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WSN-Based Data Acquisition System for Collecting Environmental Pollution Factors for Green City

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Abstract*: Implementation with a portable, intelligent weather station is to upgrade the system for environmental management and monitoring. This gadget measures and assesses meteorological and air quality data by real-time implementation through the Internet of Things technology to provide important environmental condition insights. The monitoring station's hardware parts include the ESP32 board, MQ2, MQ3, and MQ135 sensors for gas detection. Such an intelligent weather monitoring station can easily be deployed in different environments due to its portability and versatility. This small station size and its wireless link will enable effective data collection and transfer and integration into other systems of the present day. The existing environmental monitoring system takes the temperature and humidity and measures ammonia, benzene, alcohol, smoke, and carbon monoxide. Therefore, data is brought to the monitoring station, where it communicates in real time for the users to review and analyse on the online platform Blynk. It enables users to easily make data presentations and create notifications and dashboards using a mobile app of Blynk and the web platform, enabling them to create interfaces that meet their satisfaction easily. Users may also upload the uploaded data to a web server for remote access and analysis, which eases scalability and flexibility. Portable intelligent weather monitoring station has significant areas of influence on applications like public health, urban planning, and environmental monitoring, among others. It thus provides decision-makers with information on pollution management and climate resilience. This provides a sustainable and resilient future; it is approachable since the interface used in the system is accessible, befitting the two settings: urban and rural. The Intelligent Portable Weather Monitoring Station provides great usefulness in the disclosure, development, innovation of technology, and practice in the quest for meeting challenges of the environment with the promotion of sustainability. This not only allows smarter and more sustainable city development with effective environmental monitoring and management that includes IoT technologies but can also allow flexible data transmission facilities.*

Keywords: Environmental Monitoring, Data Acquisition System, IoT Technology, Green City, Sustainability, Air Quality, Pollution Factors, Real-time Data Analysis

I. INTRODUCTION

Cutting-edge technology becomes essential in light of growing environmental concerns and the pressing need for sustainable growth. The development of Wireless Sensor Networks (WSNs) has allowed for real-time data collection, processing, and distribution, revolutionizing environmental monitoring. This paper comprehensively explores a WSN-based Data Acquisition System designed specifically for collecting environmental pollution factors, focusing on fostering the vision of a Green City.

As the global population continues to burgeon and urbanization accelerates, the strain on our environment amplifies. Urban areas, in particular, grapple with many environmental challenges ranging from air and water pollution to waste management issues. The unchecked release of pollutants into the atmosphere not only deteriorates air quality but also

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poses grave health risks to inhabitants. Similarly, water pollution undermines the availability of clean drinking water and disrupts aquatic ecosystems. These challenges necessitate proactive measures to monitor, mitigate, and address environmental degradation.

In response to burgeoning environmental challenges, sustainable urban development has gained prominence. A Green City embodies the principles of sustainability, striving to minimize its environmental footprint while maximizing the quality of life for its residents. Central to this endeavor is integrating advanced technologies to enhance environmental monitoring, resource management, and energy efficiency. By leveraging cutting-edge solutions, cities can transition towards a more sustainable trajectory, safeguarding the well-being of current and future generations.

The emergence of Wireless Sensor Networks (WSNs) heralds a paradigm shift in environmental monitoring capabilities. Comprising spatially distributed autonomous sensors, WSNs enable seamless data acquisition across vast geographical areas. These sensors are equipped with various environmental sensors capable of measuring parameters such as temperature, humidity, air quality, and pollution levels. By harnessing the power of WSNs, environmental monitoring becomes more granular, comprehensive, and real-time, empowering stakeholders with actionable insights to address environmental challenges proactively.

At the heart of effective environmental monitoring lies the deployment of intelligent data acquisition systems. These systems integrate state-of-the-art sensor technologies with advanced data processing algorithms to collect, analyze, and disseminate real-time environmental data. By leveraging Internet of Things (IoT) technologies, these systems enable seamless connectivity and communication, facilitating remote monitoring and control. Moreover, intelligent data acquisition systems are characterized by their adaptability, scalability, and energy efficiency, making them ideal for deployment in diverse environmental monitoring applications.

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II. LITERATURE REVIEWS

All aspects of wireless sensor networks were examined in depth in this study, including their design, implementation, surroundings, uses, and safety concerns. After that, we examined the most current studies that tried to use ML approaches to improve WSN security and looked at the ML algorithms used. Additionally, the study's advantages and disadvantages were detailed. Future solutions that could leverage machine learning approaches in WSN security were outlined in this article because of its great promise in this area. According to statistics, ML algorithms are often used for error and intrusion detection in WSN security. SDN is how to employ ML algorithms in more security-related contexts. Using it may reduce overall use costs and increase the efficiency of WSN nodes. [1]

In a WSN setting, examine how the LEACH algorithm impacts power use and network longevity. While LEACH does reduce node energy usage, the uneven distribution of it leads to network congestion. This is addressed by merging LEACH with an improved version of the K-means clustering method, which extends the life and performance of the network. The results show improved performance and a prolonged network lifespan when comparing continuous energy usage in various pollution scenarios using K-LEACH in static and dynamic settings. The optimal routing and clustering of data in environmental situations will be the subject of future study into software-defined networking and edge computing systems. [2]

Several studies have shown that air pollution and monitoring systems should be high on the list of priorities. This page provides a synopsis of the several methods researchers use to ascertain the quantities of gases and particles in the air. This study investigates the effectiveness of the pollution monitoring system's many networks. [3]

A wireless sensor network (WSN) is a new network that uses networked sensors to monitor environmental conditions and human health. Many fields, including medicine and the military, may benefit from this network. Prioritizing data security should be a top concern while designing a protocol for wireless data transmission. Despite offering secure data transfer, several conventional routing algorithms disregarded power use. Developing a routing architecture for wireless sensor networks (WSNs) while keeping energy consumption minimal is challenging. Maintaining high scalability and prolonging the life of a WSN is no easy feat. [4]

A data visualization system is built to assess the results and aid in implementing real-time visualization technologies. Examining virtualization technologies has been successful for the researchers. One acquires theoretical knowledge of the process in tandem with building the system. The visualization system may accomplish the main goal of this project's design by connecting to a computer via a serial port, gathering and storing data from a sensor network, making data

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searches easier, and modeling distributions in the actual world. Several techniques for real-time data visualization are covered and evaluated in this paper. The goal is to rebrand using the data collected from ongoing pollution monitoring, establish a healthy standard for travel, and reduce pollutant emissions via targeted and efficient techniques[5].

This study introduces a new method for environmental monitoring by creating a system that considers five previously overlooked variables: humidity, light intensity, temperature, barometric pressure, and gas concentration. It is the first of its kind in environmental monitoring systems that use AES encryption for data security, RSSI-based network efficiency calculation, and the PAN ID-secured Zigbee network all at once[6].

The findings demonstrate a ceiling on the potential expansion of mobile sensor networks linked to the Internet of Things to preserve optimum energy usage. Mathematical and computational data and a proposed approach for selecting coverage and connectivity with nearby nodes back up these claims. A new entry is added to the list to allow energy sharing among close nodes, which updates the routing table with the state of surrounding nodes and calculates optimum transmit power. This ensures that the network connection will always fall within the binomial distribution. Free-space propagation is considered in this paper's study. Moving further, it is important to consider the impact of multi-path fading and interference from neighboring nodes on the received signal intensity. Increasing the transmit power might be necessary to achieve the desired signal-to-interference noise ratio. Another angle to consider is the battery life. Estimating a vehicle's energy needs concerning speed is one potential future use of artificial intelligence technologies like convolutional neural networks (CNNs)[7].

The topic of this article is the use of a Wireless Sensor Network for environmental monitoring. The concept, development, and experimental evaluation of a miniature antenna for sensor nodes were also covered in depth. An RF controller may control the six-section BS antenna. An environmental monitoring WSN is formed by combining the two antennas with Lopy4 transceivers. Along with researching the coverage and maximum range of the suggested design, field experiments show that the BS antenna's RF switching mechanism works well and has a 360 field of view. Due to the constraints imposed by the measurement site's location, the provided network and the WSN-EM project met their criteria with a maximum distance of 3.85 kilometers between the SN and BS [8].

Careful use of the several tactics outlined in this paper is required to implement WSNs for EMAs effectively. While designing WSNs for EMAs, it is crucial to consider the network architecture, the number of sensors, and the parameters to ensure the network will last and provide good service. Addressable communication between sensor nodes is made possible by the hardware design of EMAs. Anybody with an internet connection or access to the cloud may see the data stream emanating from the sensor nodes placed by EMA at any given moment. A dashboard displaying sensor data generated from parameters is a common web interface feature. The topologies of wireless sensor nodes allow EMAs to conserve power, reuse hardware, manage resources, and operate in real-time. This research (IoT) also explored improvements to WSNs made possible by AI[9].

This special journal issue is titled "Wireless Sensor Networks for Environmental Monitoring" and comprises papers summarising its contents. Peruse this Special Issue's most recent advances, setbacks, and improvements in environmental data collecting, monitoring, analysis, risk assessment, and management. Wireless sensor networks (WSNs) allow for the worldwide monitoring of environmental conditions via features and the development of aesthetically pleasing and innovative solutions. Risk management, monitoring of different physical systems, and distant environmental sensing have all been substantially enhanced by these networks, which include several dispersed devices with sensing, processing, and wireless communication capabilities[10].

Various items may be monitored and managed with the help of Wireless Sensor Networks (WSN), which are currently being developed for use in weather stations and agriculture. Hardware platforms for sensor networks are embedded systems with several sensors, including built-in sensors and the ability to connect more sensors via analog I/O ports. Developing a WSN substantially facilitates the construction of authentic environmental communication and monitoring systems. A wireless sensor network (WSN) is a network of interconnected, geographically dispersed sensors that can detect, measure, and record changes in environmental variables before relaying their data to an analysis hub. WSN's most salient features are its low power consumption (since sensor nodes run on batteries), mobility (as opposed to traditional cables), adaptability to different environments, ease of use, and multi-layer design functioning. Controlling power consumption and optimizing data transmission is more important for WSN environment-monitoring applications than the limitations imposed on energy storage devices by their applications and deployment circumstances. The best ways to lessen traffic congestion and, by extension, pollution in cities may be found by using descriptive and predictive models built from real-time environmental and traffic data recorded by a WSN[11].

This study presents the development of an Environmental Monitoring (EM) Wireless Sensor Network (WSN). There will be a reduced form factor antenna for the sensor nodes (SN) and a multi-sector base station (BS) antenna made of several microstrip Quasi-Yagi elements. These will be designed, implemented, and experimentally characterized. The article continues by detailing the deployment of a WSN that uses the created BS and SN antennas and is based on Lopy4 transceivers. Ultimately, provides field testing findings that measure the network's performance in terms of coverage area and maximum coverage distance. The field tests have shown that, at distances greater than 3.5 km and for all antenna sectors of the multi-sector BS that achieve a 360 field of view, the connection between the sensor nodes and the created WSN base station is reliable[12].

This research study delves into designing and implementing a data acquisition system that utilizes wireless sensor networks (WSNs) to gather information on environmental pollution causes. The particular goal is to help bring about a Green City. Provide a thorough evaluation of the current body of information on WSN and its applications using several methodologies. This study uses WSN technology to monitor air and water pollution, noise levels, and other important environmental indicators in real time in an economical and scalable way. This system proposes an intelligent and flexible WSN system that can capture, analyze, and transmit real-time environmental data by synthesizing ideas from multiple literature sources. Findings stress the need for cutting-edge sensor integration into WSN architecture for comprehensive pollution factor monitoring. In addition to investigating different data-gathering approaches, this investigation investigates the possibility of obtaining valuable insights using sophisticated data analytics and visualization tools[13].

Data collection and dissemination architecture based on Wireless Sensor Networks (WSNs) These systems can assess pollution continuously in (near) real-time, even in difficult-to-reach or dangerous areas. This may have a major impact on how well we can notice and foresee potential sources of pollution. However, these methods still need more frequent usage due to technical restrictions. This article gives a synopsis of the present technical endeavors striving to continuously monitor the air and water quality cheaply and in near real-time. Methods and methods for data collection, processing, and transmission are its main areas of interest. Though it faces many challenges, it investigates why new technologies are needed, how they are structured in terms of hardware and communication, and whether or not they can replace the existing technologies. Further, it proposes research directions for academics, engineers, and future studies that will improve the actual systems [14].

Focusing on energy-efficient WSNs for environmental monitoring, this research prioritizes decreased power utilization and optimized data transport. The TelosB mote and TinyOS are used to build the infrastructure, and an algorithm is used to preserve energy and extend the network's lifespan. Lightweight cipher text addition is utilized instead of cryptographic methods to increase network lifetime and minimize aggregator burden. Using MAX, Average, and Sum to aggregate data eliminates duplication, boosts WSN lifetime, and decreases communication overhead. Even if it is not feasible, the research suggests a probability-based approach to turning off sensors to save energy. It considers integrating camera modules into the system to take low-light pictures and identify infrared motion[15].

III. PROPOSED SYSTEM

A block diagram of the proposed system is presented in Fig. 1.

The methodology employed in developing the portable intelligent weather monitoring station revolves around a systematic approach to measuring weather and air quality parameters using an IoT-based system. This section delves into the purpose and design of the monitoring station, the hardware components utilized, the parameters measured, data transmission mechanisms, and data accessibility for users.

The primary purpose of this project is to design and implement a portable smart weather monitoring station capable of providing real-time data on meteorological and air quality indicators. To fulfill this purpose, the design of the monitoring station is carefully crafted to incorporate various hardware components and software systems, facilitating accurate data collection, analysis, and transmission.

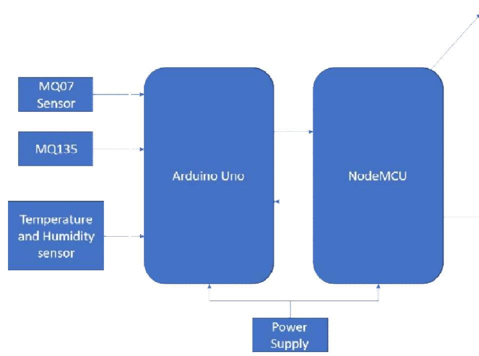

Fig.1 Block diagram of the ANPR system

The hardware components utilized in the monitoring station play a crucial role in ensuring its functionality and reliability. The main microcontroller employed is the Arduino UNO board, chosen for its versatility and compatibility with various sensors and modules. Additionally, a node MCU with an ESP8266 Wi-Fi module is integrated into the system to enable wireless data transmission. This combination of microcontroller and Wi-Fi module forms the backbone of the monitoring station, allowing seamless communication with external devices and platforms.

The monitoring station measures various parameters to provide comprehensive insights into environmental conditions. These parameters include temperature, humidity, pressure, PM2.5, PM10, O3, CO, and VOC levels. By monitoring such a wide range of indicators, the station can offer valuable information for various applications, including environmental monitoring, urban planning, and public health initiatives.

Data transmission is critical to the monitoring station's operation, facilitating the transfer of collected data to external platforms for analysis and visualization. The collected data is sent to the ThingSpeak web platform, a robust IoT platform capable of handling large volumes of data and providing user-friendly interfaces for data visualization. Additionally, the data can be displayed on a portable screen via a Wi-Fi connection, allowing for on-site monitoring and analysis.

Accessibility of data is essential to ensure that users can effectively utilize the information provided by the monitoring station. To this end, multiple avenues are provided for accessing and analyzing the collected data. Users can access the data through the ThingSpeak platform, which offers web-based data visualization and analysis interfaces. A mobile application has also been developed to enable users to access data on their smartphones or tablets, providing flexibility and convenience. Furthermore, data can be accessed through a web server, allowing for remote access and analysis from any location with an internet connection.

The methodology employed in developing the portable intelligent weather monitoring station encompasses various aspects, including purpose and design, hardware components, measured parameters, data transmission, and data accessibility. By following a systematic approach and leveraging IoT technology, the monitoring station can provide valuable insights into environmental conditions, thereby contributing to environmental monitoring, urban planning, and public health initiatives.

IV. IMPLEMENTATION

This section presents the implementation of the proposed system.

4.1 Software specification

- Microcontroller Programming: The modern and most common microcontroller used today is probably the Arduino UNO. It is programmed usingArduino IDE or other available software development environment. Everything, from the Wi-Fi module ESP8266 to data processing and sensor interfaces, is implemented in C/C++ code.

- Data Transmission Protocol: The monitoring station uses HTTP or MQTT protocols to transmit data to ThingSpeak online. The MQTT protocol is preferred for lightweight publish-subscribe messaging with efficient communication, and HTTP is just for the lightweight transport of data protocol.
- Data visualization and analysis: ThingSpeak includes built-in tools for visualizing recorded data, made possible via customizable charts, graphs, or gauges. Data trends, events, alerts triggering, and historical analysis are some of the analytics capabilities present on the platform.
- Mobile App Development: Develop mobile applications for iOS and Android platforms using React Native or Flutter. The mobile app will include the provision for smartphone or tablet live data access, which could be anything from past purchases or favorites and notifications to users, including custom-made settings on the method of monitoring.
- Web Server Configuration: In hosting the user interface for remote access to data being monitored, some of the technologies employed include HTML, CSS, JavaScript, and other scripting languages on the server side. It augments dynamism through Node.js on the pages designed to visualize and analyze data.

4.2 Hardware Specification

- Microcontroller: The dominating microcontroller is the Arduino UNO board, which provides processing power and interfacing capability to sensor and peripheral attachments. The microcontroller is ATmega328P-based, which is supposed to run at 16 MHz.
- Wireless Communication Module: In transferring the measurements over a wireless medium, the monitoring station may use a Node MCU board integrated with an ESP8266 Wi-Fi module. Further, the ESP8266 module has 802.11 b/g/n Wi-Fi standards to connect to local networks and the internet.
- Sensors:
  - DHT11 Sensor: Measures temperature and humidity with an accuracy of ±2°C and ±5% RH, respectively.
  - MQ2 Sensor: Detects various gases, including LPG, propane, hydrogen, and methane.
  - MQ3 Sensor: Detects alcohol vapor concentrations.
  - MQ135 Sensor: Measures concentrations of gases such as carbon monoxide, ammonia, smoke, and benzene.
  - PM2.5 and PM10 Sensors: Measure particulate matter concentrations in the air, providing insights into air quality.
  - Ozone (O3) Sensor: Measures ozone levels in the atmosphere, aiding in air quality monitoring.
  - Carbon Monoxide (CO) Sensor: Detects carbon monoxide concentrations, an important indicator of indoor air quality.
- Power Supply: Provided by USB connection or other external connections, such as batteries and solar cells. Operates with an input voltage of 5V to 12V DC.
- Interface Display: The station's interface should consist of an LCD screen or module that will enable the required information to be displayed at the place. The place of display should be in a capacity to offer real-time readings for temperature, humidity, gas concentrations, and others.

These software and hardware specifications outline the technical requirements and capabilities of the portable intelligent weather monitoring station, enabling efficient data collection, transmission, visualization, and analysis for various environmental monitoring applications.

V. RESULTS

This section presents the results of the proposed WSN-Based Data Acquisition System for Collecting Environmental Pollution Factors for Green City. The hardware setup of the proposed system is shown in Fig.2.

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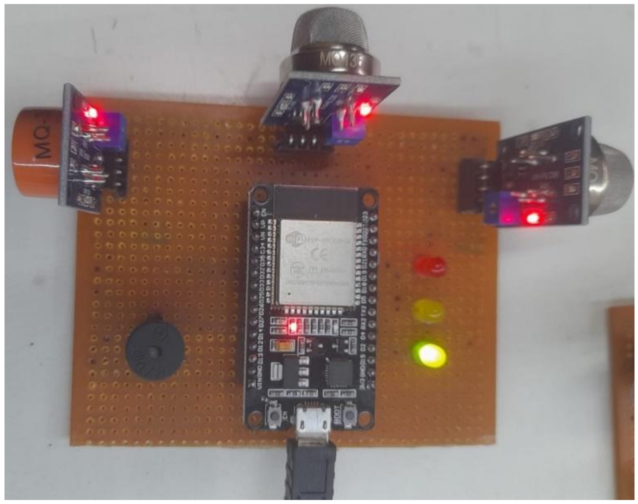
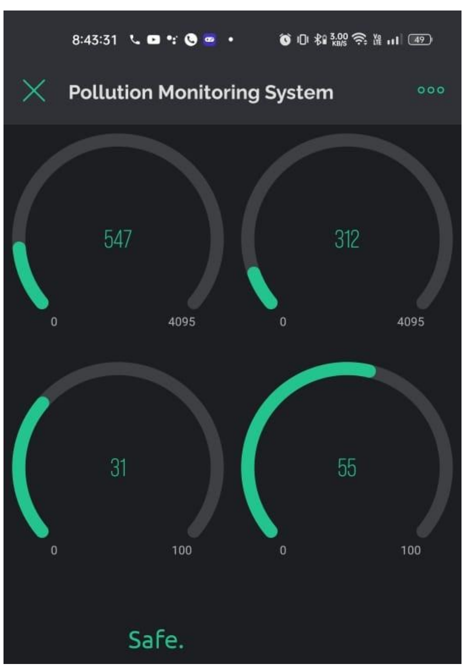
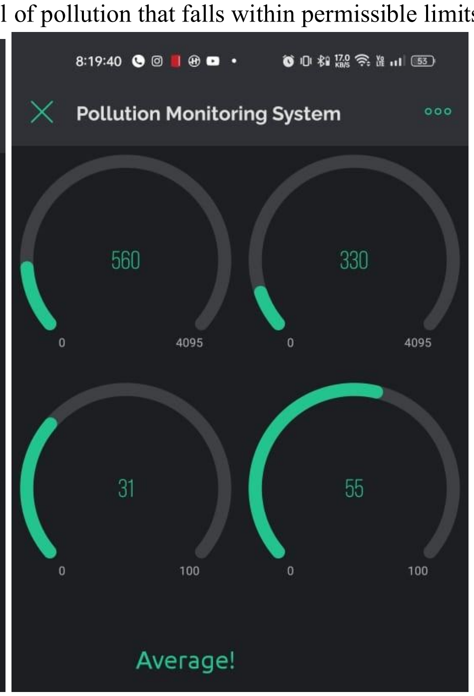


Fig.2 Hardware setup of the WSN node for collecting Environmental pollution data.

The sensor records the real-time data of pollution parameters from the environment and is pushed to the ThingSpeak IoT platform through the MQTT protocol. The dashboard of the Thingspeak platform is shown in Fig.3. values, signaling minimal environmental pollution. Consequently, the indicator displays a 'Safe' indication, denoting satisfactory air quality and the absence of significant health risks.

Moving to Fig. 3(b), a moderate increase in pollution levels is observed as sensor data elevates, albeit remaining within acceptable thresholds. This signifies a discernible yet tolerable rise in pollution intensity. Consequently, the indicator reflects an 'Average' indication, suggesting a moderate level of pollution that falls within permissible limits.





(a) (b)

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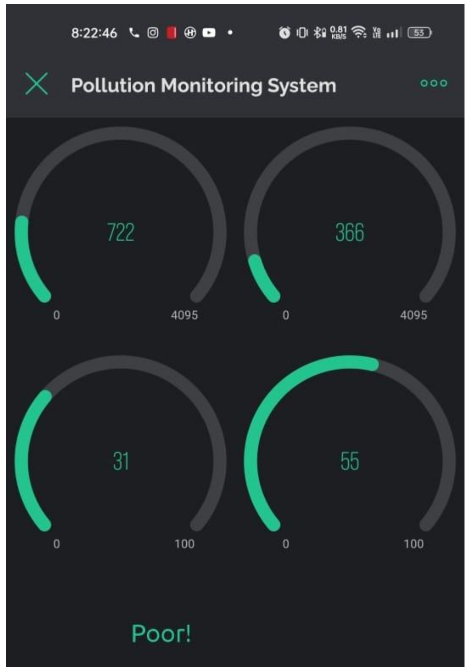

(c)

Fig.3 Resultant graphs of environmental parameters and their indication

On the other hand, Fig. 3(c) shows the case where the pollution is above the required levels, hence being of poor quality. To the sensors, the readings are above the safe limits, hence indicating high levels of pollutants in the surroundings. The indicator, therefore, portrays a reading of "Poor," warning people of the possible hazardous air quality.

The graphs in Fig. 3 are the technical graphing of the indicator response at the diverse pollution levels. This information shall provide the user with a basis for a conclusion concerning changes in air quality value and necessary precautionary action for health protection from related health hazards caused by poor air quality.

VI. CONCLUSION

As proposed above, developing an intelligent movable weather-monitoring station would be a great leap in monitoring and managing the environment. They have IoT technology that, by using many sensors, provides real-time measurement and analysis of the meteorological parameters and air quality indicators at the monitoring station. It will, therefore, play an important role in presenting stakeholders with valuable environmental information to help them make informed choices in pollution control, urban planning, and public health.

Versatility and portability enable the system to take monitoring stations for deployment in various urban and rural environments. Its small size and wireless connection allow it to use existing systems for better data collection and transmission efficiency. Regarding the interfaces, platforms like Blynk or ThingSpeak offer very easy access to monitoring data, thanks to which the user can control environmental conditions and perform very proactively in the case of any risk.

There are several avenues for future research and development in this field.First, improving sensor technology will lead to more sensors, which can measure more pollutants and wider environmental parameters, and further allow the sensing capabilities of the monitoring station to give a wider range of sensing that would allowmore data for analysis. Second, advances in technology in monitoring technology data analysis methods, for instance, through the application of the methods indicated in this paper, including machine learning algorithms, will allow more sophisticated data analyses and result in deeper insights and the ability to make more accurate predictions on trends in the environment. To make them more efficient in their success, predictive modeling tools could be developed to assist in forecasting impending environmental challenges and prearranging proactive strategies to bring impact down.

This is expected to enhance collaboration and sharing of information among the key stakeholders of environmental monitoring, which would include standardized protocols in data collection and sharing establishment of collaborative platforms for data exchange and analysis. This will be helpful in the advancement of environmental sustainability and resilience,as well as portable, intelligent weather monitoring stations. Therefore, the technologies of the Internet of Things, together with data insights, have the potential to provide tangible impacts on the way the environment will be monitored and managed in such a manner that the future is more sustainable and resilient.

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