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IoT-Based Air Quality Monitoring and Analysis at MSME Locations

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Abstract. Air is a crucial element that affects the survival of living things, but air pollution is often overlooked, especially in areas with intensive human activities, such as MSME locations. This research aims to design an Internet of Things (IoT)-based air quality monitoring device in MSME trader locations, especially in open spaces exposed to cigarette smoke and closed air-conditioned spaces. The method used was a quantitative descriptive approach with experiments, collecting primary data through an MQ-135 air quality sensor that measured the concentration of gases such as CO and NH3. The results showed that in an air-conditioned room, the gas concentration was detected at 536.00 PPM, while in the cigarette smoke area it was 197.36 PPM. A significant decrease in sensor resistance at both locations indicates the presence of air pollution that is harmful to health. Data were collected continuously for seven days. Based on OSHA exposure limits, concentrations above 50 ppm may pose health risks, indicating that the detected 536 ppm is significantly beyond safe thresholds. This device demonstrates real-time environmental monitoring applicability for MSME settings. This study proposes continuous monitoring and pollution mitigation to improve air quality and reduce health impacts.

Keywords: Internet of Things; Air Quality Monitoring; MSME Environments; Air Pollution; Real-Time Monitoring

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1. INTRODUCTION

Air plays an essential role in sustaining life, primarily due to its quality and composition, which directly influence the health of living organisms. Poor air quality can lead to severe health issues, substantially impacting vulnerable populations, including children, the elderly, and those with pre-existing health conditions. Studies have shown that air pollution is linked to respiratory diseases, cardiovascular problems, and even cancer [1], [2]. Furthermore, the impacts of air pollutants are not limited to human health; they extend to ecological systems, disrupting various biotic processes and the functioning of ecosystems [3], [4]. The interaction between life forms and their air quality underscores the critical importance of air management strategies aimed at pollution reduction, which can significantly mitigate these adverse effects [3]. Thus, recognizing air as a vital component for survival emphasizes the need for continuous academic and practical efforts in protecting and enhancing air quality for the sake of all life on Earth [2].

Awareness of air quality and its implications is often insufficiently prioritized, leading to environmental challenges exacerbated by human activities. Daily actions, particularly those related to transportation and industrial processes, significantly contribute to air pollution [5], [6]. Research indicates that while community members recognize the importance of air quality, there is a gap in knowledge and understanding of pollution sources and their health impacts, with studies illustrating that the general knowledge of air pollution is often poor in various communities [7], [8]. Tailored education can enhance public engagement, prompting necessary behavioral changes and pollution mitigation strategies [6], [9]. This awareness can be bridged through clear communication channels and technology, enabling individuals to access real-time air quality data and alerts, which has been shown to improve public responsiveness to air quality issues [10], [11]. Promoting community participation in monitoring efforts can enhance knowledge and collective action against air pollution [12]. As evidenced by various studies, improving awareness through targeted initiatives is crucial for fostering both individual and collective responsibility in curtailing air pollution [13], [14].

One of the various impacts caused is due to industrial waste disposal activities through soil, water and air [15], [16]. In addition, tightly enclosed buildings and motor vehicle pollution are also factors in the occurrence of air pollution [17], [18]. An article published

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by the Cabinet Secretariat of the Republic of Indonesia states that according to IQAir2021 world air quality data in March 2022, Indonesia is ranked 17th in the world as a country with the highest air pollution with PM2.5 concentrations reaching 34.3 µg per cubic meter and occupies the top position with the highest air pollution in the Southeast Asian region [19]. Figure 1 shows that until November 2025, the problem of air pollution in Indonesia is still a significant problem [20].

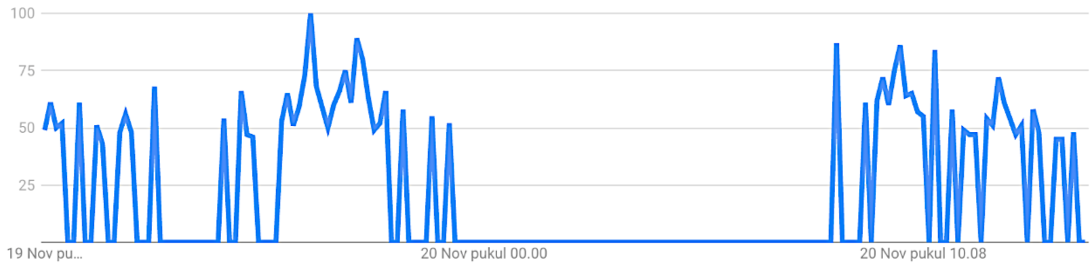

Figure 1. Air Pollution Trends

One of the unavoidable activities is gathering at MSME traders to buy food, drinks and others. Gathering while telling stories makes a person no longer aware of the air condition in that place, especially if the place is an open place that allows visitors to smoke. Seeing this, monitoring air quality is very important. Although humans have a sense that can directly feel the air pollution around them, it cannot be done continuously, because a person will not linger in a place where they feel uncomfortable considering that it will also have an impact on health, thus a tool is needed to monitor air quality in real-time. Air quality monitoring can be done by applying internet of things (IoT) technology by designing a device [21], [22]. The author tried to conduct research to design an IoT device using a NodeMCU microcontroller with the title "IoT-Based Air Quality Monitoring and Analysis at MSME Locations" in the hope of helping to find out how the air quality around the trader's location is. Previous research states that for humans, the results of PM 2.5 particulate matter and CO gas are in good condition while those that are unhealthy for humans are NO2 gas [23]. Other studies have also produced the highest pollution values at 3 location points by utilizing Internet of Things technology [24] and real-time air quality monitoring prototypes can provide convenience in providing air quality information [25].

Based on the above background, the formulation of the problem in this study is how to design a device that can monitor and analyze air quality based on the Internet of Things

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(IoT) at MSME locations with a smoking area in enclosed spaces. Existing IoT-based air monitoring studies generally focus on residential or urban locations; however, limited research compares indoor air-conditioned MSME environments with outdoor smoking-exposed MSME areas using real-time IoT monitoring. This gap motivates the present study to provide comparative measurements relevant to MSME worker and visitor exposure. MSME trader locations are often crowded, and workers experience repeated exposure to pollutants, especially in semi-open areas where smoking is common. These characteristics make MSMEs important environments for air quality monitoring.

2. METHODS

This study adopts a quantitative descriptive approach combined with an experimental method. The descriptive approach is utilized to describe the air quality monitored through the designed IoT device, providing insights into the environmental conditions. The experimental approach is employed to assess the effectiveness of the device in monitoring and analyzing air quality within the MSME environment. As shown in Figure 2, the research framework outlines the steps involved in the study, including the key stages of device design, data collection, and analysis. The framework provides a clear overview of the methodology guiding the study. Additionally, Figure 3 presents the experimental flowchart, detailing the process of testing the IoT device in the MSME environment. It outlines the steps taken to evaluate the device's performance, including data collection, analysis, and the conditions under which air quality is monitored.

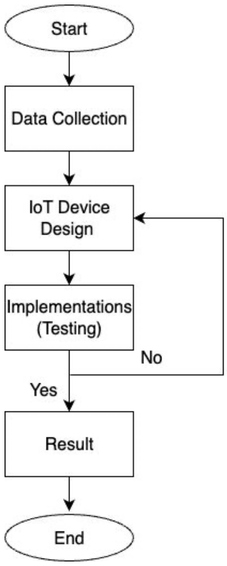

Figure 2. Research Framework

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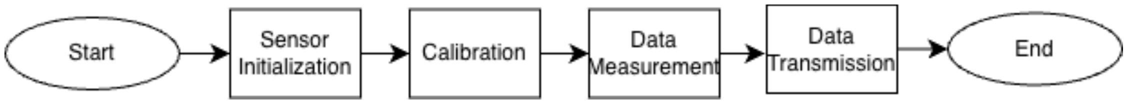

Figure 3. Experimental Flowchart

2.1. Data Collection Process

The data collection method in this study uses a combination approach between primary data and IoT-based sensor tools. Primary data was collected through air quality measurements in a closed spaces MSME locations. Some of the air quality parameters to be measured include the concentration of carbon monoxide (CO) and ammonia (NH3) gases, as well as temperature and humidity factors that can affect air quality. To collect this data, an MQ-135 air quality sensor connected to an Internet of Things (IoT) device is used. The sensor is placed on a table at a height of approximately 1 meter. The distance between the sensor and the source is about 1 to 2 meters. These sensors transmit data every 3 seconds for 7 days in real-time through an IoT platform that connects the device to the internet. The collected data is then processed using an Arduino-based data processing device, which functions to process information from sensors and send it to a cloud-based platform for further analysis.

2.2. IoT Device Design

The design of the hardware system began by connecting the air quality sensor used in this study with an Arduino-based microcontroller. This system will ensure that the sensor can transmit accurate and timely data regarding the measured air quality parameters. Figure 4 illustrates the architecture diagram depicting the connection between the MQ-135 sensor, ESP32 module, and LCD. The MQ-135 sensor is used to detect air quality by monitoring gases such as ammonia (NH3), carbon monoxide (CO), and other gases. The data received from the MQ-135 sensor is processed by the ESP32 and displayed on the LCD, providing real-time information about the air quality condition. The connected wires represent the flow of power and signals between these components, as well as the sensor configuration via a potentiometer for more accurate calibration.. This device is powered by a 5V DC power supply. The development of IoT devices aims to enable devices to automatically transmit data obtained from sensors over an internet connection. This data transmission process uses communication protocols such as MQTT or HTTP that allow real-time transmission of data to a cloud-based platform for further analysis. The sensor reading is visualized using the Blynk platform.

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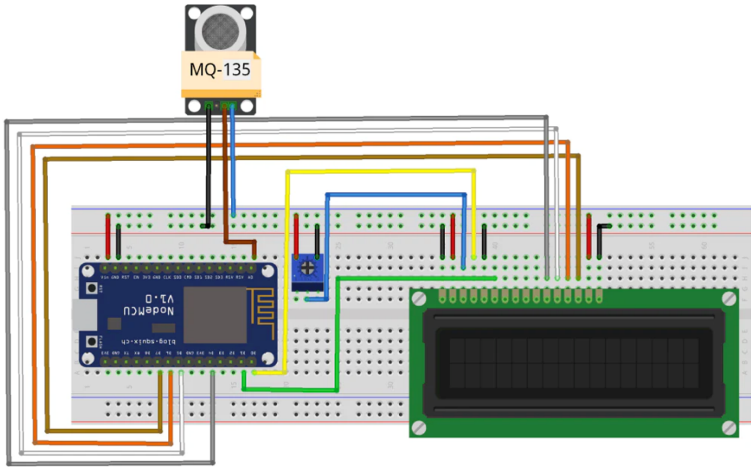

Figure 4. An architectural diagram illustration of the IoT device design

2.3. Data Analysis

The data collected from the air quality sensors will be processed and stored in a cloud system for easy further analysis. The air quality monitoring system collects real-time data from various sensors deployed across the monitoring area. These sensors measure key pollutants such as ammonia (NH3), carbon monoxide (CO), benzene, and particulate matter (PM2.5, PM10), along with environmental factors like temperature and humidity. Once collected, the data is transmitted to a cloud platform for further storage and analysis. To ensure the reliability of the data, preprocessing steps are performed, including handling missing values and outliers. Missing data is addressed by either interpolation or discarding readings, while outliers are identified using statistical methods such as Z-scores or interquartile ranges (IQR). Additionally, noise in the data is minimized using smoothing techniques like moving averages to ensure more accurate analysis.

Descriptive statistics, such as the mean, standard deviation, and percentile distribution, provide an overview of the air quality data. For instance, the mean concentration of CO might be 5.2 ppm with a standard deviation of 1.1 ppm. This helps in understanding the central tendency and variability of pollutant levels. Furthermore, trend analysis is conducted to examine how air quality changes over time. Time-series analysis is applied to identify patterns, such as peak CO concentrations during rush hours, while seasonality is assessed to explore any seasonal variations, such as higher pollutant levels in winter.

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The system also performs correlation analysis to explore the relationships between pollutant levels and environmental factors. For example, a negative correlation between humidity and PM2.5 concentrations might indicate that higher humidity reduces the dispersion of fine particulate matter. In addition, multivariate analysis, such as Principal Component Analysis (PCA), is used to identify the key factors contributing to variations in air quality.

To make the data more actionable, pollutant levels are classified according to established thresholds, such as the Air Quality Index (AQI). This classification helps categorize air quality into different levels such as "Good," "Moderate," or "Unhealthy." For example, a CO concentration of 8 ppm may be classified as "Moderate," while 15 ppm could be classified as "Unhealthy." The AQI is calculated as an aggregate measure, providing a clear indication of overall air quality. For more advanced insights, predictive models are employed to forecast future air quality levels based on historical data. Techniques such as Random Forest Regression or Long Short-Term Memory (LSTM) networks are used to predict future pollutant concentrations. Additionally, anomaly detection methods, like Isolation Forest, are implemented to identify unusual spikes in pollutant levels, which may indicate a potential pollution source or equipment malfunction. The analyzed data is visualized through real-time dashboards, geographic heatmaps, and trend graphs. These visualizations make it easy for stakeholders to interpret the data and take necessary actions. Automated alerts are triggered when pollutant concentrations exceed safe limits, notifying local authorities or residents about potential health risks.

The analysis conducted in this study is a descriptive analysis, which aims to describe the air quality at MSME locations with a smoking area in enclosed spaces. Testing of the device conducted at MSME locations with a smoking area in enclosed spaces, to see if the device can detect changes in air quality effectively and reliably. The data analysis will provide insight into the factors that affect air quality in MSME locations and allow for the evaluation of the success of the device in monitoring air quality continuously

3. RESULTS AND DISCUSSION

The following are the results of research that has been conducted in enclosed spaces. Based on the data obtained from the MQ135 sensor in figure 3, it can be explained in

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detail about the measured values. RZero shows the sensor's resistance value under clean air conditions, which is 98.99 ohms, which serves as a basic reference for the sensor before exposure to gases. After corrections were made to environmental factors such as temperature and humidity, the Corrected RZero value became 100.27 ohms, which reflects a more accurate RZero value and in accordance with field conditions. The rated resistance is 63.60 ohms, which indicates the resistance of the sensor when exposed to the gas. This value is lower than that of RZero, which indicates that the gases in the air have affected the sensor and changed its resistance. For gas concentrations, the measured PPM is 190.92, which indicates the amount of gas present in the air before the correction, and after correction for environmental factors, the Corrected PPM value becomes 197.36, which reflects a higher gas concentration after the adjustment. The ambient temperature around the sensor is measured at 24.80°C, which can affect the sensitivity of the sensor, as higher temperatures tend to increase the sensor's reactivity to gases. Lastly, the relative humidity of the environment in which the sensor operates is recorded at 70.00% RH, which can affect the performance of the sensor, as high humidity can interact with gases in the air and affect sensor readings.

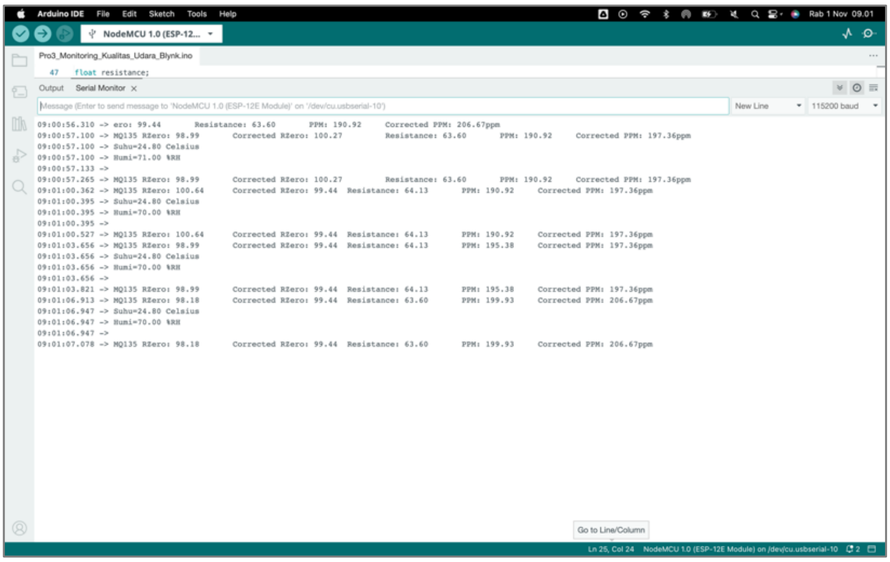

Figure 3. Results of the sensor reading for the smoking area in enclosed spaces

3.1. Air quality in smoking areas within enclosed spaces

In areas with exposure to cigarette smoke, the detected PPM value was 197.36 after correction, which also indicates significant air pollution. Although the value is lower than in an air-conditioned room, the concentration of this gas is still quite high and potentially

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harmful to health. The recorded temperature is 24.80°C and the humidity is 70.00% RH, indicating more humid conditions, which may also affect the sensitivity of the sensor. Even so, corrections have been made for these environmental factors. In this context, the detected gas concentrations are most likely related to cigarette smoke, which contains a variety of harmful pollutants, including carbon monoxide (CO), which if exposed in high concentrations can cause respiratory distress and poisoning. Therefore, it is necessary to carry out continuous monitoring and identification of sources of pollution to reduce their impact on air quality and human health.

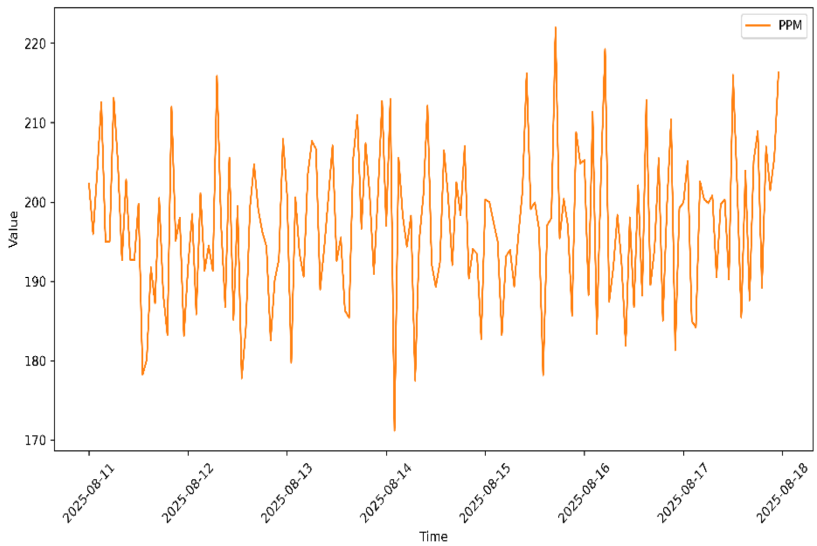

Figure 4. PPM values overtime for the smoking area in enclosed spaces

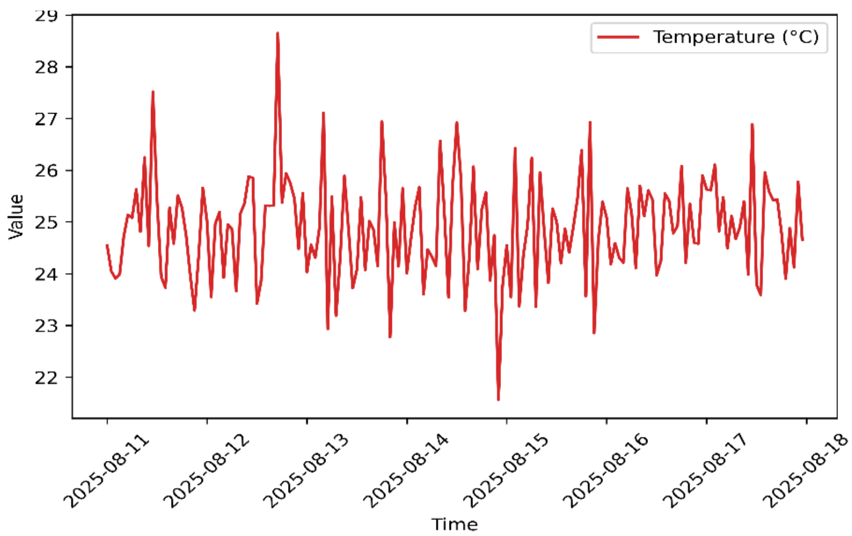

Figure 5. Temperature values overtime for the smoking area in enclosed spaces

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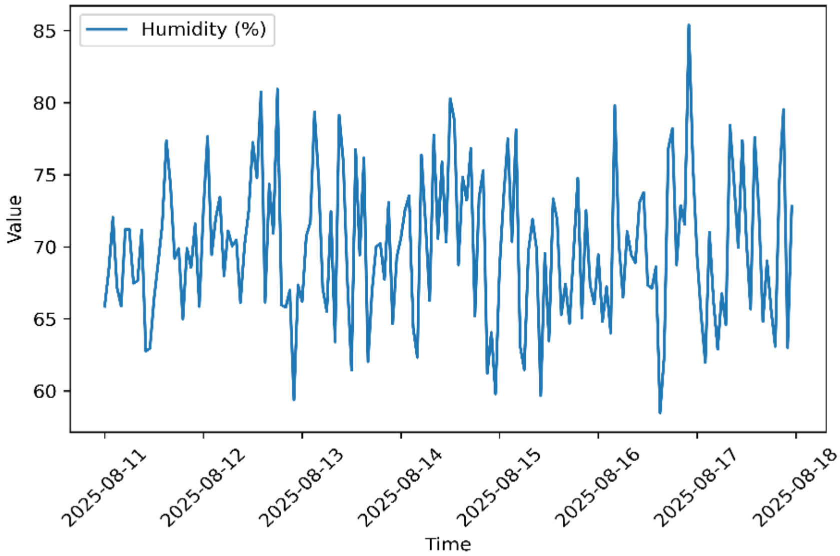

Figure 6. Humidity values overtime for the smoking area in enclosed spaces

3.2. Discussion

The results from the IoT-based air quality monitoring device underscore the effectiveness of real-time data collection in MSME environments, particularly in smoking areas within enclosed spaces. The study revealed significant air pollution, especially in locations exposed to cigarette smoke. The MQ-135 sensor consistently detected harmful gases like carbon monoxide (CO) and ammonia (NH3), with gas concentrations reaching 197.36 PPM after environmental adjustments. Although the readings were not as high as those in air-conditioned rooms, they still indicate a substantial level of pollution that could potentially lead to adverse health effects, particularly with long-term exposure. These findings align with previous research that highlights the harmful impact of tobacco smoke on indoor air quality, reinforcing the need for consistent monitoring in such environments.

The temperature and humidity data collected during the study show that environmental conditions significantly influence sensor accuracy. The recorded temperature of 24.80°C and humidity level of 70% RH may have affected the sensor's reactivity, causing slight fluctuations in the readings. High humidity can lead to condensation on the sensor, affecting its ability to accurately measure certain gases. However, corrections for these factors were applied to ensure the data reflected the actual air quality, making it clear that while the device provided valuable real-time data, environmental conditions must always be accounted for when interpreting sensor results. This sensitivity to environmental factors demonstrates the complexity of using IoT devices for air quality monitoring in varying conditions.

Despite the influence of environmental factors, the study's results underscore the importance of continuous air quality monitoring, especially in MSME locations, where exposure to pollutants like CO and NH3 is frequent. In smoking areas, even moderate concentrations of gases can be harmful, and prolonged exposure can lead to respiratory issues, cardiovascular problems, and other serious health conditions. The data provided by the IoT device gives valuable insights into the levels of pollution present in such areas and can serve as an early warning system for individuals and authorities. The ability to monitor air quality in real time allows for swift action when pollutant levels exceed safe thresholds, reducing the risks associated with poor air quality.

One of the key challenges identified in this study is the need for broader implementation of air quality monitoring systems in high-traffic environments like MSMEs. The data from this study demonstrate that air quality in these settings is often compromised due to the high volume of people and activities, including smoking. While the device provided reliable measurements in both open and closed areas, its effectiveness could be enhanced with the addition of more advanced sensors capable of detecting a wider range of pollutants. Future improvements to the IoT device could also include better calibration for varying temperature and humidity conditions, improving the device's reliability across different environments.

This study highlights the potential of IoT technology to address air quality concerns in MSME environments, providing a practical and scalable solution for continuous monitoring. The real-time data gathered can assist in identifying pollution sources, implementing corrective measures, and ultimately improving the health and safety of workers and visitors. With the growing recognition of air pollution as a significant public health issue, the integration of IoT-based air quality monitoring in MSME settings represents a crucial step toward better environmental management. Further research and development in this area could expand the capabilities of such devices, making them even more effective in addressing the global challenge of air pollution.

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4. CONCLUSION

Continuous monitoring of air quality is essential. If gas concentrations remain high as detected at the location, then pollution control measures should be implemented immediately. Actions such as improving ventilation, using air purifiers, and identifying and reducing sources of pollution can help improve air quality. In areas with exposure to secondhand smoke, for example, restricting smoking or separating smoking spaces from public spaces can be an effective first step.

In addition, further analysis of pollution sources, such as vehicle exhaust gases or industrial activities, needs to be conducted to identify more comprehensive solutions. Increasing public awareness about the importance of maintaining air quality can also support pollution mitigation efforts and safeguard public health. The need for further analysis of pollution sources, such as vehicle exhaust and industrial emissions, is critical for developing effective air quality management strategies. Vehicles are significant contributors to urban air pollution, emitting harmful pollutants like nitrogen oxides (NOx) and volatile organic compounds (VOCs). Industrial activities also release particulate matter and other toxic substances that severely impact public health. Understanding the specific sources and mechanisms of these emissions can facilitate more targeted regulations and interventions.

Additionally, boosting public awareness about the necessity of air quality maintenance is paramount. Enhanced knowledge about air pollution is linked to improved community engagement and support for mitigation efforts. For example, public health policies can be significantly more effective when the populace is informed about the health risks associated with pollution and the steps they can take to mitigate these risks. Furthermore, as individuals become more aware of air quality issues, they are more likely to advocate for healthier practices and support policies that address air pollution, ultimately contributing to better public health outcomes.

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