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Air Quality Monitoring & Purification

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ABSTRACT: Air pollution stands as a critical hazard affecting the well-being of all living organisms and the environment, particularly in urban regions. It leads to substantial health problems in numerous countries, posing a threat to human health when pollutant concentrations surpass acceptable levels. The monitoring of these pollutants and their concentrations serves as a pivotal preventive measure to inform the public about the air quality in their vicinity.

The main objective of this paper is to devise a smart air pollution prototype for air purification, leveraging a PM sensor, gas sensors, an Analog-to-Digital Converter (ADC), an STM microcontroller, and multiple filters. A step-by-step filtration process will be applied to particles ranging from 200 to 0.3 microns using various filters. The gas sensors, including MQ2 and MQ135, assess the presence and concentration of LPG, smoke, CO, CO2, and NH4 both before and after the filtration process. Additionally, the PMSA003 sensor is employed to detect Particulate Matter (PM) within the range of 0.3 to 10 microns. The ADC and STM microcontroller convert the outputs of the gas sensors and PM sensors into particle concentrations. These outcomes are transmitted to the Thingspeak Cloud platform via the Wi-Fi module, enabling users to access sensor data on any system or mobile device within the Thingspeak Cloud platform.

The paper further includes comparisons of gas concentrations and measured particle size concentrations before filtration. The findings reveal that the designed filter effectively removes particles exceeding 0.3 microns. Comprehensive tests evaluating the performance and efficiency of both the air quality monitoring and air purification systems are conducted.

KEYWORDS: IOT, filters, sensor, STM microcontroller, Thingspeak Cloud platform.

I. INTRODUCTION

Air pollution inflicts harm on crops, animals, forests, and water bodies, while also contributing to the depletion of the ozone layer. According to the World Health Organization (WHO), a staggering 93% of children are exposed to polluted air containing Particulate Matter (PM) smaller than 10 microns, which leads to chronic diseases [1]. In 2019, the primary driver behind the global spread of the coronavirus disease (COVID-19) was the SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) virus, transmitted through the air. This transmission primarily occurs via respiratory droplets larger than 5 microns and aerosol droplets smaller than 5 microns [2]. Aerosols, which encompass both liquid and solid particles suspended in the atmosphere, represent a significant source of air pollution [3].

Particulate Matter, commonly abbreviated as PM, is also referred to as particle pollution. Particles with a diameter of 10 microns or less are categorized as respirable PM10. The same classification applies to PM2.5, which consists of particles with a diameter of 2.5 microns or less. Particles with a diameter smaller than 1 micron are termed PM1 or ultra-fine particles [4]. Globally, the presence of PM is responsible for nearly seven million premature deaths each year. An analysis of Aerosol Optical Depth (AOD), one of the properties of aerosols, was conducted at Gandhi College in Jaipur, Karunya University, New Delhi, and Pune. This analysis utilized a ground-based remote sensing network known as AERONET (Aerosol Robotic Network) during the years 2017 and 2018 [6]. The results of this analysis revealed variations in AOD across these locations, ranging from 0.13 (observed at Karunya University) to 2.26 (recorded at Gandhi College). It's worth noting that an AOD value greater than 0.4 is indicative of a polluted area [7].

Coarse particles, which include wind-driven dust, large sea salt particles, and mechanically generated anthropogenic particles from sources like agriculture and surface mining, typically have a diameter larger than 2.5 microns but smaller than 10 microns. These particles are relatively heavy and tend to settle quickly on the Earth's surface. They have a short atmospheric residence time.

In contrast, fine aerosol particles, measuring 2.5 microns in diameter or smaller, pose a significant risk to human health. They can penetrate deep into the respiratory system, leading to conditions such as asthma, bronchitis, and even cancer.

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Fine particles are a primary contributor to deaths resulting from cardiovascular disease. A global study on disease burden has established that indoor air pollution and outdoor atmospheric particulate pollutants ranked third and seventh, respectively, among the risk factors contributing to the overall burden of disease [13]. Fine particles take a longer time to disperse from the atmosphere and are responsible for a significant portion of visibility impairment in the atmosphere.

II. SYSTEM MODEL AND ASSUMPTIONS

The block diagram for the proposed IoT-enabled air pollution monitoring and air purifier system, as depicted in Figure 1, comprises a pre-filter unit, a filtering unit, an IoT-based sensing unit, and a control unit. The system includes three types of filters, gas sensors, PM sensors, an STM microcontroller for data acquisition, a power unit, and fans. As shown in Figure 1, the polluted air from the environment first passes through a pre-filter situated before the filtering unit. This pre-filter is designed to capture visible particles and remove them from the air, effectively filtering out larger particulate matter and dust particles with diameters greater than 10 microns. Its function is to reduce the overall filtering load on the system, and it can be easily cleaned at regular intervals.

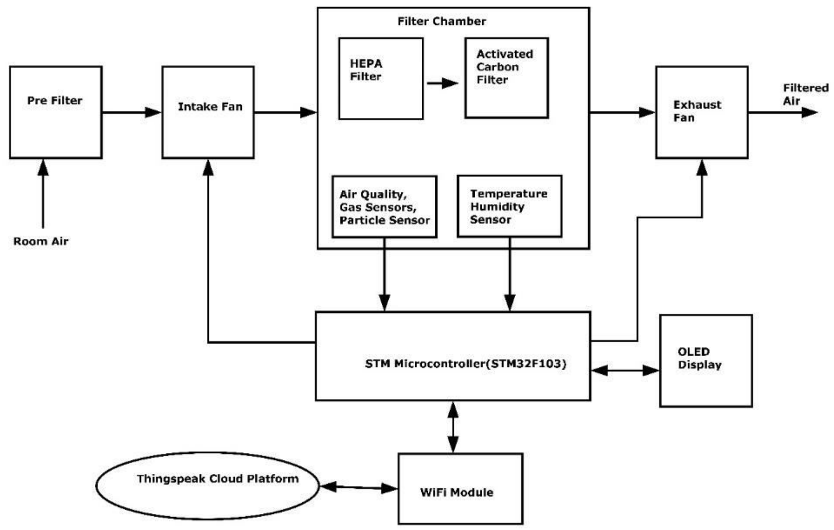

Fig 1: System Model

III. METHODOLOGY

In the filtering unit, an exhaust fan is positioned for efficient suction, as depicted in Figure 1. Subsequently, three filters are arranged in sequence. The first filter, the primary filter, is designed to capture the largest contaminant particles, such as dust. This filter is constructed using cotton and thin cloth materials.

The second filter is an activated carbon filter, which consists of activated carbon particles. It effectively removes Volatile Organic Compounds (VOCs), odors, and other gaseous pollutants through the adsorption process.

Adjacent to the activated carbon filter is the HEPA (High-Efficiency Particulate Air) filter, which is responsible for removing particles of approximately 0.3 microns in size. This filter ensures the release of the cleanest air into the environment.

The prototype features two sets of sensors to assess air quality both before and after filtration. One set of sensors is placed before the filtering unit, following the pre-filter, while the other set is connected after the filtering unit. Each IoT-based sensing unit includes gas sensors (MQ2 and MQ135 sensors) and PM sensors. These sensors are linked to an STM microcontroller via an Analog-to-Digital converter and a 5 to 3.3 V Logic level shifter. The gas sensors can detect

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gases such as LPG, Carbon Dioxide, Carbon Monoxide, Smoke, and Ammonia present in the polluted air. The gas sensors identify the concentrations of particles at the inlet and outlet of the filtering unit. Likewise, the PM sensor measures dust particle concentrations in terms of mass and count, which can be expressed in either micrograms per cubic meter ($\mu g/m^3$) or the number of particles per cubic meter. The PMSA003 sensor is employed to detect Particulate Matter within the range of 0.3 to 10 microns.

The STM microcontroller board is employed for data acquisition, serving as the interface for all the sensors. The data obtained from these sensors is processed by the STM microcontroller unit, and the values corresponding to each gas and Part Per Million (PPM) level at the location are transmitted via the WiFi Module. This data is made accessible on the Thingspeak Cloud platform. Thingspeak, an IoT analytics software, is utilized to send the concentrations of polluted particles measured by the sensors to other users for further analysis.

To ensure the release of clean air into the atmosphere at the end of the filtering unit, an additional fan is positioned. The concentrations of various gases and particles are then plotted before and after filtration, with the results being analyzed in Section 7.

Further details on the hardware and software tools used for the prototype's development can be found in Sections 4 and 5, respectively.

IV. SURVEY DESCRIPTION

In the last decade, there has been a growing focus on the development and deployment of Air Pollution Control Prototypes. This increased attention can be attributed to advancements in science and technology, as well as rising levels of air pollution. Below, we provide an overview of some relevant literature about air quality monitoring and the filtration of air pollutants.

A notable air quality measurement system, developed by [19], employed a Raspberry Pi as a central component. The system featured two Arduino Nano boards, a Raspberry Pi 3, a GPS module, and three gas sensors. This setup enabled the collection of various data, including temperature, humidity, air quality status, latitude and longitude coordinates of the current location, and an Application Program Interface (API) address. The gathered information was then presented through a web server and an LCD (Liquid Crystal Display) screen.

This system was designed to measure the concentration of PM2.5, PM10, and four harmful gases: sulfur dioxide, carbon monoxide, nitrogen dioxide, and ground-level ozone. It underwent testing in both high-traffic and low-traffic areas. The results were promising, with an estimated error of 3.23% following validation against data from Continuous Air Quality Monitoring Stations (CAQMs) in Malaysia.

Dinesh Panicker and his colleagues have introduced a method for monitoring air quality in various environments, shedding light on air quality concerns during routine indoor and outdoor activities. Their system comprises two essential components: a filtering unit and an air quality monitor.

The filtering unit includes a dust filter, pre-filter, and fine filter. Depending on the dust sensor's measurements, the system's software automatically activates or deactivates the air purifying unit when certain thresholds are reached. To detect a range of gases, including NH_3, NO_x, alcohol, benzene, smoke, and CO_2, this smart air purifier makes use of the MQ135 sensor.

The air quality monitoring unit is responsible for identifying air pollution and particulate matter in the environment. The prototype of this monitoring device has been tested to confirm the functionality of the system. The results generated by this device hold promise for daily air quality monitoring. However, a limitation of this system is that the sensors employed in the prototype are designed for small-scale use and may not efficiently sense pollutants in the air when dealing with larger filtration areas [20].

An indoor air quality monitoring framework was developed, making use of an Internet of Things (IoT) platform to enable real-time tracking of environmental pollution [21]. This system incorporates a variety of components, including gas sensors, temperature sensors, humidity sensors, dust sensors, an LCD, an Arduino UNO microcontroller, and an ESP8266, which is an IoT-enabled board. The system leverages a WiFi module for the real-time transmission of measurement data to the Thingspeak cloud and a mobile app. Its key advantages encompass mobility, a cost-effective

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design framework, ease of implementation, and the utilization of open-source technology. This system is designed to monitor the concentration levels of CO, CO2, NO2, PM10, temperature, and humidity. If pollutant emissions surpass defined thresholds, the system sends alerts to users through the mobile phone application.

Additionally, an IoT-based system for real-time air quality monitoring has been developed [22]. This system employs various components, including an ESP32 Microcontroller Unit (MCU), an SDS011 dust optical sensor, an MQ135 sensor, and temperature and humidity sensors. Its primary purpose is to monitor gases like CO2, CO, ammonia, PM2.5, and PM10 in industrial environments to ensure the safety and well-being of workers. The system measures the Air Quality Index (AQI) and displays it through the Virtuino app and the Thingspeak platform. Readings are updated continuously at 5-minute intervals. The data can also be sent via email to specific users for monitoring and control. The primary objective of this system is to prevent fire and explosion risks in industrial settings due to the presence of gas leaks.

V. FUTURE SCOPE AND DISCUSSION

In the future, the scope of air quality monitoring and purification is poised for remarkable advancements driven by technological innovation and growing environmental concerns. Real-time monitoring systems utilizing IoT devices, drones, and satellite technology will become ubiquitous, providing precise data on air pollutants and their sources. Integrated with AI algorithms, these monitoring systems will enable predictive modelling and early warning systems for pollution events. Simultaneously, advancements in air purification technologies, such as advanced filtration systems, photocatalytic oxidation, and nanotechnology-based solutions, will offer increasingly efficient and cost-effective means to combat pollution at various scales, from indoor environments to urban areas. The convergence of these developments holds promise for significantly improving public health, mitigating the impacts of climate change, and fostering sustainable development globally.

VI. CONCLUSION

In conclusion, the future of air quality monitoring and purification presents a compelling narrative of technological innovation, environmental stewardship, and public health advancement. With the integration of cutting-edge monitoring systems and advanced purification technologies, societies can aspire to achieve cleaner air and healthier living environments. Embracing these developments not only addresses pressing challenges such as urban pollution and climate change but also signifies a collective commitment to safeguarding the well-being of current and future generations. As we continue to push the boundaries of scientific research and engineering prowess, the vision of pristine air quality and sustainable living becomes increasingly attainable, heralding a brighter, healthier future for all.

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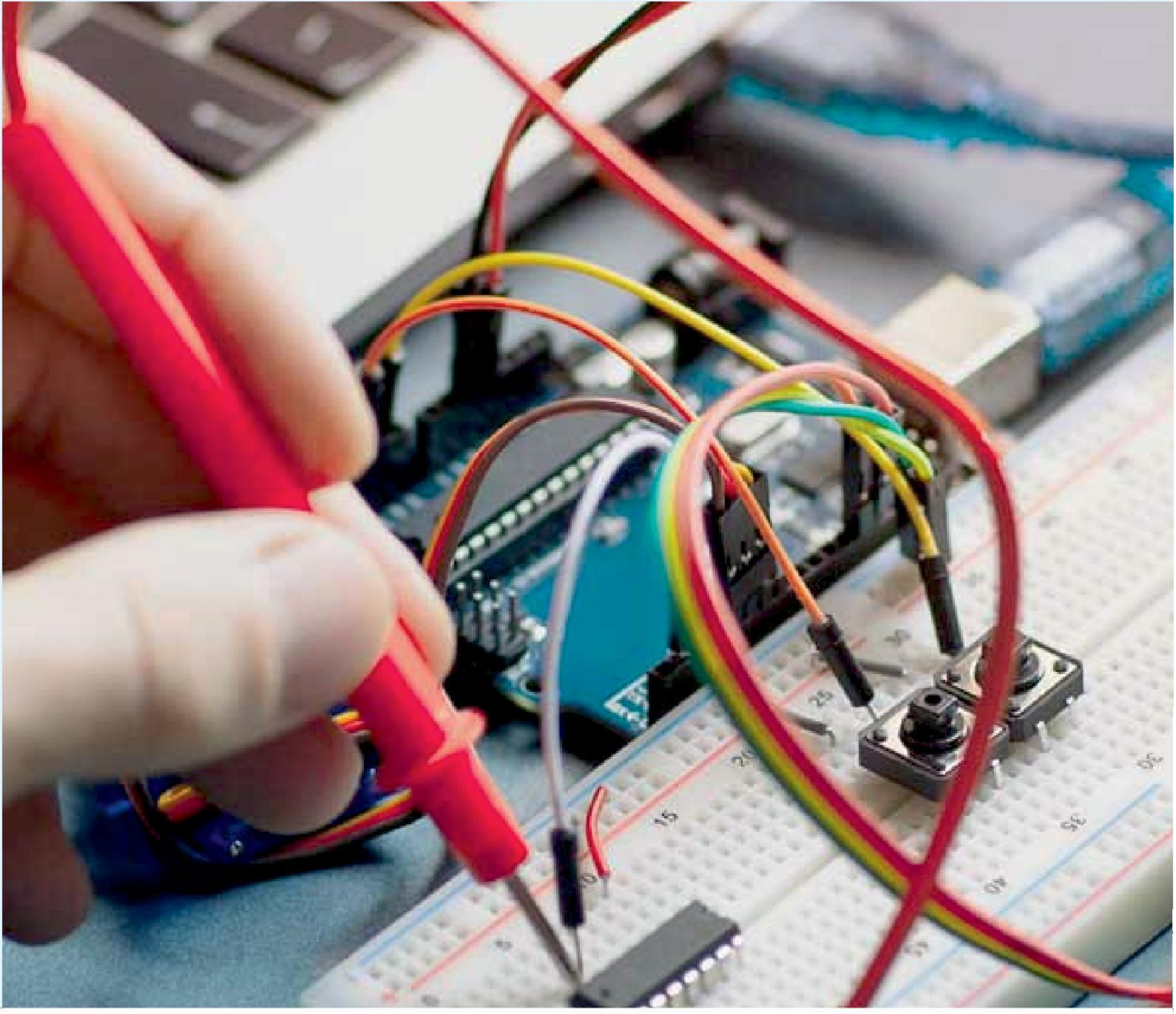

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