**Dynamic Air Pollution Monitoring Using IoT**

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 **ABSTRACT**

An air quality monitoring system was developed using the Arduino platform to obtain precise air quality data for buses. This innovative system is capable of identifying various atmospheric pollutants such as PM2.5 (Fine Particulate Matter), formaldehyde, and carbon monoxide (CO). Subsequently, the collected data is wirelessly transmitted to a mobile device via Bluetooth communication and securely stored in an SQLite database. This database serves as a valuable resource for conducting comprehensive analyses of environmental conditions. Additionally, if the recorded data surpasses predefined safety thresholds, an immediate warning message is dispatched to alert the user. Notably, the system's experimental results indicate a low mean square error in predicting air quality, demonstrating its accuracy in detecting air pollution both indoors and outdoors.

**Keywords** *–Accurate, Safety, Dynamic, Pollution Monitoring*

**I INTRODUCTION**

Air quality monitoring has emerged as a prominent community-driven initiative, gaining significant importance in urban areas. Deteriorating air quality in cities poses a grave threat to public health, primarily attributable to vehicle emissions and the proximity of industrial sites to urban centers. In response, several cities have introduced costly monitoring systems to assess air quality. However, these deployments substantially escalate urban infrastructure expenses, leading to a limited number of monitoring stations covering the city. Recent research endeavors have focused on the development of cost-effective sensors capable of widespread deployment for air quality monitoring. The "Green IoT" project has introduced an innovative approach, employing wireless and stationary sensors within a test bed to assess air quality in Uppsala's urban areas. Mobile sensors have been strategically positioned to measure air quality across various locations in the city, eliminating constraints and extra expenses. The project's methodology encompasses several key steps. Firstly, the identification of bus routes offering comprehensive town coverage while traversing highly polluted zones is essential. To achieve this, route planning is undertaken, utilizing image analysis of a bus route map generously provided by Upplands Lokaltrafik (UL), the local bus company. Secondly, the sensors are deployed on public vehicles to evaluate their effectiveness in comparison to stationary counterparts. This dynamic approach seeks to determine the mobility advantages of a moving sensor platform. Lastly, the project assesses sensor performance and data quality over an extended period. Evaluation of sensor performance relies on data collected from public vehicles, while data quality is established through comparisons with readings from other sensors deployed across Uppsala. This holistic approach to air quality monitoring aims to address the pressing concerns of urban air pollution in an efficient and cost-effective manner.

Although the national environmental monitoring department does provide real-time regional air quality data, it is limited by a sparse network of monitoring stations, fixed locations, and restricted data coverage. Consequently, this existing system falls short in accurately representing air quality and does not adequately meet the requirements of everyday users seeking comprehensive air quality monitoring. To address these aforementioned challenges, we propose an air quality detection system built on the Arduino platform. This system offers real-time data uploading to a mobile application via Bluetooth communication, enabling users to monitor both indoor and outdoor air pollutants effectively. The innovative system excels in precisely detecting and displaying air quality information specific to the user's current location, with seamless data transmission to their mobile device.

**II OBJECTIVES**

The primary objective of our system design is to efficiently detect and analyze pollution levels in various locations using a single versatile device. This device is seamlessly integrated into public transportation, specifically buses, allowing it to move periodically across key city areas. This mobility enables the real-time monitoring of pollution levels at different locations.

Our system incorporates sensor modules and microcontrollers, enabling it to detect pollution originating from various sources, including transportation, traffic, industrial emissions, and other human activities. It can identify major toxic gases such as O3, SO2, NH3, as well as volatile compounds like benzene and toluene. Additionally, it can detect greenhouse gases like CO2, CH4, and N2O.

The real-time data collected by the sensors is made available through a dedicated application that is seamlessly integrated with the device, allowing users to access and visualize pollution information instantly.

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**III EXISTING SYSTEM**

The widespread use of fossil fuel-powered buses has a substantial role in exacerbating air pollution. The transportation sector is responsible for emitting over 50% of nitrogen oxides into the atmosphere, making it a significant contributor to global warming emissions. Extensive research has established a direct link between pollutants from vehicle exhaust and detrimental effects on nearly every organ system in the human body. While it is evident that air pollution poses considerable risks to both human health and the environment, there is a solution at hand. By embracing clean vehicles and advanced fuel technologies, we have the potential to make a substantial reduction in emissions and usher in a transformative era in transportation.

Numerous research initiatives have explored the application of IoT (Internet of Things) and wireless sensor networks for air quality monitoring. These projects encompass the measurement of various air pollutants, employing both stationary and mobile sensors. For instance, in 2015, the University of Patras conducted a study to assess the power consumption of the Waspmote platform. This platform, developed by the company Libelium, offers a range of sensors, radio technologies, an open-source Software Development Kit (SDK), and an Application Programming Interface (API) for the development of sensor networks. The research paper primarily focused on the identification of critical operations and the establishment of a setup for measuring power consumption within wireless sensor networks.

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Similarly, researchers at the University of the Armed Forces embarked on a project to create a wireless air quality monitoring system. This study aimed to develop a comprehensive solution encompassing hardware, software, and firmware components for air quality measurement. The system was built upon the Arduino platform and utilized a network gateway to connect sensor nodes to the Internet. It successfully measured concentrations of carbon monoxide (CO) and carbon dioxide (CO2) in the city of Quito, Ecuador. In addition to stationary sensor networks, the study explored the integration of mobile sensors to enhance air pollution monitoring capabilities.

Another noteworthy project, known as OpenSense, was carried out in Zurich, Switzerland. Here, a tram served as a mobile platform to transport sensors for air quality assessment. Communication between the sensors and the cloud was facilitated through GPRS (General Packet Radio Services). This innovative approach also involved the deployment of sensors on city buses, offering broader coverage within the city and greater flexibility in selecting bus routes. City buses presented distinct installation infrastructures, dynamic speeds, and varying movement patterns, enhancing the versatility of the monitoring system.

In a separate project conducted by Sapienza University of Rome in 2016, air quality was monitored using an autonomous wheeled rover. This rover was equipped with sensors capable of measuring a range of pollutants, including methane (CH4), ethylene (C2H4), ammonia (NH3), benzene (C7H8), LPG (C4H10), carbon dioxide (CO2), carbon monoxide (CO), and nitrogen oxides (NOx). Sapienza University developed the rover, equipping it with GPS sensors, three-axis gyros, accelerometers, and a magnetometer to enable navigation and obstacle avoidance while scanning pollution levels over expansive areas.

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The Green IoT project has a primary goal of researching and developing an energy-efficient Internet of Things (IoT) platform, which the public can utilize to create innovative applications based on open data provided by the Green IoT testbed. A case study for this initiative was conducted in Uppsala, the fourth largest city in Sweden. The focus of this study involved deploying an IoT testbed in the city center to monitor air pollution levels. Uppsala experiences occasional breaches of EU standards for particulate levels, particularly during the winter and spring seasons. This situation drives the project's objective to reduce air pollution through active monitoring, traffic management, and improved urban planning.

Another noteworthy project centered around urban pollution monitoring through opportunistic mobile sensor networks, primarily within the context of public transportation. The paper aimed to report on advancements in mobile sensor-based urban pollution monitoring networks. This work built upon the implementation of a single pollution sensor-based sensing node prototype, previously reported elsewhere. The project's focus extended to enhancing the basic sensing system by modularly transforming it into a multi-pollutant sensing system capable of providing additional data on temperature, humidity, and geographic positioning. Corresponding software architecture was developed to efficiently process the substantial volume of data generated.

Several prototypes underwent testing within the public transportation system of Vigo city, with multiple test runs conducted in the northwest city of A Coruna, Spain, yielding highly promising results. The data related to air pollution, including emissions, smoke, and other pollutants, is collected through sensors installed on public transport buses. This data is aggregated and transmitted to a central sink node. Leveraging IoT principles, the collected data is then uploaded to a cloud server, often referred to as the IoT cloud, where it is stored in large quantities. This stored data can be accessed at any time for analysis, enabling informed decision-making and effective measures to combat air pollution.

**IV PROPOSED SYSTEM**

1. ***Description***

The portable air quality detection system's architecture comprises various components, including a microcontroller, sensor module, LCD module, noise sensor, communication module, and more. The control platform chosen for this system is the Arduino Uno. Arduino Uno is a development platform centered on the ATmega328P microcontroller, featuring 14 digital IO pins and 6 analog input pins. It supports multiple soft serial ports and facilitates the connection of various analog and digital sensors [2]. Real-time processing and analysis of air pollutant signals collected by the air sensor are carried out by the Arduino micro-control platform. The processed results are then transmitted to both the LCD display and the mobile phone terminal for user accessibility. Simultaneously, the processed results are compared with preset threshold values in real time, triggering a warning message to the user when the threshold is exceeded. This system effectively detects and presents the air quality at the user's current location, with data uploaded to the mobile terminal. The sensor module encompasses PM2.5, carbon monoxide, formaldehyde, temperature, and humidity acquisition circuits.

The IoT-based Air Pollution Monitoring System is designed to monitor air quality via a web server over the internet. It triggers an alarm when air quality deteriorates beyond a predefined threshold, indicating the presence of harmful gases such as CO2, smoke, alcohol, benzene, NH3, NOx, and LPG. Air quality is displayed in parts per million (PPM) on both an LCD and a webpage for easy monitoring. The system also tracks temperature and humidity levels. The MQ9 sensor detects LPG gas, while the MQ135 sensor monitors air quality by accurately measuring the concentration of harmful gases. This IoT project allows for remote pollution level monitoring via computers or mobile devices. It can be deployed anywhere and has the capability to trigger alerts or notifications when pollution levels surpass predefined limits, such as sending alert SMS to users.

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Fig 1: Block Diagram

***B. Working***

The system employs an Arduino Uno in conjunction with a sensor, and data is transmitted via Bluetooth communication to a mobile phone application. This arrangement enables the display of air quality data, data storage, and alarm functionality, facilitating real-time air quality monitoring and detection. The liquid crystal display provides information on PM2.5, carbon monoxide, formaldehyde, temperature, and humidity.

Upon launching the mobile application, the Bluetooth module is initially detected, followed by a search and connection process. Once a successful connection is established, the app displays a connection page. Subsequently, the app receives data on the current air temperature, humidity, PM2.5, carbon monoxide (CO), and TVOC (formaldehyde) values detected by the hardware system in real-time. When these values surpass predefined thresholds, a buzzer alarm is triggered, and an alarm prompt dialog box appears within the app.

1. ***Advantages***
* Ease of handling
* Easy to Install
* Updates On mobile phones directly
* Accurate Pollution monitoring
* Remote location monitoring
* It can be used at home, in public areas, and in rural and urban areas wherever the network is available
* Vital parameters can be constantly monitored and kept under check
* Better access to healthcare
* The system is user friendly
* Improved quality of healthcare
* Cost of this device is affordable
* An alert message will be sent to the mobile phone if any abnormality is detected at the Pollution level.
1. ***Disadvantages***
* It requires continuous power supply. If the battery is used, battery discharges quickly
* Limited amount of parameters can be monitored
* Susceptible to network hackers
* The cost of the system will be increased if large air quality sensors increases
1. ***Application***
	* Industrial perimeter monitoring
	* Indoor air quality monitoring.
	* Site selection for reference monitoring stations.
	* Making data available to users.

**V RESULT**

The system implementation was successfully completed. Initially, power was supplied to the system and regulated to 15V using a step-down transformer. Upon activation, the CO2 sensor, CH4 sensor, noise sensor, temperature sensor, and humidity sensor commenced measurements of the corresponding environmental parameters. The sensor outputs were processed by an Arduino UNO ATMEGA328P. Subsequently, the temperature, CO2 level, methane concentration, and humidity of the environment were displayed on a 2x16 LCD screen.

For remote monitoring and data access, a Bluetooth module was integrated into the product, allowing users to view parameters such as temperature, CO2 level, methane concentration, noise level, and humidity as separate numerical values within a dedicated app. The app not only displays the preset or nominal values but also provides real-time readings from the sensors. It includes the option to enable or disable SMS notifications with a simple toggle. Additionally, the app offers GPS functionality to track the bus's current location.

In the event of abnormal readings in noise level, methane concentration, CO2 level, humidity, or temperature, the system sends an alert message to the registered mobile number. This feature serves as a safety mechanism to inform individuals that the environmental conditions at a particular location are not within safe parameters.

The product provides a valuable means to measure and monitor essential parameters, including temperature, humidity, methane concentration, CO2 levels, and noise levels in the surrounding environment. When connected to Bluetooth, it allows for SMS alerts and the transmission of the device's exact location to the mobile number registered in the app. Any parameter exceeding the nominal value triggers an SMS alert, specifying which parameter has exceeded its acceptable range. Consequently, this device is a valuable tool for monitoring pollution levels, particularly when mounted on a bus for continuous monitoring of various locations.

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Fig 2: Output shown in Mobile App

 

Fig 3: Alert Message



Fig 4: LCD Output

 **VI CONCLUSION**

Detecting air quality in real-time is a critical concern in contemporary air pollution monitoring. This study presents an air quality detection system employing Bluetooth communication. It leverages cost-effective air sensors to perform real-time monitoring of indoor and outdoor air quality. The collected data is promptly transmitted to a mobile application, enhancing user accessibility and query capabilities. The experimental findings affirm the system's ability to accurately assess and present air quality at the user's current location, underscoring its importance in cost-effective air quality monitoring.

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