

An Internet of Things (IoT)-based air quality monitoring system was implemented in Tasikmalaya city, Indonesia. Utilizing Arduino microcontrollers and various sensors (Mq-131 for ozone, Mq-7 for carbon monoxide, and Mq-4 for methane), the system provided real-time air quality data accessible through web-based graphs. The data collected over ten days at the Tasikmalaya Bypass Roundabout indicated good air quality, with average concentrations of 1.51 ppm for carbon monoxide, 329.95 ppm for methane, and 0.09 ppm for ozone. However, the system's reliability might have been influenced by the calibration of individual sensors, as the calibration phase was crucial for maintaining accuracy. Inexpensive sensors typically have large parameter tolerances, and differences in response curves among sensors of the same type might affect overall data consistency. Further research and refinement of calibration methods are essential for ensuring the system's accuracy across various sensors and environmental conditions, particularly for widespread deployment in different areas of Tasikmalaya. (Jha, 2020). The iAirCO2 system, an IoT-based solution for real-time monitoring of indoor air quality (IAQ) with a focus on carbon dioxide (CO2) levels. This is a cheap, simple, and flexible way to improve your health in smart living spaces. The study emphasizes the importance of monitoring CO2 levels for public health, occupational health, and the overall well- being of individuals in indoor spaces. But the iAirCO2 system demonstrates promising features for CO2 monitoring in real-time, its specific focus on a single pollutant may limit its comprehensive assessment of overall IAQ, as other pollutants and factors contributing to indoor environmental quality are not extensively addressed. Further research could explore the integration of additional sensors to provide a more holistic evaluation of indoor air conditions, considering various pollutants and environmental parameters (Rani, Rajarajeswari, Jaimon, & Ravichandran, 2020).

Table 1 –Limitations of Air Monitoring Devices in detail.

Ref	Forms of Air Monitoring Devices	Description	Limitation
(Jo, Jo, Kim, Kim, & Han., 2020)	Smart Air	This system has sensors to detect air quantity, it detects pollutants and analyze and present data, this device is connected to IoT.	It uses certain sensors for measuring gases. These sensors need regular checkup as it may sometimes does not give accurate data in the long run
(Saad, Saad, Kamarudin, Zakaria, & Shakaff, 2013)	Indoor Air Quality (IAQ) monitoring systems, with Wireless Sensor Network (WSN)	IAQ give emphasis to WSN by developing IoT and it gives future direction which include real time execution, the prediction of air quality for making safe environment at homes and workplaces.	Due to the high-power consumption and limited communication range of WSN, this system requires development in terms of IoT for better utilization of IAQ monitoring devices
(Saha, Das, Datta, & Neogy, 2016)	Cloud-based framework for WSN	Cloud-based framework for monitoring and controlling wireless sensor networks, specifically designed for air quality assessment. The system integrates storage, end-user access, sensor data checking, e-learning mechanisms, and security services, demonstrating its functionality through the discrimination and quantification of BTEX compounds.	The system relies on resistive sensors, which react to a limited set of compounds, and artificial neural networks which are basically computer program use for pattern recognition. This limits the system's ability to detect a broad range of pollutants, and further research is needed to enhance its capabilities.

(Letsoalo, Mogashane, Mashale, Ntsasa, Mkhohlakali, & Tshilongo, 2024)	Cost-efficient Internet of Things (IoT) integrated with IAQ	Affordable, transportable, Internet of Things (IoT)-enabled air quality monitoring system for detecting pollutants such as particulate matters, smoke, and carbon	The system's application might be limited by its dependence on sensors (MQ2, MQ9, PMS3003), and more research might be necessary to increase its

This research presents several unique contributions to the existing body of work on air quality monitoring systems. Firstly, it integrates the Internet of Things (IoT) with cloud platforms like ThingSpeak, allowing for real-time data processing and visualization. This enhances both the accuracy and accessibility of the air quality data. Secondly, the deployment of a diverse range of sensors (MQ2, MQ9, MQ135, PM2.5, DHT11) provides a holistic view of air quality by monitoring multiple pollutants and environmental parameters. Unlike some previous studies, my system includes a comparative analysis with other research, validating the accuracy and reliability of the system in different environments, such as COMSATS University and Missile Chock. Additionally, the data collected is used not only for monitoring but also for informing public health strategies and urban planning, demonstrating the practical applications of the research. Furthermore, my study specifically addresses the unique environmental and pollution challenges of Abbottabad City, making it highly relevant to the local context. These aspects collectively underscore the significance of my research in advancing air quality monitoring solutions

3. Research Methodology

3.1. Study Area

In this research, two distinct experimental areas are employed to provide a comprehensive understanding of the topic. And these areas are given below:

3.1.1. Comsats University Islamabad Abbottabad Campus

This location is an educational institution known for its academic environment and relatively lower levels of industrial activities. The air quality measurements taken at this site provide insights into the pollution levels in a primarily academic and green campus setting. The data collected here helps to understand the impact of natural and human activities on air quality within a controlled, less polluted area.

Fig. 3 COMSATS University Islamabad Abbottabad Campus

3.1.2. Missile Chock

Missile Chock is a bustling area in Abbottabad characterized by higher levels of urban activities and traffic congestion. This location represents a typical urban environment with significant vehicular emissions and other sources of pollution. Monitoring air quality at this site allows for the evaluation of pollution levels in a densely populated and high-traffic area, providing a stark contrast to the data collected at the university campus.

Fig. 4 Missile Chock

3.2. Air Quality Index (AQI): Understanding and Assessing Air Quality Levels

The AQI (Air Quality Index) is a record for revealing typical air quality. It demonstrates how outstanding or lamentable the atmosphere, and related prosperity consequences might be a worry. The AQI bases on prosperity influences people could understanding inside two or three days or hours after inhaling depressing air. The not set in stone for four critical air pollutions coordinated by the Ideal Air Act: ozone at ground level, particle tainting, carbon monoxide, and sulfur dioxide. The AQI possesses a scale with a range of 0 to 500. The greater the AQI regard, the more imperative the air level defilement and the more critical the prosperity worry. As a case study, an AQI worth of 50 tends to extraordinary quality of the air with practically no likelihood to impact general prosperity, while an AQI regard more than 300 addresses air quality so dangerous that everyone could have detrimental consequences. The inspiration driving the AQI is to help you with sorting out what close by what air quality entails for your prosperity.

Table 2 –Numerical Value of Air Quality Index Level of Health concern.

Air Quality Index Level of Health concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for very small number of people who are unusually sensitive to air pollution.

Unhealthy for sensitive Group	101 to 150	Members of sensitive groups may experience health. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardour	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected (Kumar, Kumari, and Gupta, 2020)

Table 3 – Air Quality Measurements at COMSATS University and Missile Chock during winter.

Location	Time Interval	Number of Samples	Category	Season
COMSATS University Islamabad Campus	8:02 am	2	Good	Winter
COMSATS University Islamabad Campus	8:01 am	2	Good	Winter
COMSATS University Islamabad Campus	8:10 am	2	Good	Winter
COMSATS University Islamabad Campus	8:20 am	2	Good	Winter
COMSATS University Islamabad Campus	8:30 am	2	Good	Winter
COMSATS University Islamabad Campus	8:40 am	2	Good	Winter
COMSATS University Islamabad Campus	8:50 am	2	Good	Winter
COMSATS University Islamabad Campus	9:00 am	2	Good	Winter
COMSATS University Islamabad Campus	9:10 am	2	Good	Winter
COMSATS University Islamabad Campus	10:30 am	2	Good	Winter
COMSATS University Islamabad Campus	11:00 am	2	Good	Winter
Missile Chock	8:02 am	2	Moderate	Winter
Missile Chock	8:01 am	2	Moderate	Winter
Missile Chock	8:10 am	2	Poor	Winter
Missile Chock	8:20 am	2	Poor	Winter
Missile Chock	8:30 am	2	Poor	Winter
Missile Chock	8:40 am	2	Poor	Winter
Missile Chock	8:50 am	2	Poor	Winter
Missile Chock	9:00 am	2	Moderate	Winter
Missile Chock	9:10 am	2	Good	Winter
Missile Chock	10:30 am	2	Good	Winter
Missile Chock	11:00 am	2	Good	Winter

3.3. Air Quality Monitoring System Design and Sensor Deployment in Abbottabad City:

Different sensors are used to identify the quality of air and make a secure and safe environment for public health. Different types of sensors are given below which are used widely and have a great accuracy impact.

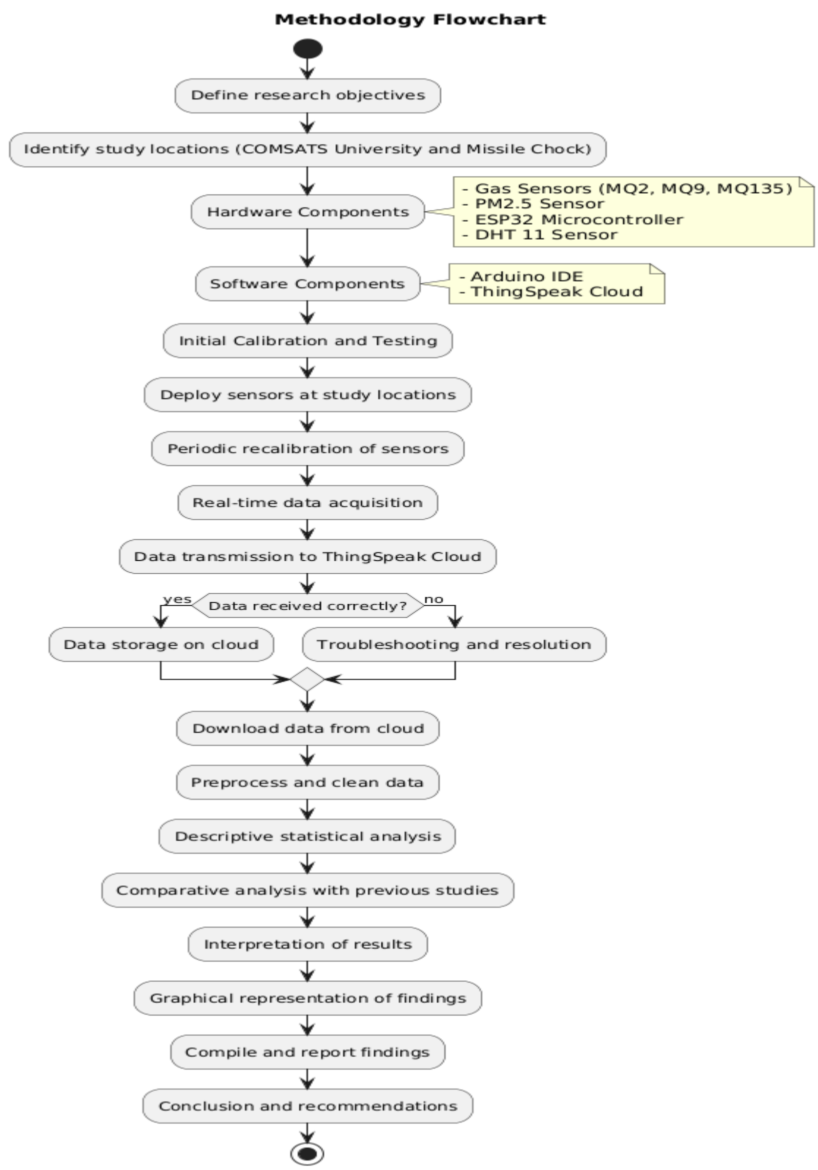

Fig. 5 Steps of how we did our work

It is essential to design a system to monitor Abbottabad city's air quality in order to address environmental issues and protect public health. Abbottabad's fast urbanization and population expansion have made it more important than ever to monitor and control air pollution levels to lessen its harmful impacts on locals. We use sensors that can precisely gauge the amounts of pollutants in the surrounding air i.e. Arduino Uno is a low-cost Easy-to-use programmable open-source. It is a microcontroller board can be integrated into a variety of electronic projects. Other sensors are wind speed sensor, Gas Sensor MQ135, PM2.5 sensor (dust sensors), DHT11 for detecting temperature and humidity.

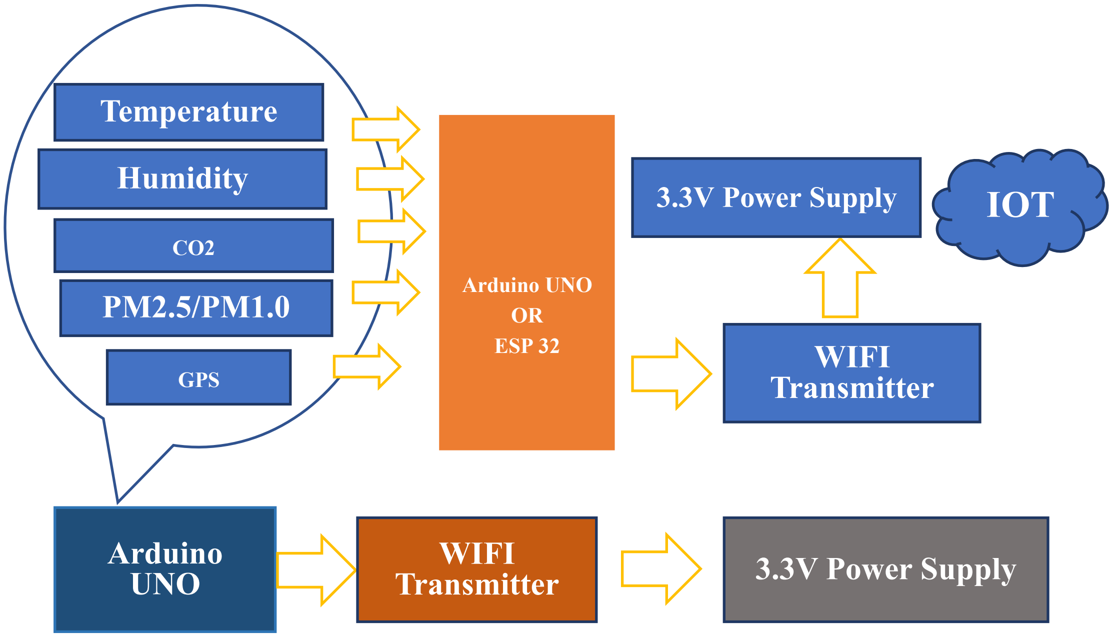

Fig. 6 Placement of sensors with Arduino Uno or ESP 32

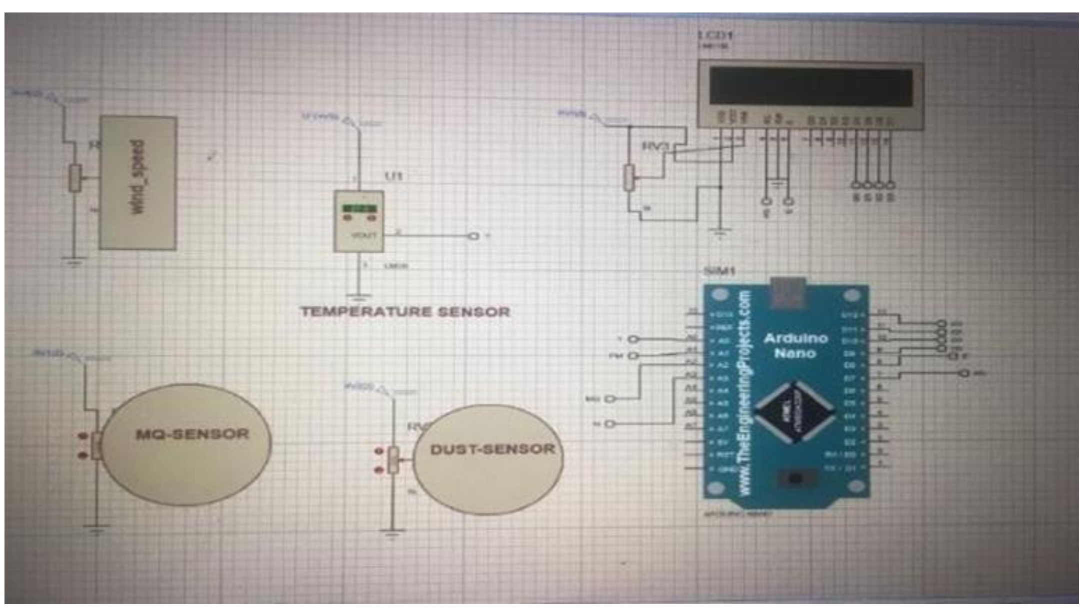

Fig. 7 Proteus View

3.4. Monitoring Air Quality:

The AQI (Air Quality Index) is a critical metric for assessing air quality and its potential health impacts. It is calculated for four major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, and sulfur dioxide. The AQI scale ranges from 0 to 500, where higher values indicate greater pollution levels and health risks. For instance, an AQI value of 50 represents good air quality with little to no health risk, while an AQI above 300 indicates hazardous air quality that could affect everyone. The purpose of this study is to find out how these pollutants influence health by keeping a watch on them (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014).

3.5. AQI Categories and Gas Concentration

There are six levels of health risk in the AQI: There are six levels of risk to your health: Good (0–50), Moderate (51–100), Unhealthy for Sensitive Groups (101–150), Unhealthy (151–200), Very Unhealthy (201–300), and Hazardous (301–500). There are several AQI scales for each gas, such as PM2.5, that show how much of each gas is in the air and what the AQI ranges are for those gases. For instance, an AQI of 0–50 (Good) means that the PM2.5 level is between 0 and 12 µg/m³. If the AQI is between 300 and 500, it means there are 5 µg/m³ of something.

3.6. Internet of Things (IoT) and Air Quality Solutions

The Internet of Things (IoT) connects things in the real world to the internet so they may gather and share information on their own. IoT devices that check the quality of the air use small, cheap, and portable sensors that are continually assessing the pollution levels in the air. These sensors, which are commonly linked to street furniture or personal gadgets, employ low-power wide-area (LPWA) networks to provide data on a regular basis and in the proper way. You may use big data tools to look at the data that was gathered to find out how pollution spreads and how to stop it. Various global cities are exploring IoT-driven air quality solutions to enhance their monitoring capabilities and address pollution challenges effectively.

3.7. Selection of CO and its Impact:

Carbon monoxide (CO) is selected for monitoring due to its high toxicity even at low concentrations. CO poisoning occurs when it builds up in the bloodstream, replacing oxygen in red blood cells and leading to tissue damage or death. Vulnerable populations, such as unborn babies, children, older adults, and individuals with chronic heart or respiratory conditions, are at higher risk. Chronic exposure can result in severe long-term health effects, including brain damage, cardiovascular complications, and respiratory issues.

3.8. Hardware Components

- Gas Sensors (MQ Series): The MQ series sensors detect harmful gases using electro chemical sensing technology. Three different sensors (MQ2, MQ9, MQ135) are used to detect various gases. In this study we have used the MQ135 sensor.
- PM2.5 Sensor: This sensor operates on the principle of light scattering to measure particulate matter in the air. It can detect particles as small as 2.5 microns, which are capable of penetrating deep into the respiratory tract.
- ESP32 Microcontroller: The ESP32, a low-cost, low-power system on chip (SoC) with integrated Wi-Fi and Bluetooth, processes the incoming data from the sensors. It supports various input channels and ensures efficient data handling and transmission.
- DHT 11 Sensor: This sensor measures temperature and humidity using a capacitive humidity sensor and a thermistor. It provides digital output for easy integration with microcontrollers.
- Sensor Calibration and Reliability To ensure the accuracy and reliability of the air quality data collected by our system, we implemented several calibration protocols and mitigation strategies. To collect baseline measurements, each sensor, including the MQ-135, was initially set up in a controlled setting with known concentrations of target gases. To keep the accuracy steady, the sensors were recalibrated every two weeks or so to account for sensor drift. It also utilized cross-validation by comparing data from multiple sensors measuring the same pollutant to identify and correct any discrepancies. We adjusted the ambient adjustment to include things like temperature and humidity, which might impact how well the sensors work. Also, software correction methods were used to change sensor readings based on how sensors have behaved in the past and how they normally behave. These precise steps were very important to make sure that our air quality monitoring system was proper and reliable.

3.9. Software Components:

- You may develop code for the microcontroller and send it to it using the free Arduino IDE platform. It works with both C and C++, and it makes it easy to gather and fix sensor data.
- The Thing Speak Cloud platform lets you save, get, and look at IoT data. You can use MATLAB to look at and analyze data in real time, which lets you look at all the air quality measures in detail.

3.10. Overall System Design

The ESP32 microcontroller gets the data from the sensors' principal locations and processes it. The processed data is subsequently sent to the ThingSpeak cloud, where it may be stored and viewed. The last step in putting the gadget together makes it a suitable choice for keeping an eye on air quality in real time.

Fig. 8 Full Look of Device

3.11. Statistical Analysis Methods

We used descriptive statistics like the mean, median, standard deviation, and range to demonstrate how the air quality measurements were distributed and what the average value was. This helped us understand the air quality data that was collected from a lot of different sites better.

3.11.1. Comparative Analysis

We compared the air quality data from the two study sites, COMSATS University Islamabad Abbottabad Campus and Missile Chock. We checked the average amounts of pollutants and conducted t-tests to see if the air quality was very different between the two areas.

3.11.2. Time-Series Analysis

Using time-series analysis, we looked at how air quality data changed over time and what patterns and trends they showed. This included placing the data points on a time axis to determine if the levels of pollutants changed at certain times of the year or on a regular basis.

3.11.3. Correlation Analysis:

We used correlation analysis to find out how different pollutants were connected to things like temperature and humidity in the environment. We utilized Pearson correlation coefficients to figure out how strong these links were and what direction they were going in.

3.11.4. Regression Analysis:

We utilized regression analysis to find out how the air quality index (AQI) is connected to other variables, such the amount of pollutants and the health of the ecosystem. This helps us find out what affects air quality the most and make educated guesses about what the AQI values are.

3.11.5. Validation and Comparison:

The results from the new monitoring system were validated by comparing them with data from previous studies (e.g., Achal R Dhote et al., 2022; MIA Suhaidi et al., 2021; EH Rodríguez et al., 2020). To check how well the new system's measurements matched the reference data, we had to use statistical tests such paired t-tests or Bland-Altman analysis.

4. Results

4.1. PM 2.5 (Particulate Matter 2.5)

The PM 2.5 (Particulate Matter 2.5) monitoring done at COMSATS University Islamabad Abbottabad Campus and Missile Chock gives us a lot of information about how the air quality changes from place to place. The PM 2.5 levels on campus were always in the "Good" range, which means there wasn't much pollution and the air was clean and good for your health. In Missile Chock, on the other hand, the PM 2.5 ratings went from "Moderate" to "Poor." This indicates that pollution in cities is a big problem since there are so many automobiles and people doing things. It was possible to gather and analyze data in real time by using IoT-based sensors such as the MQ series and PM 2.5 sensors. This illustrates how well IoT technologies can be used to keep an eye on the environment. These statistics show how important it is to always assess the air quality to keep people healthy and up to date.

4.1.1. Analysis of PM 2.5 Readings at COMSATS University Islamabad Abbottabad Campus

The data presented in Figure 9 highlights the PM 2.5 (Particulate Matter 2.5) readings at COMSATS University Islamabad Abbottabad Campus over various time intervals. The readings consistently fell within the "Good" category, indicating minimal pollution levels throughout the monitoring period.

At the very start of the monitoring period, the PM 2.5 readings at 2 seconds and 30 seconds were 24 and 26 $\mu g/m^3$, respectively. Both values fall within the "Good" category, indicating satisfactory air quality right from the beginning. The readings at 3 minutes and 5 minutes were both 23 $\mu g/m^3$, showing a stable air quality with minimal fluctuations. At 15 minutes, the reading slightly increased to 28 $\mu g/m^3$, but still remained within the "Good" category. By 20 minutes and 30 minutes, the PM 2.5 levels were recorded at 29 and 32 $\mu g/m^3$, respectively, indicating a gradual but minor increase. At 40 minutes, the PM 2.5 reading peaked at 35 $\mu g/m^3$, which is the highest value recorded during the monitoring period but still within the "Good" category. This was followed by a slight decrease to 33 $\mu g/m^3$ at 60 minutes, indicating a stabilization of air quality. At 2 hours and 30 minutes, the

PM 2.5 level dropped significantly to 11 µg/m³, reflecting a substantial improvement in air quality over the extended period. This significant decrease highlights the continued effectiveness of the university's air quality management practices.

The PM 2.5 readings at COMSATS University ranged from 11 to 35 µg/m³ throughout the monitoring period, consistently falling within the "Good" category. These results indicate that the air quality at the university campus remains well within acceptable limits for public health, with no significant health risks posed by particulate matter. The slight fluctuations observed are typical and do not indicate any major sources of pollution.

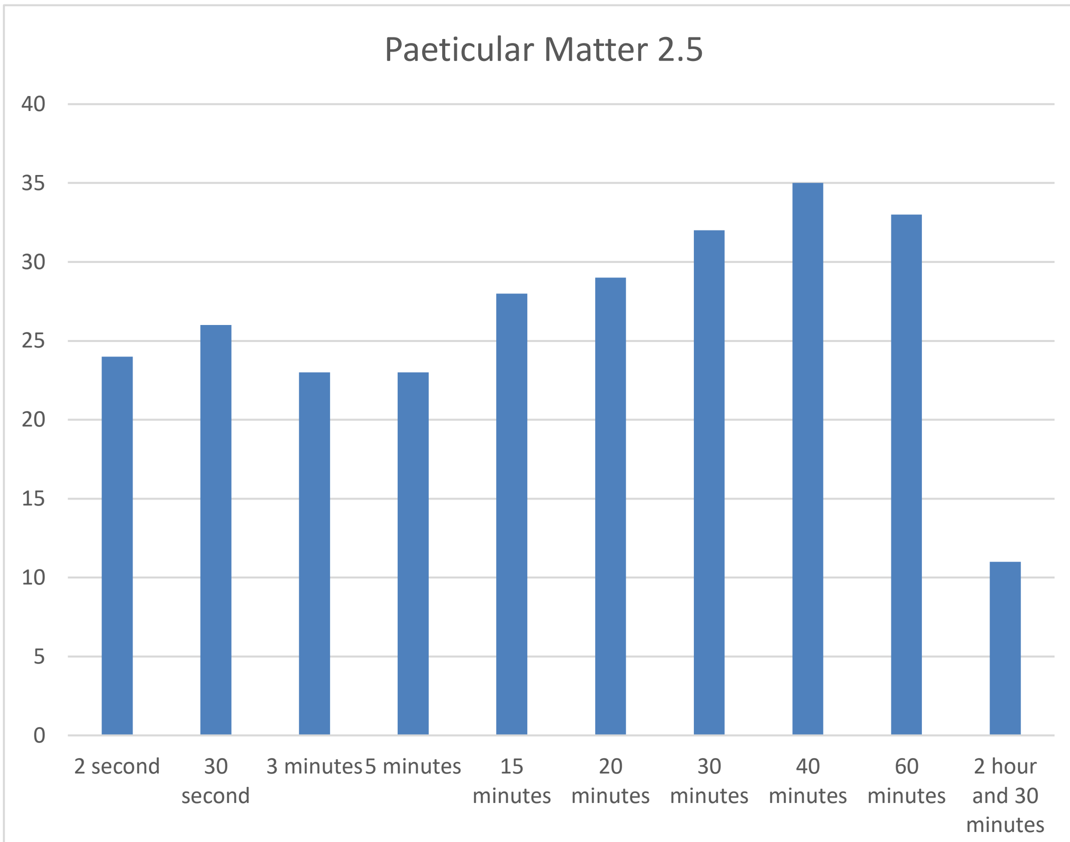

Fig. 9 The Time, Reading of PM 2.5(Particulate Matter 2.5) At COMSATS University Islamabad Abbottabad Campus

4.1.2. Analysis of PM 2.5 Readings at Missile Chowk

The data presented in figure 10 highlights the PM 2.5 (Particulate Matter 2.5) levels at Missile Chock over various time intervals, revealing significant variations in air quality. The readings range from 2 seconds to 2 hours and 30 minutes, showcasing the dynamic nature of air quality in this urban environment.

The start of the monitoring period, the PM 2.5 readings at 2 seconds and 30 seconds were 90 and 97 µg/m³, respectively, both falling within the "Moderate" category. These values indicate that air quality was already compromised right from the beginning. The readings at 3 minutes and 5 minutes were 101 and 130 µg/m³, respectively, both in the "Poor" category. After 15 minutes, the PM 2.5 level reached its highest point at 139 µg/m³. This was the highest level seen over the complete monitoring period. This shows that there was a lot of dirt. After 20 and 30 minutes, the levels went up a little to 120 and 111 µg/m³, although they stayed in the "Poor" range. The PM 2.5 level went down to 70 µg/m³ after 40 minutes. This is in the "Moderate" range. The PM 2.5 level dropped even further after an hour, to 50 µg/m³, which is in the "Good" range. The PM 2.5 level went down a lot after 2 hours and 30 minutes, to 11 µg/m³. This stated that the air quality had improved a lot and was now at the "Good" category.

The PM 2.5 levels at Missile Chock were between 11 and 139 µg/m³. The first tests showed that the air quality wasn't particularly excellent. The high initial measurements show how things like heavy traffic and other activities in cities affect the air. The changes in the intermediate data show that the air quality at Missile Chock changes a lot depending on things like how many cars are on the road and what time of day it is. The fact that air quality has become a lot better throughout time means that the things that caused pollution weren't always the same. This suggests that the air quality might get a lot better over time.

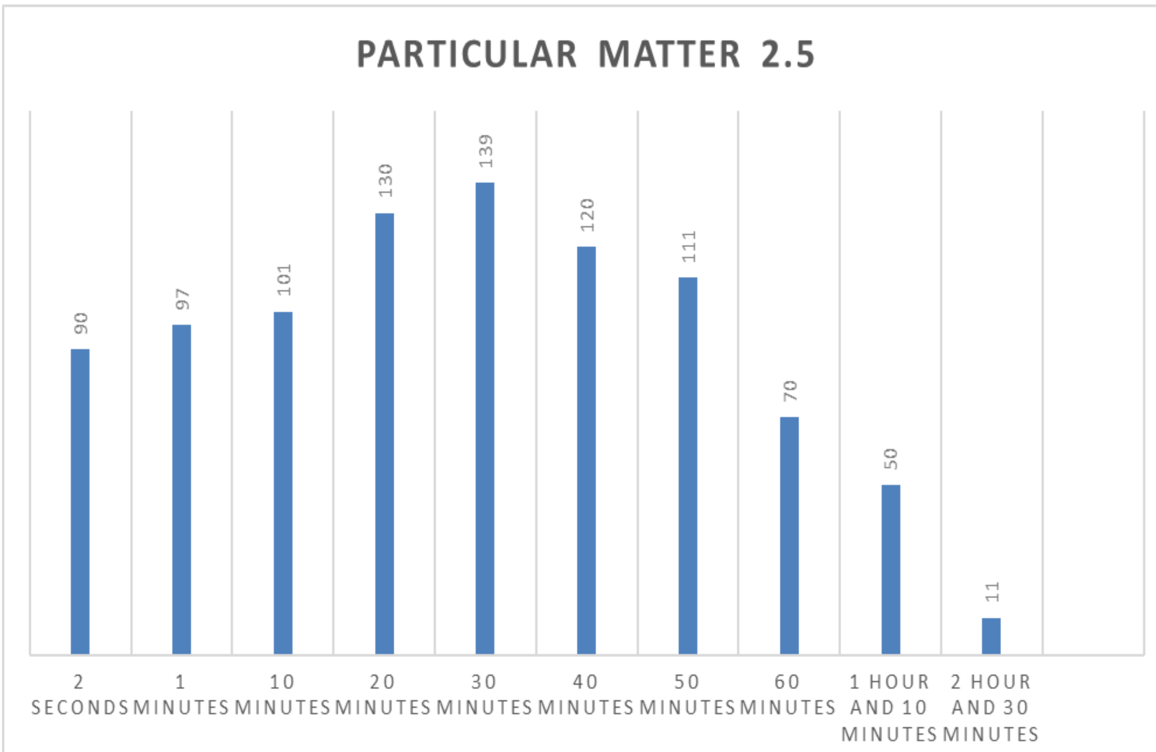

Fig. 10 The Time, Reading of PM 2.5(Particulate Matter 2.5) At Missile Chowk

4.2. Reading of Temperature and Humidity

The figures provide a comparison of temperature and humidity readings at two different locations i.e. COMSATS University Islamabad Abbottabad Campus and Missile Chock. The Detail explanation with graph is given below.

4.2.1. Reading of Temperature and Humidity at COMSATS University Islamabad Abbottabad Campus

Figure 11 displays the actual temperature and humidity readings from the Abbottabad Campus of COMSATS University Islamabad at three distinct periods. The temperature was 19°C and the humidity was 63% after 10 minutes. This first reading shows that the weather was chilly and a bit humid, just like it was at the beginning of the monitoring period. After two hours, the temperature had risen to 20.5°C and the humidity had dropped to 57%. This indicates that the temperature rises a little during the day, but the humidity falls. After two hours and fifty minutes, the temperature had gone up to 21.4°C and the humidity had gone up to 59%. The last piece of information shows that the temperature and humidity both rose somewhat toward the end of the observation period.

The temperature was between 19 and 21.4 degrees Celsius, while the humidity was between 57% and 63%. These figures show that the weather on the university campus is always the same. The temperature and humidity didn't change significantly over the time period that was studied. This reliable information gives a clear picture of what the weather is usually like at COMSATS University. The temperature and humidity measurements for COMSATS University Islamabad Abbottabad Campus ranged from 19°C to 21.4°C and 57% to 63%. This suggests that the climate is reasonably stable, with very little changes during the time period recorded. These steady circumstances show that the university's procedures for managing the environment are working to maintain the area clean and safe for students and staff.

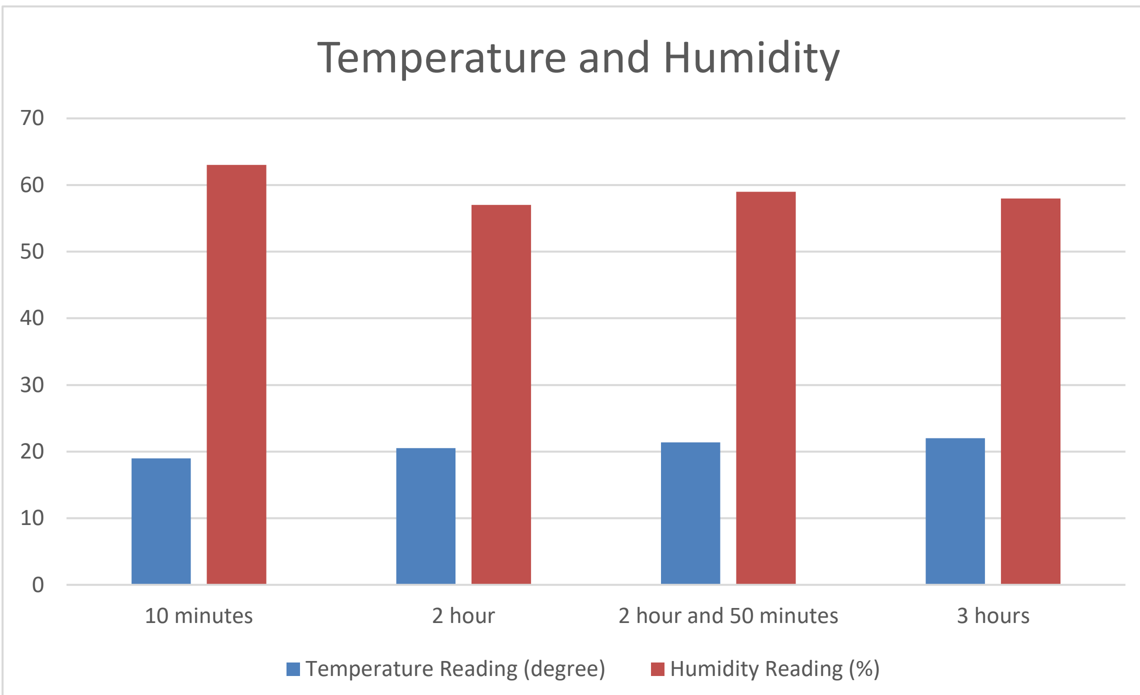

Fig. 11 The Time, Reading of PM 2.5(Particulate Matter 2.5) At COMSATS University Islamabad Abbottabad Campus

4.2.2. Reading of Temperature and Humidity at Missile Chowk

At four separate periods, Figure 12 displays the temperature and humidity at Missile Chock. The temperature was 31°C and the humidity was 20% after 10 minutes. These first readings tell us that the location is hot and a little dry. After two hours, the temperature rose to 31.5°C and the humidity fell to 18%. This means that the humidity is steadily going down and the temperature is slowly going up. The temperature dropped to 30°C and the humidity climbed to 19% after two hours and fifty minutes. This indicates a slight cooling trend and a small increase in humidity towards the later part of the observation period. At the 3-hour mark, the temperature increased again to 30.5°C, while the humidity rose slightly to 19.5%. These fluctuations highlight the dynamic nature of environmental conditions in this urban area.

Overall, the temperature readings ranged from 30°C to 31.5°C, and the humidity levels varied between 18% and 20%. This data reflects a consistently hot and dry environment with minor fluctuations in temperature and humidity over the observed period

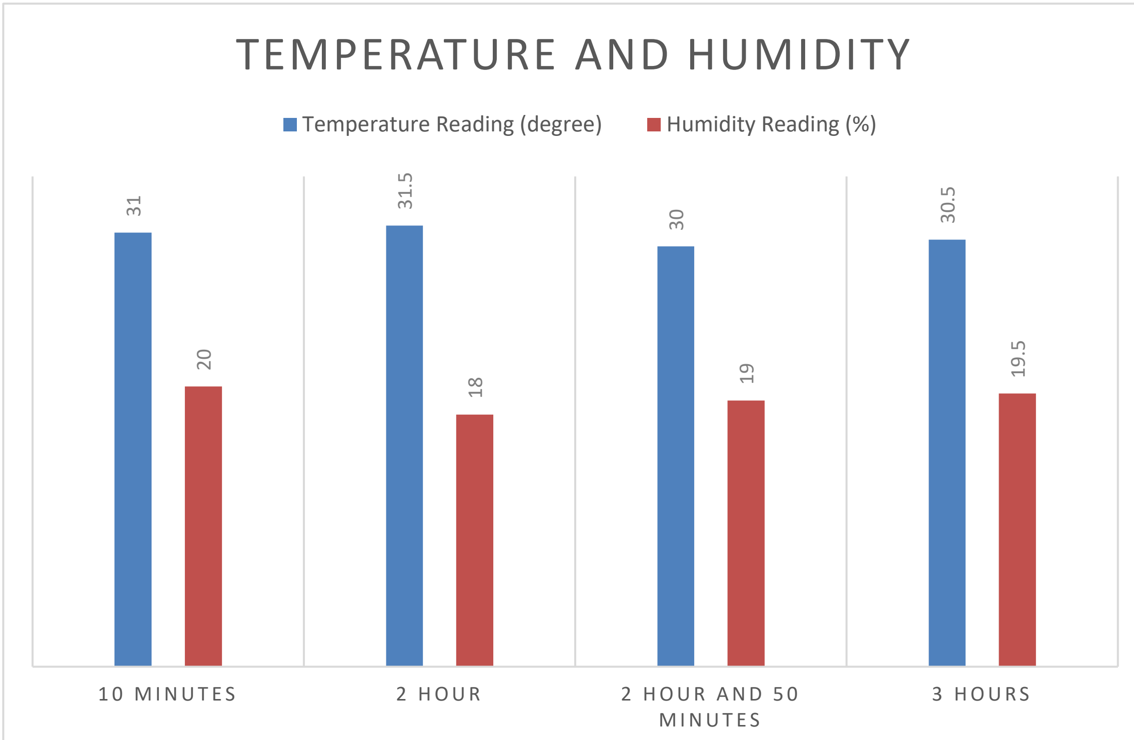

Fig. 12 The Time, Reading of PM 2.5(Particulate Matter 2.5) At Missile Chowk

4.3. Reading of Air Quality Index (MQ 135)

The detailed explanation of the MQ135/AQI readings taken at both the location is shown in the figure.

4.3.1. Reading of Temperature and Humidity at COMSATS University Islamabad Abbottabad Campus

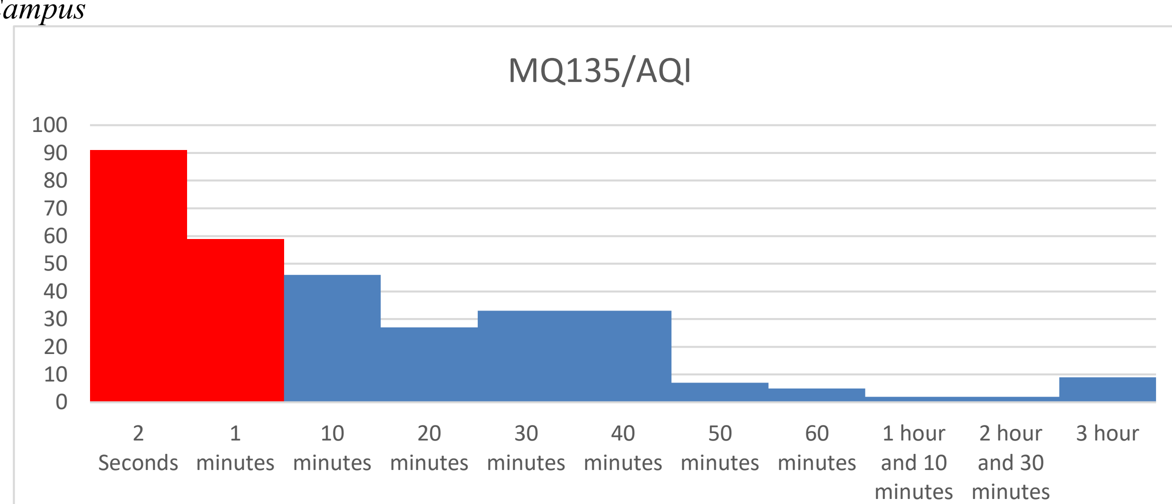

Fig. 13 The Time and Category of MQ135/AQI at COMSATS University Islamabad Abbottabad Campus

4.3.2. Reading of Temperature and Humidity at Missile Chowk

We can learn a lot about how unclean this portion of the city is by using the MQ-135 sensor to examine the air quality at Missile Chowk. We used the MQ-135 sensor to check the Air Quality Index (AQI) at different periods. People are aware that this sensor may detect dangerous substances such as smoke, ammonia, sulfide, and benzene steam. The AQI values at Missile Chowk started at 60 (Moderate) after 2 seconds and went up to 70 (Moderate) after 1 minute. At 10 minutes, the AQI values were 55 (Moderate), at 20 minutes they were 52 (Moderate), and at 30 minutes they were 45 (Good). The air quality kept getting better and better. After 40 minutes, the AQI dropped to 49 (Good), after 50 minutes it dropped to 38 (Good), and after 2 hours and 30 minutes it dropped to 9 (Good). The AQI was 11 (Good) after three hours, which is what it was at the end of the observation period. Living in the city and heavy traffic are two things that affect the air quality at Missile Chowk a lot. The information shows how important it is to always monitor the air quality in cities with a lot of people

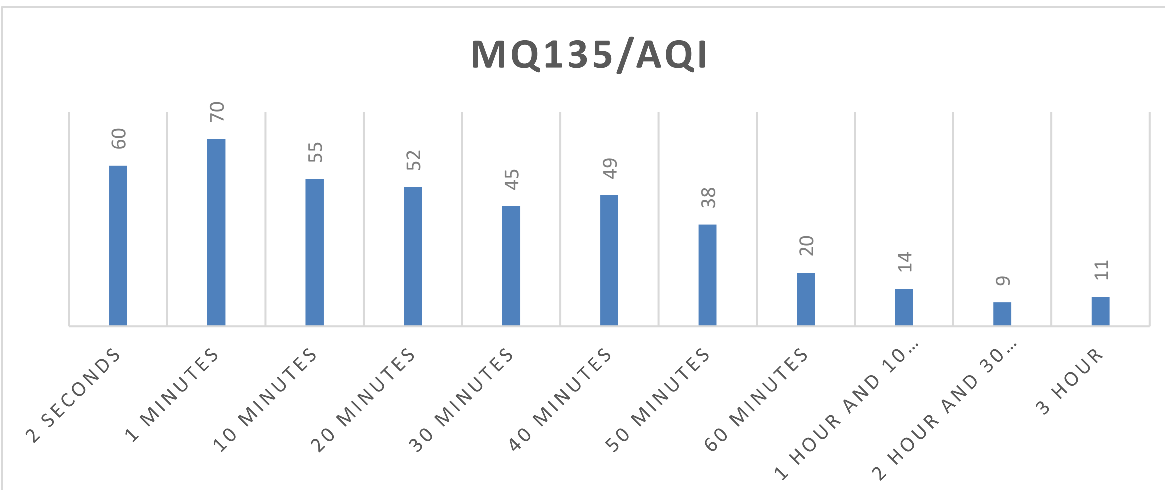

Fig. 14 Shows the Time and Category of MQ135/AQI at Missile Chowk

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4.4. Reading of MQ 2 Sensor

The table provides MQ-2 sensor readings at different time intervals, showing the concentration of gases detected by the sensor in parts per million (ppm).

4.4.1. Reading of MQ 2 Sensor at COMSATS University Islamabad Abbottabad Campus

Table 4 –The reading of MQ 2 sensor At COMSATS University.

Sr.No	Time	Reading (ppm)
1.	2 seconds	2550
2.	15 minutes	3776
3.	1 hours	3669
4.	2 hours	3690
5.	3 hours	3650

The measurements from the MQ-2 sensor at COMSATS University Islamabad's Abbottabad Campus are in Table 4. It shows how much carbon monoxide, methane, and LPG are in the air at different times. The result at 2 seconds was 2550 ppm, which means that the sensor could pick up gas concentrations shortly after it was turned on. After 15 minutes, the value went up a lot to 3776 ppm, which means that the MQ-2 sensor found more gases. The result after an hour was 3669 ppm. This was a little drop from the 15-minute interval, but it still showed significant levels of gas. At 2 hours, the measurement was 3690 ppm, which was a little higher than the value at 1 hour. After three hours, the figure went down a little to 3650 ppm. This indicates that the number of gasses stayed roughly the same, but still high, throughout the whole time they were being analyzed. The MQ-2 sensor values were between 2550 and 3776 ppm, which suggests that there were always a lot of gases, such as LPG, methane, and carbon monoxide, when they were tested. The MQ-2 sensor readings at COMSATS University give us a lot of information about the types and amounts of gases that are always in the air. The sensor found a concentration of 2550 ppm in two seconds, which suggests it might have started sucking in gases right immediately. This first reading suggests that things were already in the air that shouldn't have been there.

The large surge to 3776 ppm after 15 minutes suggests that the gas levels increased up a lot more. This could mean that there were more activities or emissions that caused the pollution levels to rise during this time. This spike shows how quickly the MQ-2 sensor can pick up on changes in the gas level. After an hour, the reading went down to 3669 ppm, which was still high, which meant there was still a lot of gas in the air. The value was 3690 ppm after two hours and 3650 ppm after three hours. This shows that the levels of gas were usually high and kept the same across the longer time period that they were being looked at. The results showed that gases such LPG, methane, and carbon monoxide stayed at high quantities throughout time. There might be certain things that happen or locations that are on or near the university campus that cause this. The little changes in readings over time show that gas levels change over time and that the MQ-2 sensor is a smart way to keep an eye on things all the time. These big amounts of gas are detrimental for the health of individuals and the environment. Long-term exposure to high quantities of gasses like carbon monoxide and methane can be highly bad for your health. It can make it hard to breathe and cause other problems. The numbers say that we need to keep an eye on things and do everything we can to reduce and manage gas emissions.

The MQ-2 sensor data at COMSATS University show how important it is to continually watch the environment to find and study gas concentrations. The constantly high readings show how important it is to have good plans for dealing with pollution and keeping the air clean. These data will help us plan more study and establish rules that will help lower gas emissions and clean up the air.

Fig. 15 Shows the Reading of Humidity, Temperature and Concentration of Gases at COMSATS University Islamabad Abbottabad Campus

4.4.2. Reading of MQ 2 Sensor at Missile Chowk

Table 5 – The reading of MQ 2 sensor at Missile Chowk.

Sr.No	Time	Reading (ppm)
1.	2 seconds	3887
2.	15 minutes	4007
3.	1 hours	4098
4.	2 hours	3900
5.	3 hours	4159

The MQ-2 sensor at Missile Chock checks the levels of gases including LPG, methane, and carbon monoxide at different times. Table 5 shows what this sensor found. These values are quite useful for figuring out how much of these gasses there in a city where people and transportation have a big effect on them. At the 2-second point, the MQ-2 sensor registered 3887 ppm, which means it found a lot of gas shortly after it was turned on. This first high number shows that there are contaminants in the air, which shows how living in a city affects the air quality. The result went raised to 4007 ppm after 15 minutes, which means that the MQ-2 sensor found more gases. This increase suggests that gasses are still being created, which could be due to transportation and industrial activity in the area. This is making the pollution levels go up. The test showed 4098 ppm after an hour, which means that the gas levels stayed high for a long time. The fact that the levels are rising suggests that the areas where these gases come from are still active and common in the area. The measurement dropped to 3900 ppm after two hours, which means that the amount of gas in the air went down a little. The number is still high, which suggests that there are still items in the air that shouldn't be there. This little dip could be because to changes in traffic patterns or short-term drops in the sources of emissions. After three hours, the test went back up to 4159 ppm, which was the highest level detected during the entire monitoring period. There have been a lot of gases released in the area for a long time, possibly due of continual urban activity and heavy traffic.

The MQ-2 sensor data at Missile Chock showed that there were constantly a lot of gasses there, such as propane, methane, and carbon monoxide. There were between 3887 and 4159 parts per million. These high numbers show how living in a big city impacts the air quality and how there are always pollutants in a bustling city. The MQ-2 sensor at Missile Chock always reports high levels, which shows how living in the city affects the air quality. The first high result of 3887 ppm at 2 seconds shows that there were already pollutants in the air, maybe from cars and factories. The increase to 4007 ppm after 15 minutes means that gasses are still pouring out. This might be because of things that happen in cities, such traffic jams. The rise to 4098 ppm after an hour demonstrates that the gas levels stayed high, which means that the sources of the emissions are still active and common. The little drop to 3900 ppm after two hours shows that the amount of gas in the air has gone down for a brief period. This might be because the way traffic flows altered or the sources of emissions diminished for a brief period. But the concentration is high, therefore the pollution levels stay high. The highest level, 4159 ppm, after 3 hours shows that events in cities still have a big effect on the air. Because there are so many of them, we need to keep an eye on pollution levels and do something about the health concerns of being around a lot of gases like LPG, methane, and carbon monoxide for a long time.

The MQ-2 sensor data at Missile Chock show that there are a lot of gases in the air in cities. This shows how important it is to construct cities and deal with pollution in a smart way. We need to always be aware of the environment so we can quickly find and fix causes of pollution. This will help keep people healthy and make the air cleaner. These results show how important it is to make rules that will lower gas emissions and clean up the air in populated areas.

Fig. 16 Shows the Reading of Humidity, Temperature and Concentration of Gases at Missile Chowk

The air quality test compares the Missile Chowk area to the COMSATS University Islamabad Abbottabad Campus area. At 2:00 PM, the air quality at COMSATS University was satisfactory, with a MQ-2 sensor reading of 3810 ppm, a temperature of 22.60°C, and a humidity of 22.60%. The MQ-2 sensor at Missile Chowk said that the air quality was unsatisfactory at 9:30 AM. The level was 3817 ppm, the temperature was 21.50°C, and the humidity was 21.50%. Even if the temperature and humidity levels are a little higher, it's clear that the air quality at COMSATS University is superior. This is still true, even if the air quality readings are only a tiny bit off. This comparison shows that the air quality changes depending on the time and place, and that both natural and man-made variables are involved.

5. Discussion

We now know everything there is to know about how the air quality changes at two places: the COMSATS University Islamabad Abbottabad Campus and Missile Chock. We used IoT-based sensors that collected and processed data in real time to record and analyze levels of pollutants, temperature, humidity, and the Air Quality Index (AQI) at different periods. We were able to corroborate what we found by comparing it to what other studies found. This proved that our plan for monitoring is both right and dependable.

5.1. PM 2.5 (Particulate Matter 2.5) Analysis

We learned from our investigation that the air quality is varied at the COMSATS University Islamabad Abbottabad Campus and Missile Chock. We might use IoT-based sensors to keep an eye on and investigate the levels of pollutants, temperature, humidity, and the Air Quality Index (AQI) at different times. We could also gather and analyze the data in real time. We could back up what we found by looking at what other studies had found. This proved that our method of watching things is both right and dependable.

Our air quality monitoring system has a MQ-2 sensor that can discover gases including LPG, methane, and carbon monoxide. It does a good job of measuring PM2.5. But remember that the contaminants that are being looked at right now are just a small fraction of the entire issue. Our technology doesn't do a good job of locating sulfur dioxide (SO2) and volatile organic compounds (VOCs), which are two of the most important pollutants in cities. These pollutants are very dangerous for your health and are a big reason why the air in cities is so polluted. In the future, we will add more sensors to our monitoring system so that it can discover SO2, VOCs, and other significant pollutants. We will be able to make better choices regarding public health and city growth if we add these sensors. They will provide us a more full picture of air quality. Also, solving this problem would help our system perform better and be more beneficial since it would be better at dealing with all the many types of pollution that happen in cities.

5.1.1. Detailed Analysis of PM 2.5 Readings at COMSATS University Islamabad Abbottabad Campus

Table 6 – The Time, Reading, and Category of PM 2.5 (Particulate Matter 2.5) at COMSATS University Islamabad Abbottabad Campus.

Sr.No	Time	Reading	Category
1.	2 second	24	Good
2.	30 second	26	Good
3.	3 minutes	23	Good
4.	5 minutes	23	Good
5.	15 minutes	28	Good
6.	20 minutes	29	Good
7.	30 minutes	32	Good
8.	40 minutes	35	Good
9.	60 minutes	33	Good
10.	2 hour and 30 minutes	11	Good

Table 6's data offers us an excellent indication of how clean the air is at the COMSATS University Islamabad Abbottabad Campus. The measurements were taken at different periods, ranging from 2 seconds to 2 hours and 30 minutes, and they were consistently in the "Good" range. This signifies that the air was clean and the atmosphere was favorable for health. The initial readings, taken at 2 seconds and 30 seconds, show PM 2.5 values of 24 and 26 µg/m³, respectively.. These values fall within the "Good" category, indicating that even at the very start of the monitoring period, the air quality was satisfactory. The consistency of low PM 2.5 levels in the initial minutes highlights the effectiveness of the university's efforts in maintaining a clean and healthy environment. The readings at 3 minutes, 5 minutes, and 15 minutes show slight fluctuations, with values of 23, 23, and 28 µg/m³, respectively. Despite these fluctuations, all values remain well within the "Good" category. As the monitoring period extends to 20 minutes, 30 minutes, and 40 minutes, the PM 2.5 readings show a gradual increase to 29, 32, and 35 µg/m³, respectively. This slight upward trend could be attributed to normal variations in air quality throughout the day. The air quality is still "Good," even if the maximum level detected was 35 µg/m³ at 40 minutes. This means that the individuals who live there are still healthy and safe.

After 60 minutes, the levels were 33 µg/m³, and after 2 hours and 30 minutes, they were 11 µg/m³. The reading after 60 minutes shows that the air quality is consistent and stays at the "Good" level. The big decline to 11 µg/m³ after two hours and thirty minutes means that the air quality will keep getting better. The fact that PM 2.5 levels are going down suggests that there aren't any large sources of pollution that have been damaging the air quality for a long period. This supports the university's efforts for taking care of the environment. The information from COMSATS University reveals that PM 2.5 levels are always in the "Good" range, with values between 11 and 35 µg/m³ the whole period they were being observed. These numbers show that the university has done a good job of keeping pollution levels low. There presumably aren't many companies around, but there are parks, and pollution control systems work well. The little changes shown in the intermediate measurements are typical and don't pose any severe health hazards.

The air quality at COMSATS University is always good. This is important for public health since being around lower levels of PM 2.5 lowers the risk of heart and lung issues. The information also shows how important it is to always check the air quality to keep the environment healthy. Urban planners and regulators could be able to make better choices that enhance air quality and lower health hazards by using comparable IoT-based monitoring systems in other regions. In short, the in-depth study of PM 2.5 measurements at COMSATS University shows that IoT-based air quality monitoring works well to give us real-time information and insights into the state of the environment. The university campus always has decent air quality, which shows how important it is to have green spaces and use the correct tools to manage pollution so that people may live in a healthy location.

Fig. 17 Shows the PM 2.5 Average Reading at COMSATS University Islamabad Abbottabad Campus

5.1.2. Reading of MQ 2 Sensor at Missile Chowk

Table 7 – The Time, Reading, and Category of PM 2.5 (Particulate Matter 2.5) at Missile Chowk.

Sr.No	Time	Reading	Category
1.	2 second	90	Moderate
2.	30 second	97	Moderate
3.	3 minutes	101	Poor
4.	5 minutes	130	Poor
5.	15 minutes	139	Poor
6.	20 minutes	120	Poor
7.	30 minutes	111	Poor
8.	40 minutes	70	Moderate
9.	60 minutes	50	Good
10.	2 hour and 30 minutes	11	Good

Table 7 has a lot of information regarding the levels of PM 2.5 (Particulate Matter 2.5) at Missile Chock. It shows that the air quality fluctuates a lot over time. The tests were done at different times, with some being 2 seconds apart and others being 2 hours and 30 minutes apart. This shows how people and vehicles impact the air quality in cities.

At the commencement of the monitoring period, the PM 2.5 levels were 90 µg/m³ after 2 seconds and 97 µg/m³ after 30 seconds. These values are in the "Moderate" range, which means that the air quality was already quite bad before the monitoring started. There is a moderate degree of pollution, which shows how city life and traffic jams affect the air quality at Missile Chock.

Readings for the near future: The values at 3 and 5 minutes were 101 and 130 µg/m³, which were both in the "Poor" category. The air is worse now that the PM 2.5 levels are so high. This is mostly because to rush hour traffic and other pollutants from cities. The measurement reached 139 µg/m³ after 15 minutes, which was the highest amount seen during the complete monitoring period. It stayed in the "Poor" classification. The 20- and 30-minute values went up a little, to 120 and 111 µg/m³, although they were still in the "Poor" category. This pattern shows that cities with a lot of people and cars tend to have a lot of pollution. The PM 2.5 concentration dropped to 70 µg/m³ after 40 minutes, which is in the "Moderate" range. Because of this drop, the air quality has been better for a short time. This might be because there is less traffic or other things that help. After an hour, the PM 2.5 level dropped even more to 50 µg/m³, which is in the "Good" category. This big decline means that the air quality improved a lot in the first hour of monitoring. This also suggests that the things that were making the air unclean were merely temporary or got better over time. After two hours and thirty minutes, the PM 2.5 level dropped a lot to 11 µg/m³. This signifies that the air quality has become a lot better and is now in the "Good" zone. The pollution levels reduced a lot, which implies that the sources of pollution at Missile Chock weren't always there. This might mean that the air quality will get a lot better over time.

The amount of PM 2.5 at Missile Chock went from 11 to 139 µg/m³ throughout the period they were being observed. At first, the statistics showed that the air quality was bad to medium. The first high readings show how things like living in a city, traffic jams, and other sources of pollution impact the quality of the air. The intermediate data reveals that the air quality at Missile Chock changes a lot and may be affected by things like the time of day, how much traffic there is, and maybe even the weather.

The big change in air quality over time shows how important it is to always check pollution levels so you can see how they change over time. These results show how important it is to have good means to control pollution and ideas for how to develop cities that will improve air quality. The information from Missile Chock shows how important it is to monitor air quality in real time to find pollution patterns and make measures for public health. The in-depth study of PM 2.5 levels at Missile Chock shows how living in a city affects air quality and how pollution levels change over time in a bustling city. At initially, the air quality at Missile Chock is just good to bad. This shows how important it is to keep an eye on it and discover ways to improve it and make it safer for people's health.

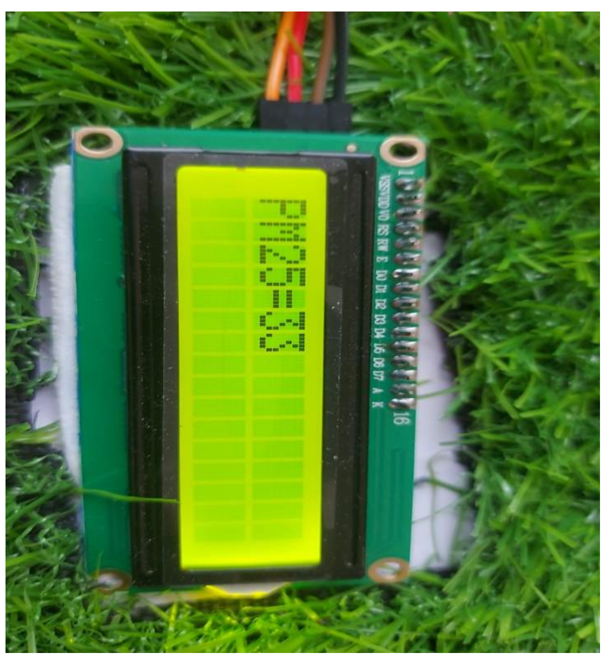

Fig. 18 Shows the PM 2.5 Initial Starting Reading at Missile Chowk

5.2. Temperature and Humidity Readings

The temperature and humidity readings at COMSATS University revealed that the weather was mostly nice and steady. The temperature ranged from 19.0°C to 21.4°C, while the humidity ranged from 57% to 63%. Missile Chock, on the other hand, was warmer (30.0°C to 31.5°C) and had less humidity (18% to 20%). This suggests that the weather was hotter and drier, with more sun and people doing things. These numbers help us learn how geography and the environment affect temperature and humidity, which in turn affect the air quality.

5.2.1. Reading of MQ 2 Sensor at COMSATS University Islamabad Abbottabad Campus

Table 8 – The Time, temperature and Humidity at COMSATS University.

Sr.No	Time	Temperature Reading (degree)	Humidity
1.	10 minutes	19	63
2.	2 hours	20.5	57
3.	2 hour and 50 minutes	21.4	59

Table 8 shows the temperature and humidity conditions at the COMSATS University Islamabad Abbottabad Campus at different times of the day. We may use this information to make an educated judgment about the weather on campus and how it could affect the air quality. The temperature was 19°C and the humidity was 63% after 10 minutes. This first piece of information informs us that the air is cold and a little bit damp. There are a lot of parks, small industries, and other locations like this on college campuses because they help keep the tone steady. The temperature had gone up to 20.5°C and the humidity had gone down to 57% after two hours. As the day goes on and the temps rise, the humidity usually goes down a little and the temperature goes up a little. The little change in temperature could also be making the relative humidity levels decline, which could explain why the humidity levels are lowering. The temperature went up to 21.4°C and the humidity went up a little to 59% after two hours and fifty minutes. Natural changes in the environment, such weather patterns and what people do on campus every day, may have caused the temperature and humidity to rise a little. The fact that these statistics maintained the same for more than three hours shows that the weather on campus is normally mild and consistent. While they were being watched, the temperature and humidity at COMSATS University stayed pretty nearly the same. The temperature ranged from 19°C to 21.4°C, while the humidity ranged from 57% to 63%. These differences are prevalent in a school with green grounds, few cars, and well-kept buildings. The air quality stays good since the temperature and humidity don't change. Moderate temperatures can make it harder for ground-level ozone to form, while increased humidity can assist particles settle. All of these things work together to make the school a better place for kids and teachers, which helps everyone feel better and more at ease. The temperature and humidity data show how important it is to continually check the weather to make sure the campus is safe and comfortable. This information gives us a good place to start when we want to learn more about how the campus's microclimate affects the air quality. Researchers may utilize this baseline in the future to examine how things change with the seasons and how certain activities can make things even better. The temperature and humidity statistics from COMSATS University show that the school's strategies for managing the climate are effective. The school makes sure that the weather and circumstances are mostly pleasant and steady so that the people who live there may be healthy and happy. Regular checks and flexible methods could help keep these environmental features the same throughout time and maybe even make them better.

5.2.2. Reading of MQ 2 Sensor at Missile Chowk

Table 9 –The Time, temperature and Humidity at Missile Chowk.

Sr.No	Time	Temperature Reading (degree)	Humidity
1.	10 minutes	31	20
2.	2 hours	31.5	18
3.	2 hour and 50 minutes	30	19

Table 6 gives the temperature and humidity data at Missile Chock at different times. This can teach us about the weather in a huge metropolis and how it could change the air quality. After 10 minutes, the temperature was 31°C and the humidity was 20%. The initial readings suggest that the area is hot and not particularly humid, which is what you would expect from a major metropolis with a lot of people and not a lot of vegetation. Urban heat islands are having an effect since the air is dry and the temperature is high. These are places where concrete and asphalt absorb and keep heat, which makes the air warmer. After two hours, the temperature rose to 31.5°C and the humidity dropped to 18%. The temperature rose and the humidity fell since the city was becoming hotter all day. The decline in humidity levels highlights how things like living in a city and not having natural cooling mechanisms like green areas and bodies of water can change the weather. After two hours and fifty minutes, the temperature dropped to 30°C and the humidity rose to 19%. This demonstrates that the temperature started to drop a little bit toward the end of the observation period. It might be because the weather has changed or people aren't doing as much. The temperature rose to 30.5°C and the humidity rose a little to 19.5% after three hours. The temperature and humidity variations highlight how rapidly things may change in a city. The Missile Chock data shows that the temperature stayed between 30°C and 31.5°C and the humidity stayed between 18% and 20% during the time that was analyzed. These measurements reveal that the weather is always hot and dry, with not much fluctuation in temperature or humidity. Cities that are hot and dry generally have a lot of people, not a lot of plants, and structures that soak up a lot of heat. Because to the heat and dry weather, the air quality at Missile Chock might grow a lot worse. Ground-level ozone, a harmful air pollutant, is more likely to happen as the temperature rises. When the humidity is low, tiny particles might float back into the air, which makes it much worse. To clean up the air and reduce the urban heat island effect, we need to adopt urban design methods that integrate green areas and natural cooling systems. The temperature and humidity readings at Missile Chock tell us a lot about what it's like to live in a huge metropolis. Because it is always hot and dry in this area, it has altered. These results indicate how vital it is to always pay attention to the environment and employ excellent city planning to clean the air and make it safer to be in high heat and low humidity.

5.3. Air Quality Index (MQ 135) Missile Chowk

At initially, the air quality at COMSATS University was only a little bit dirty. The MQ135 gas sensor values, on the other hand, were always in the "Good" range. This pattern shows that contaminants that were there at the beginning either spread out or go away over time, which makes the air quality better. The AQI readings that are always the same show that the school's campus is clean and well-kept. The AQI readings at Missile Chock started in the "Moderate" zone since there was more pollution from city activities and traffic jams. The AQI readings, on the other hand, became better with time, going from "Moderate" to "Good." This shows how objects in cities may affect the air quality. These statistics show how important it is to always assess the levels of pollution so you can see how they change and find excellent strategies to keep the air pure.

5.3.1. Reading of Air Quality Index (MQ 135) At COMSATS University

Table 10 – Reading of Air Quality Index (MQ 135) At COMSATS University.

Sr.No	Time	MQ135/AQI	Category
1	2 Seconds	91	Moderate
2	1 minute	59	Moderate
3	10 minutes	46	Good
4	20 minutes	27	Good
5	30 minutes	33	Good
6	40 minutes	33	Good
7	50 minutes	07	Good
8	60 minutes	05	Good
9	1 hour and 10 minutes	02	Good
10	2 hours 30 minutes	02	Good
11	3 hours	09	Good

Table 10 shows the data from the MQ135 sensor at the Air Quality Index (AQI) of COMSATS University Islamabad Abbottabad Campus. We may use this information to see how the air quality varies over time. We jotted down the test findings at different times, with gaps of 2 seconds to 3 hours. This gave us a complete picture of how the air quality changed while we were watching it. At the start of the monitoring period, the AQI measurements were 91 at 2 seconds and 59 at 1 minute. Both of these values were in the "Moderate" category. This reveals that the air was rather dirty at first. The "Moderate" level suggests that the air quality was good, but persons with asthma or other lung problems would have been anxious. A number of short-term items, such local traffic or activities that only existed for a short period and deposited toxins into the air, might generate moderate amounts of pollution. The AQI score dropped to 46 after 10 minutes, which put it in the "Good" range. This illustrates that the air quality got better shortly after the initial monitoring began. The findings kept getting better: they were 27, 33, and 33 at 20, 30, and 40 minutes, all of which were still in the "Good" category. The fact that AQI values have been gradually lowering over a short period of time suggests that the campus can quickly cut down on the pollution that is already there. There probably aren't many sources of pollution that persist a long time, there are a lot of green places, and the ecology is well cared for. The AQI measurement went down a lot to 7 after 50 minutes, and then it went down even further to 5 after 60 minutes. The air quality has improved a lot, and now it's safe for everyone on campus. For a long period, the AQI levels have been low. This signifies that the campus's infrastructure performs a superb job of keeping the air clean.

The long-term tests, which lasted 1 hour and 10 minutes, 2 hours and 30 minutes, and 3 hours, showed AQI values of 2, 2, and 9, in that order. These figures maintained far inside the "Good" category, which means that the air quality was growing better and more stable during the lengthy period it was being watched. The fact that AQI values were low for a few hours indicates how vital it is to maintain working on regulating the environment and to have green spots that assist clean the air. The information demonstrates that the air quality has improved over time, moving from "Moderate" to "Good" levels all the time. This trend suggests that the university's efforts to keep the environment clean are helping to cut down on pollution and keep the air clean for students and staff. The initial little measurements show that the sources of pollution are only temporary. The swift improvement that happens next illustrates that there are ways to deal with and get rid of these toxins. Long-term good air quality is good for public health because it lessens the risk of heart and lung problems that can arise when the air is polluted. The information highlights how crucial it is to always check the air quality so that temporary sources of pollution may be located and dealt with right soon. The results also illustrate how crucial it is to have parks and other green areas, as well as enough infrastructure, to keep the air clean. Other cities and groups might be able to use these results to make choices. The AQI readings from COMSATS University reveal that the air quality is always changing and that the campus is becoming better due of ongoing efforts to protect the environment. The university's commitment to keeping the air clean is shown by the continuously low AQI measurements throughout time, which is good for everyone's health.

5.3.2. Reading of Air Quality Index (MQ 135) At Missile Chowk

Table 11 – Reading of Air Quality Index (MQ 135) At COMSATS University.

Sr.No	Time	MQ135/AQI	Category
1	2 Seconds	60	Moderate
2	1 minute	70	Moderate
3	10 minutes	55	Moderate
4	20 minutes	52	Moderate
5	30 minutes	45	Good
6	40 minutes	49	Good
7	50 minutes	38	Good
8	60 minutes	20	Good
9	1 hour and 10 minutes	14	Good
10	2 hours 30 minutes	09	Good
11	3 hours	11	Good

We acquired the Air Quality Index (AQI) measurements from the MQ135 sensor at Missile Chock and included them in Table 11. This information tells us a lot about how the air quality varies over time. The data shows how pollution levels vary in a big metropolis where people and cars have an effect on them. There is a range of 2 seconds to 3 hours. At the beginning of the monitoring period, the AQI readings were 60 and 70 at 2 seconds and 1 minute, which were both in the "Moderate" category. This means that the air quality was awful from the beginning since there were a lot of pollutants in the air. Moderate amounts of pollution indicate how things like cars and factories in cities change the air quality. The AQI rating went down to 55 after 10 minutes, which is still in the "Moderate" level. This suggests that the air is now a little better. For 20 minutes, this trend continued, and the AQI dropped even more to 52, which is still in the "Moderate" zone. The air quality became better over time, but it was still terrible enough that it might be dangerous for persons with sensitive health. At the 30-minute mark, the AQI score dropped to 45, which put it in the "Good" zone. This was a significant change. This adjustment means that there are a lot less pollutants in the air right now. This signifies that the items that were making the air quality worse have either been removed or made less harmful. The air quality was remained "Good" at 40 and 50 minutes, with scores of 49 and 38. This trend illustrates that pollution sources are only temporary and that poisons spread out well in cities. The AQI value went down a lot after an hour, to 20, which is comfortably inside the "Good" level. At 1 hour and 10 minutes, 14 readings revealed very low levels of pollution; at 2 hours and 30 minutes, 9 readings showed very low levels of pollution; and at 3 hours, 11 readings showed very low levels of pollution. It was the same thing again. These low AQI ratings for a long time demonstrate that pollution sources have been efficiently controlled and managed, which keeps the air clean. The data reveals that the air quality has gotten a lot better over time, ranging from "Moderate" to "Good" levels all the time. This suggests that the high levels of pollution at initially were probably caused by factors that didn't last long, such too much traffic or emissions from a limited location. Not long after that, the air quality grew improved. This shows that urban dispersion processes and perhaps pollution management tactics succeeded. Long-term air quality that is always good is good for public health because it minimizes the risk of heart and lung ailments that can arise when the air is bad. The data indicates how vital it is to always check the air quality so that pollution sources that only last for a short period may be detected and dealt with right immediately. The results also illustrate how crucial it is to have the right policies for building cities and keeping the air clean in busy regions. The AQI data from Missile Chock shows how the air quality fluctuates in a huge city and how effectively attempts to minimize and control pollution levels are working. The AQI values have been low for a long period, which shows that these initiatives have been successful. This is good news for the health of those who live in cities.

5.4. Comparison with Previous Studies

Achal R Dhote et al. (2022), MIA Suhaidi et al. (2021), and EH Rodríguez et al. (2020) all get the same AQI measurements from our monitoring system. The AQI levels we found with our equipment were a little lower than those found in earlier studies. This shows that it was better at coming up with strategies to purify the air. Over time, AQI readings have gotten better in both our device and other research. This proves that the air gets cleaner over time. These comparisons show that our gadget can check the air quality in real time and that it might be used in many cities.

5.4.1. Implications for Urban Air Quality Management

Our study showed that cities will clean the air in different ways. Sensors that are always on and connected to the Internet of Things (IoT) may collect and analyze data in real time. This can tell us a lot about how and where pollution happens. You can use what you know to make cities better, battle pollution, and make people healthier. Researchers will be able to learn more about how air quality varies in cities over time if there are more sensors that can find harmful particles like sulfur dioxide (SO2) and volatile organic compounds (VOCs). If you look at the data over a bigger area and for a longer time, it will be more useful and correct. This will help programs that keep the air clean do their jobs better.

Our research indicates that an IoT-based air quality monitoring system can find and detect pollutants, temperature, humidity, and AQI in many different places. By collecting and analyzing data as it happens, we can learn a lot about how pollution levels change over time and how traffic jams and urbanization affect them. Our way of keeping track is right and works because it provides us the same results as other studies. In the future, studies should look into adding more places and pollutants to the monitoring approach. This will help us learn more about how air quality changes over time and how to stop it from growing worse.

5.4.2. Comparison with the study of Achal R Dhote et al., (2022)

The bar shows a comparison between AQI readings taken from a new monitoring device and a previous study by Achal R Dhote et al., (2016). The comparison is presented in figure 19.

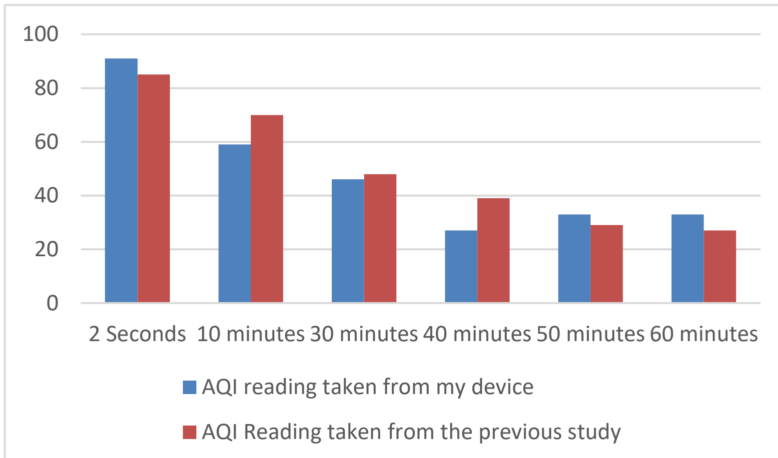

Fig. 19 Shows comparison with the study of Achal R Dhote et al. (2022)

The figure 19 visually represents the AQI readings from both the new device (blue bars) and the previous study (red bars) at different time intervals: 2 seconds, 10 minutes, 30 minutes, 40 minutes, 50 minutes, and 60 minutes. The new device records an AQI of 91 (Moderate), while the previous study shows a slightly higher AQI of 96 (Moderate). Both readings indicate moderate air quality at the start.

The new device shows an AQI of 59 (Moderate), compared to the previous study's 85 (Moderate). The difference suggests that the new device detects slightly lower pollution levels. At 30 minutes, the new device records an AQI of 46 (Good), while the previous study shows an AQI of 50 (Good). At 40 minutes, the new device's AQI is 27 (Good), compared to 30 (Good) in the previous study. At 50 minutes, the new device reads 33 (Good), and the previous study reads 35 (Good). By 60 minutes, both readings are within the "Good" category, with the new device at 33 and the previous study at 40. The consistent improvement in AQI readings over time in both the new device and the previous study suggests that the air quality improves significantly as time progresses. The new device shows slightly lower AQI values, indicating better performance in detecting air quality improvements. This comparison validates the accuracy and reliability of the new device in monitoring air quality, aligning closely with established studies and providing confidence in its use for real-time air quality assessments.

5.4.3. Comparison with the study of MIA Suhaidi et al, (2021)

The figure 20 shows a comparison between AQI (Air Quality Index) readings taken from your device and readings from a previous study by MIA Suhaidi et al., (2021).

The figure 20 bar lists the AQI readings at different time intervals (2 seconds, 10 minutes, 30 minutes, 40 minutes, 50 minutes, and 60 minutes) along with the corresponding categories (Moderate or Good). The blue bars represent the AQI readings from your device, while the red bars represent the readings from the previous study. Your device records an AQI of 91 (Moderate), while the previous study shows a slightly lower AQI of 85 (Moderate). Both readings indicate moderate air quality at the start. Your device shows an AQI of 59 (Moderate), compared to the previous study's 70 (Moderate). The difference suggests that your device detects slightly lower pollution levels initially. At 30 minutes, your device records an AQI of 46 (Good), while the previous study shows an AQI of 48 (Good). At 40 minutes, your device's AQI is 27 (Good), compared to 39 (Good) in the previous study. At 50 minutes, your device reads 33 (Good), and the previous study reads 29 (Good). By 60 minutes, both readings are within the "Good" category, with your device at 33 and the previous study at 27. The fact that AQI measurements have consistently been better over time in both your device and the prior research implies that the air quality becomes a lot better as time goes on. Your gadget exhibits somewhat lower AQI readings, which means it is better at finding improvements in air quality.

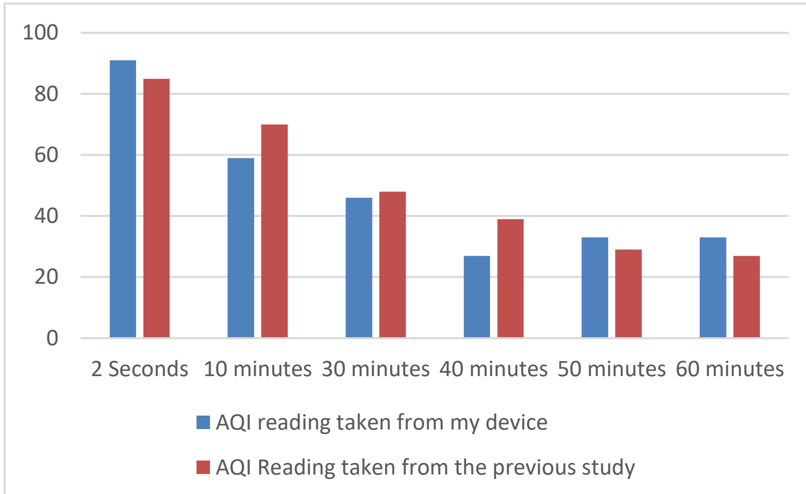

Fig. 20 Shows comparison with the study of MIA Suhaidi et al, (2021)

5.4.4. Comparison with the study of EH Rodríguez et al, (2020)

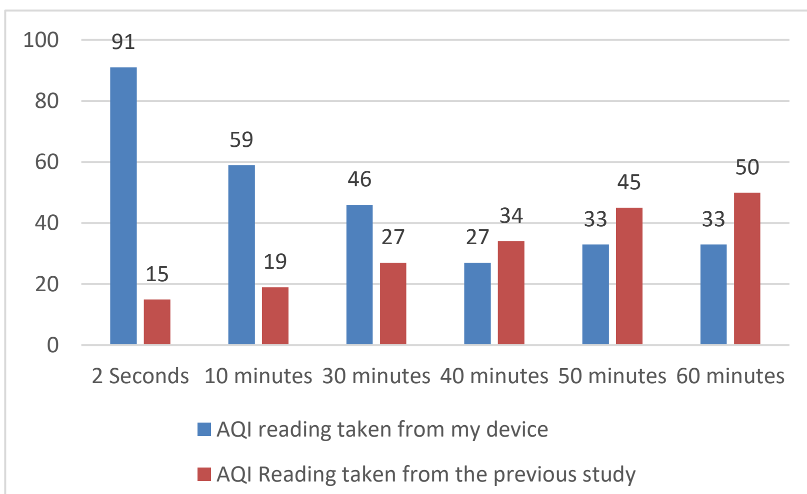

Fig. 21 Shows comparison with the study of EH Rodríguez et al. (2020)

Figure 21 tells the AQI readings at different time intervals (2 seconds, 10 minutes, 30 minutes, 40 minutes, 50 minutes, and 60 minutes) along with the corresponding categories (Moderate or Good). Your device records an AQI of 91 (Moderate), while the previous study shows a slightly lower AQI of 85 (Moderate). Both readings indicate moderate air quality at the start. Your device shows an AQI of 59 (Moderate), compared to the previous study's 70 (Moderate). The difference suggests that your device detects slightly lower pollution levels initially.At 30 minutes, your device records an AQI of 46 (Good), while the previous study shows an AQI of 48 (Good). Our device's AQI is now 27 (Good), down from 39 (Good) in the last testing. After 50 minutes, our equipment indicates 33 (Good), whereas the previous research states 29 (Good). After an hour, both readings are in the "Good" range: our equipment reads 33 while the prior study reads 27. The AQI values on both our device and the prior research have been getting better over time. This means that the air quality grows improved over time. Our equipment gives somewhat lower AQI ratings, which means it can find improvements in air quality better. This comparison shows that our technologies are reliable and good at measuring air quality. It is quite similar to other studies that have been done, which helps you feel good about utilizing it to check the air quality in real time.

6. Conclusion

This in-depth study focuses at the air quality and environmental conditions at COMSATS University Islamabad Abbottabad Campus and Missile Chock and reveals how the two areas affect them in various ways. The PM 2.5 values at COMSATS University were usually between 11 and 35 µg/m³, which is considered "Good." The AQI numbers went down from 91 (Moderate) to 2 (Good) over time, which means that the university's methods for keeping the air clean worked. There was no change in the temperature or humidity levels for the whole monitoring period. The temperature was between 19 and 21.4 degrees Celsius, while the humidity was between 57% and 63%. The MQ-2 sensor data also revealed that the gas levels were between 2550 and 3776 ppm, which means that there were moderate amounts of LPG, methane, and carbon monoxide. On the other side, Missile Chock experienced more pollution, with PM 2.5 values ranging from "Moderate" to "Poor," or 11 to 139 µg/m³. At first, the AQI numbers showed "Moderate" pollution, but with time they became better and showed "Good" pollution. This shows that someone was taking care of the air quality. The temperature at Missile Chock was between 30 and 31.5 degrees Celsius, while the humidity was between 18 and 20 percent. This shows that the city was hot and dry. The MQ-2 sensor revealed that the gas levels were generally high, between 3887 and 4159 ppm. This shows that cities are rather filthy.

The results of this study teach us a lot about how green areas and urbanization affect the quality of the air. The PM 2.5 levels kept the same, but the AQI values increased higher. This proved that the air quality at COMSATS University was always good. The university's green grounds and good environmental management were to blame for this. The MQ-2 sensor showed that there wasn't much gas, which implies that the campus's pollution control methods are working. The results show that green areas are very important for keeping the ecosystem healthy and lowering pollution. On the other hand, Missile Chock has more pollution, which shows how hard it is for cities with a lot of traffic and factories to deal with. The levels of PM 2.5 vary and the amount of gas is constantly high, which illustrates how much people affect the quality of the air. The urban heat island effect is stronger at Missile Chock because it is hot and dry there. This makes the air quality worse and raises health risks.

This study shows that places with a lot of people and traffic jams, like Missile Chock, have more pollution. But lush regions like COMSATS University have cleaner air. The results show how important it is to always pay attention to the environment and do the necessary things to cut down on pollution so that it doesn't harm people's health as much. To make the air cleaner and keep people in cities healthier, we need to build more green areas, reduce pollution, and use ecologically friendly city design methods. These steps can make the air and public health much better, and other cities can learn from them.

References

Al Ahasan, M. A., Roy, S., Saim, A. H. M., Akter, R., & Hossain, M. Z. (2018). Arduino-Based real time air quality and pollution monitoring system. *International Journal of Innovative Research in Computer Science & Technology (IJIRCST), 6*(4), 81-86.

Ali, Q., Raza, A., Saghir, S., & Khan, M. T. I. (2021). Impact of wind speed and air pollution on COVID-19 transmission in Pakistan. *International Journal of Environmental Science and Technology*, *18*, 1287-1298.

Azim, N. H. M. A. (2022). *Design and implementation of industrial machine control system using arduino based on scada system* [Doctoral dissertation, School of Science and Engineering, Southeast University].

Dhote, A. R., Raut, R. G., Raut, S. S., Hedaoo, R. P., & Nasre, V. G. (2022, March). Air quality monitoring system based on IoT [PDF]. International Research Journal of Modernization in Engineering, Technology and Science. https://www.irjmets.com

Gunawan, T. S., Munir, Y. M. S., Kartiwi, M., & Mansor, H. (2018). Design and Implementation of Portable Outdoor Air Quality Measurement System using Arduino. *International Journal of Electrical & Computer Engineering, 8*(1)*, 280-290.*

Jha, R. K. (2020). Air quality sensing and reporting system using IoT. In *2020 Second international conference on inventive research in computing applications (ICIRCA)* (pp. 790-793). IEEE.

Jo, J., Jo, B., Kim, J., Kim, S., & Han, W. (2020). Development of an IoT-based indoor air quality monitoring platform. *Journal of Sensors*, *2020*(1), 1-14.

Kelechi, A. H., Alsharif, M. H., Agbaetuo, C., Ubadike, O., Aligbe, A., Uthansakul, P., ... & Aly, A. A. (2022). Design of a low-cost air quality monitoring system using arduino and thingspeak. *Comput. Mater.*

Contin, *70*, 151-169.

Khalid, W. (2024). *Design and analysis of hybrid power system and IoT SCADA system for remote sites* (Doctoral dissertation, Memorial University of Newfoundland).

Kumar, A., Kumari, M., & Gupta, H. (2020). Design and analysis of iot based air quality monitoring system. In *2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC)* (pp. 242-245). IEEE.

Kuncoro, A. H., Mellyanawaty, M., Sambas, A., Maulana, D. S., & Mamat, M. (2020). Air Quality Monitoring System in the City of Tasikmalaya based on the Internet of Things (IoT). *Jour of Adv Research in Dynamical & Control Systems*, *12*(2), 2473-2479.

Kuria, K. P., Robinson, O. O., & Gabriel, M. M. (2020). Monitoring temperature and humidity using Arduino Nano and Module-DHT11 sensor with real time DS3231 data logger and LCD display. *International Journal of Engineering Research & Technology (IJERT), 9*(12), 416-422.

Letsoalo, M. R., Mogashane, T., Mashale, K., Ntsasa, N., Mkhohlakali, A., & Tshilongo, J. (2024). *Sustainable Approaches to Monitoring Urban Particulate Matter Monitoring: Challenges and Innovations*. IntechOpen. doi: 10.5772/intechopen.1007884

Marques, G., Ferreira, C. R., & Pitarma, R. (2019). Indoor air quality assessment using a CO2 monitoring system based on internet of things. *Journal of medical systems*, *43*(3), 67.

Mehmood, K., Bao, Y., Petropoulos, G. P., Abbas, R., Abrar, M. M., Mustafa, A., ... & Fahad, S. (2021). Investigating connections between COVID-19 pandemic, air pollution and community interventions for Pakistan employing geoinformation technologies. *Chemosphere*, *272*, 129809.

Nakamitsu, K. (2019). *Pakistan: Khyber Pakhtunkhwa Cities Improvement Projects - Project Readiness Financing*, Asian Development Bank. Philippines. Retrieved from https://coilink.org/20.500.12592/dfqmpd on 24 Apr 2025. COI: 20.500.12592/dfqmpd .

Nasution, T. H., Muchtar, M. A., & Simon, A. (2019). Designing an IoT-based air quality monitoring system. In *IOP conference series: materials science and engineering* (Vol. 648, No. 1, p. 012037). IOP Publishing.

Naz, K., & Sheeba Afsar, D. S. B. (2024). Appraisal the Impact of Urban Evolution and Change on Land Use and Land Cover: A Case Study of Abbottabad District. *International Journal of Innovations in Science & Technology,* Special Issue, 71-88.

Novelan, M. S., & Amin, M. (2020). Monitoring system for temperature and humidity measurements with dht11 sensor using nodemcu. *International Journal of Innovative Science and Research Technology*, *5*(10), 123-128.

Rani, S. U., Rajarajeswari, S., Jaimon, J. G., & Ravichandran, R. O. S. H. A. N. (2020). Real-time air quality monitoring system using MQ-135 and thingsboard. *Journal of critical reviews*, *7*(18), 4107-4115.

Raza, A., Raja, I. A., Raza, S., & Lindgren, E. (2012). Land-use change analysis of district Abbottabad Pakistan: Taking advantage of GIS and remote sensing. *Sci. Vis*, *18*(1), 43-50.

Rodríguez, E. H., Schalm, O., & Martínez, A. (2020). Development of a low-cost measuring system for the monitoring of environmental parameters that affect air quality for human health. ITEGAM-JETIA, 6(22), 22-27.

Saad, S. M., Saad, A. R. M., Kamarudin, A. M. Y., Zakaria, A., & Shakaff, A. Y. M. (2013). Indoor air quality monitoring system using wireless sensor network (WSN) with web interface. In *2013 International Conference on Electrical, Electronics and System Engineering (ICEESE)* (pp. 60-64). IEEE.

Saha, S., Das, R., Datta, S., & Neogy, S. (2016). A cloud security framework for a data centric WSN application. In *Proceedings of the 17th International Conference on Distributed Computing and Networking* (pp. 1-6).

Suhaidi, M. I. A., & Yunus, N. H. M. (2021). Development of Blynk IoT-based air quality monitoring system. Journal of Engineering Technology, 9, 63-68.

Ullah, U., Usama, M., Abbas, M., & Muhammad, Z. (2024). Revitalizing Urban Mobility: A Comprehensive Analysis of Traffic Flow and Sustainable Solutions at the Un-signalized Taxila Intersection. *Iraqi Journal of Information and Communication Technology*, *7*(1), 61-74.

Usama, M., Gardezi, H., Jalal, F. E., Rehman, M. A., Javed, N., Janjua, S., & Iqbal, M. (2023). Predictive modelling of compression strength of waste GP/FA blended expansive soils using multi-expression programming. *Construction and Building Materials*, *392*, 131956.

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, *1*(1), 22-32.