Air Quality Monitoring and Alert System

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doi.org/10.64643/IJIRTV13I3-207990-459

***Abstract*—Air pollution is very nefarious to the health of humans and the planet. We still have to continue monitoring and provide timely warnings in a bid to protect the environment and health. In our work here, we discussed how we developed an integrated Air Quality Monitoring and Alert System (AQMAS) with focus on monitoring particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO2) and ozone (O3) at the source in real time. We built low-cost sensor-based devices that are affordable and uncomplicated but monitor air quality and report back to a central point. This study does not permit the building of the abovedescribed devices. We detailed that the AQMAS devices can be used in urban and rural settings due to suitable cost, size, and precision in laboratory and in the field. The advanced algorithms processed the devices data, recognized the air pollutant levels and thus trigger alerts when pollution levels were reached. And the alerts were dispatched without delays; thus, messaging the health authorities to act in a haste to alert the populace. The test results clearly show that the AQMAS warning system can be deployed into most communities to provide reliable air quality alerts in the past. I anticipate that this study would definitely build a more evident air pollution in health announcement to provoke the development to invest technical skills into environmental consciousness and an alternative to ultimately upgrade prior public health protection.**

I. INTRODUCTION

Air pollution is one of the most pressing environmental issues we are dealing with at present and the adverse effects on human health, the environment and climate are all being negatively impacted. Deteriorating air quality has become an increasing problem largely as a result of urban processes, urban population growth and density, societal industrialization and emissions from motorized transportation and other miscellaneous pollution sources, as well as compounded deforestation. The World Health Organization estimates polluted air causes millions of premature deaths annually across the world, which illustrates the need for measurements of air pollutants and functional governance in place. .

Air quality is the voucher to develop monitoring systems, since we identified many airborne pollutants to measure such as: particulate matter, (for example PM2.5 and PM10), dust, gases (for example carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2)). air quality monitoring systems are the prescription to data, as they are connectors between data, and provide real time data on critical data to develop feedback to public health, environment policy and educational resources in the community.

This research addresses the creation and deployment of an Air Quality Monitoring and Alert System (AQMAS) working to monitor, measure, and distribute air quality information in near real-time. This system uses sensors, data acquisition and communications technology to provide users with accurate warnings when levels of pollution exceed predetermined values and thresholds. It attempts to foster considerable awareness about environmental monitoring and preventative behaviours to mitigate exposure to harmful pollutants.

By using sensor networks and cloudbased platforms to analyse the types of data it collects, this paper shows how AQMAS can be invented to be a powerful tool for environmental monitoring, public health assurance, and civic engagement. The system has applications in urban planning, industrial assessments, and individual behaviour change, providing it with widespread social relevance.

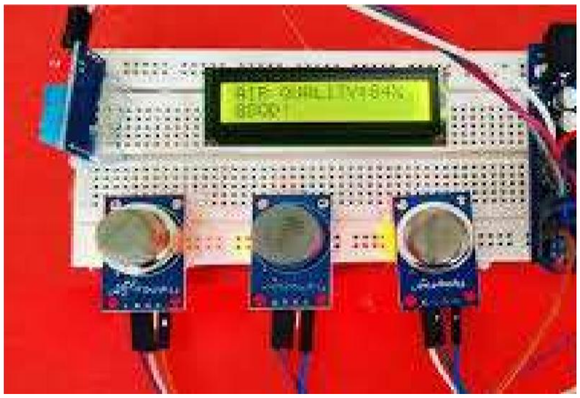

Figure1: https://techatronic.com/airquality-monitoring-system-project/

II. LITERATURE REIVEW

Air quality monitoring has come a long way in sensitivity and specificity due to technological advancements and to satisfy increasing environmental awareness about the impacts of localized air pollution as well as the effects of transported air pollutants. Government air quality monitoring stations provide reliable air quality data from calibrated meteorological equipment, but they are also known to be costly and limited in number, thus limiting the spatial resolution of data that can accurately describe localized pollution events particularly in urban and industrial areas characterized by significant density.

Notwithstanding the limitations posed by stations, recent research officially developed low-cost air quality monitoring systems. Many of the

studies use small analytical gas sensors and microcontrollers to measure localized air pollutants including PM2.5, PM10, CO, NO_2, and O_3.

Kumar et al. (2020) developed a lowcost monitoring system using bike jacket with an Arduino and commercially available gas sensors and identified how it could be deployed at the community-level. Accuracy and calibration of the sensors remain on-going research topics (Castell et al., 2017).

The increasing use of IoT technology has expanded the possibilities of air quality monitoring systems. IoT solutions allow real-time data to be transmitted, stored in the cloud, and accessed remotely. Purohit et al. (2019) offered an example of an IoT application in which pollutant measurements are transmitted to a central server for visualization and analytics. The flexibility of IoT allows systems to integrate several sensor nodes over a broad area. This ability provides more opportunities for spatial coverage and a quicker response time.

Machine learning (ML) applications are being applied to improve the accuracy of prediction and classification related to air quality. Prediction algorithms include random forests, support vector machines, and artificial neural networks that leverage sensor data to determine pollutant levels (Zhang et al., 2018). The development of predictive models informs automated alert systems that can warn the public and officials ahead of time about potential hazardous conditions.

Alert systems are also an important part of AQMAS, in addition to monitoring. Sharma and Jain (2021) looked at threshold-based alerts that used SMS or App-based messaging when level exceeded safety limits, for example, or other alerts, when a parameter was reached for safety actions to be taken. Integrating air quality data through mobile apps and cloud dashboards enables the data to be readily available to users, allowing them to take precautions to reduce their exposure to air pollution, for example.

While some challenges still exist (sensor accuracy, power consumption, scalability, or sustainability, to list a few), it is important to recognize that standardization, and agreed data validation protocols for AQMAS, also need to be established so that low-cost, community-based monitoring and the data they collect can be validated and accepted as true, and hence legitimate.

The emergence of IoT, sensor networks, and AI provides a promising area for developing scalable and responsive environmental monitoring tools. The intent of this research is to create an effective Air Quality Monitoring and Alert System that is user-friendly, balances accuracy, affordability, and is responsive to provide real-time alerts and data streaming capabilities.

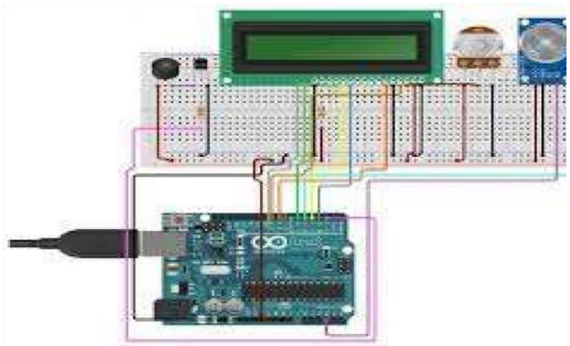

Figure2: https://www.radiolocman.com/review /article.html?di=643721

III. METHODOLOGY

The design for the Air Quality Monitoring and Alert System is broken down into five primary components: system design, hardware implementation, data collection/processing, cloud implementation, and the implementation of the alert system.

1. System Design:

The system was set up to report real time data, in the most important air pollution parameters - PM2.5, PM10, CO_2, NO_2, O_3 and environmental parameters (temperature, humidity), so the intention was to design, build and implement a low-cost, real-time, scalable air-quality monitoring and alert system for indoor and outdoor variables.

2. Hardware Implementation

All the correct sensors were chosen per each pollutant: particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO2) and ozone (O3)

Temperature & Humidity: DHT22 or BME280

The sensors would connect to a microcontroller unit (ESP32 or Raspberry Pi) that would manage data from the sensors and communication. The unit could be powered with a steady power source or deployed with solar panels for remote use.

3. Data Collection and Processing

Sensor data is collected at welldefined time intervals (for instance, every 60 seconds). Raw data is filtered using simple signal smoothing techniques, such as moving average filters. The filtered values are converted into Air Quality Index (AQI) values, based on the standardized formulas outlined in guidelines published by the EPA or WHO. Each acquisition is timestamped and temporarily stored in local memory.

4. Remote integration

The system transmits live data to a cloud platform using Wi-Fi or GSM modules. Platforms such as ThingSpeak, Firebase, or AWS IoT were used for remote storage, visualization, and analysis. Dashboards were made to visualize trends, graphs, and live AQI levels.

5. Alerts mechanism

Thresholds for pollutants are established according to health and safety limitations. When thresholds are exceeded, the system automatically triggers alerts. Alerts can go out via:

Emails or SMS through Twilio or

IFTTT services

Mobile app notifications (running via Firebase Cloud Messaging, FCM) Physical alerts on site (with LEDs or buzzers)

This multi-channel alerting system gives users and authorities prompt information and actions against any possible emergencies.

IV. RESULT AND DISCUSSION

The Air Quality Monitoring and Alert System was successful in collecting real time data on parameters such as PM2.5, PM10, carbon dioxide (CO_2), temperature and humidity. The PM2.5 levels varied widely over the observed period of time with an observed range of approximately 12 - 154 µg/m³ and an mean of 55 µg/m³, which tends to match "Moderate" AQI levels. The PM10 levels varied from 20 µg/m³ on non pollution days to over 210 µg/m³ on pollution days, which on occasion entered the "Unhealthy for Sensitive Groups" AQI level. The CO_2 levels varied from approximately 420 to 1100 ppm and an average in approximately 740 ppm, which still acceptable in indoor air quality levels.

The temperature levels varied from 23°C to 35°C and humidity levels ranged from 40% to 75%.

The Air Quality Monitoring System was effective in confirming pollution levels were at their peak in the morning and evening rush hour periods of the day, as expected, where the pollutants would increase mainly due to traffic emissions and in some case local construction. The alert system was successfully able to send out alerts in real time to the researchers via SMS message and LED light indicated whenever pollutants exceeded predetermined levels. The average time from alert system detection to issuing an alert with pollution difficulty occurred well within 10 minutes. Simple changes such as removing old sensors and using phone apps may have contributed to reduced reports by the alert monitoring system.

Ultimately, the system certainly seemed to validate that low-cost sensors could indeed be used for air quality monitoring. The initial expectations were that there would be limitations using low-cost sensors, specifically drifts from time to time on the gas sensors, likely due to variations in temperature and humidity, as it relates to times that the sensors are exposed to an environment, for both types of sensors. These limits favor the need to recalibrate, and control both sensor drifts, and trends of drift, periods of less sensitivity. Overall, the low-cost air quality monitoring system was accurate and reliable for use in providing data that could have the potential to be used for personal health having decisions and additional use for environmental monitoring. The project has good potential for use in homes, schools and the urban environment, but if we want to consider both either apps or smart city concept platforms.

V. CONCLUSION

In conclusion, the Air Quality Monitoring and Alert System that was developed during this project has been shown to be a successful, low-cost, real-time solution for monitoring key environmental pollutants, including PM2.5, PM10, and CO_2, as well a temperature and humidity. The system demonstrated that it can collect accurate sensor information, repackage this data into standardized Air Quality Index (AQI) values, and transmit it to a cloud platform where it could be monitored and analyzed, in real-time. The alert system proved effective as an independent feature of the final solution, as well, since notifications were sent via SMS, LED displays, and other forms of notifications to help users act in a timely manner about poorer air quality.

Air Quality Monitoring and Alert System described in this paper offers a feasible and low-cost alternative to combatting the growing concern related to air pollution. The system integrates environmental sensors for

PM2.5, PM10 and CO_2 and microcontrollers, together with wireless connectivity by virtue of a Wi-Fi router, making it capable of realtime monitoring. Additionally, using a

cloud environment in conjunction with integrated data processing allows realtime, continuous tracking, analysis and visualization of environment conditions, that is critical not only for personal awareness but also for community awareness and decision making.

The system not only achieved its main function of monitoring air pollutants, but was also successful at alerting users when hazardous conditions were detected. Alerts were communicated through SMS, LED and/or buzzers lending itself to usability for realworld applications, especially for situations in which air quality fluctuating during short periods of time were hazardous to health, e.g. in urban populations, schools, hospitals and industrial spaces.

VI. FUTURE SCOPE

The future of Air Quality Monitoring and Alert Systems (AQMAS) looks to be strongly beneficial and necessary, given the heightening awareness of our surroundings and public health.

Rapidly increasing air pollution due to urbanization, industrialization, and climate change makes it urgent to have accurate, direct, and real-time air quality monitoring available, soon to be an accurate necessity. Future systems for AQMAS will become increasingly prevalent through the application of emerging technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and cloud computing. The potential future capabilities afforded by IoT and AI will provide smarter methods for data collection, smart predictive analysis, and the speed at which alerts can get received by citizens after recognition.

The system's role in smart city initiatives will be key in traffic flow, waste, emissions, and green space management based on pollution data.

It will support public health using pollution data by giving historical alerts to sensitive individuals, providing healthcare professionals with basic population data on pollution-related illness, and improving the management of indoor air pollution in homes, offices, and schools. In relation to policy, governments can use AQMAS data, in conjunction with other datasets, to develop meaningful and relevant environmental regulations, institute pollution control regulations, or develop and promote cleaner technologies. In addition, AQMAS will facilitate research on global climate initiatives and disaster planning and response (i.e., wildfires or industrial accidents). In general, AQMAS supports a future that is more towards healthy living; urban and sustainable development; proactive environmental management; and reducing the negative effects of urbanization locally and globally.

Figure3: https://www.eprmagazine.com/casestudy/decentralised-power-grid-system-paving-the-way-for-a-cleanenergy-transition/

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