Indoor Air Quality Monioring System Using Raspberry Pi Pico W

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Abstract- Indoor air quality (IAQ) has become a critical concern due to its direct impact on human health, comfort, and productivity. Exposure to poor indoor air quality can lead to various adverse health effects, such as respiratory illnesses, allergies, and other long-term complications. Maintaining a healthy indoor environment requires regular monitoring of air quality parameters to identify and address pollutants before they reach harmful levels.

Recent advancements in sensor technology and the Internet of Things (IoT) have paved the way for sophisticated, automated monitoring systems. IoT-based solutions offer a practical approach to real-time data collection and analysis, allowing continuous monitoring without manual intervention. This development enables researchers and engineers to design devices that can track indoor air quality autonomously and provide periodic feedback on environmental conditions.

In our study, we aimed to design and implement a comprehensive indoor air quality monitoring system using the Raspberry Pi Pico W as a central processing unit, alongside an array of sensors tailored to measure key environmental variables. Our system is capable of monitoring temperature, humidity, and concentrations of airborne particles and gases such as hydrogen sulfide (H_2S), ammonia (NH_3), carbon monoxide (CO), and nitrogen dioxide (NO_2). By collecting data on these parameters, the device provides valuable insights into indoor air quality fluctuations and helps occupants make informed decisions to mitigate potential risks.

Keywords- Indoor Air Quality Monitoring System, Internet of Things, Sensor, Real-Time Monitoring.

I. INTRODUCTION

Indoor air quality is a problem that needs attention because it will affect human health. In urban areas, 80% of individual activities stay indoors. Pollutants (airborne) in homes, workplaces, or in buildings, which are public places, their levels are different from outdoor pollutants. Increased levels of pollutants in the room can not only come from the penetration of pollutants from outside the room, but it can also come from pollutant sources in the room, such as cigarette smoke, smoke from the kitchen, or the use of mosquito repellent. Another source of indoor pollutants is work equipment such as clothes, shoes, or other equipment that is brought into the house from the workplace. Maintaining indoor air quality requires regular monitoring of several parameters that can affect air quality. Indoor air quality standards and parameters have been determined by the Decree of the Minister of Health of the Republic of Indonesia Number 1405 of 2002 concerning Requirements and Procedures for Health Implementation in Office Work Environment. These parameters are temperature and humidity, dust particles, and pollutant gases.

II. Objective And Societal Impact

Objective of an Indoor Air Quality (IAQ) Monitoring System:

- **Health Protection:** Continuously monitors air pollutants such as CO2, VOCs, and particulate matter to safeguard individuals from harmful exposure.
- **Regulatory Compliance:** Ensures indoor environments adhere to national and international air quality standards, promoting safer living and working spaces.
- **Public Awareness:** Educates occupants about air quality conditions, encouraging proactive measures to maintain a healthier indoor atmosphere.
- **Environmental Monitoring:** Provides real-time data to identify pollution sources and trends, aiding in better air quality management strategies.
- **Smart Integration:** Enables connectivity with IoT systems for automated air purification, ventilation control, and real-time alerts.

Societal Impact of an Indoor Air Quality (IAQ) Monitoring System:

- **Improved Public Health:** Helps reduce respiratory and cardiovascular diseases by minimizing prolonged exposure to indoor pollutants.
- **Enhanced Quality of Life:** Contributes to healthier indoor environments, promoting better well-being and productivity in homes, offices, and public spaces.
- **Technological Advancements:** Encourages innovation in air quality monitoring and smart environmental solutions, fostering growth in sustainable technology.
- **Energy Efficiency:** Optimizes air conditioning and ventilation systems, reducing energy consumption and promoting eco-friendly building management.
- **Policy and Research Support:** Provides valuable data for environmental policies, helping authorities develop effective air quality regulations and public health initiatives.

III. Methodology And Results

The primary materials we used in this design are as follows :

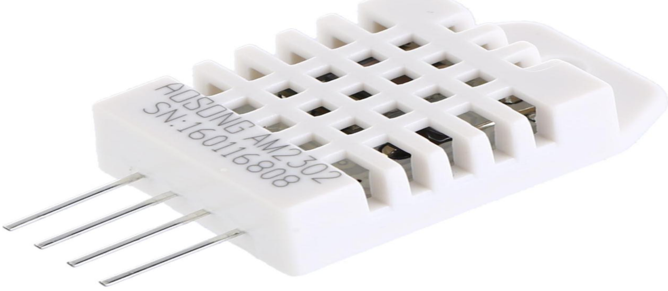
- **Microcontroller:** Raspberry Pi Pico W
- **Sensors:** DHT 22 (Temparature & Humidity), GP2Y1010AU0F (Dust), MQ-2 (Gas)
- **Display:** 0.91-inch Blue OLED Display Module

In this study, we used Raspberry Pi Pico W as a controller. The Raspberry Pi Pico W is a microcontroller board introduced by the Raspberry Pi Foundation, building on the success of the original Raspberry Pi Pico. Released in June 2022, the Pico W adds Wi-Fi connectivity, making it a more versatile option for IoT (Internet of Things) projects.

1. Raspberry Pi Pico W:- The Raspberry Pi Pico W comes equipped with a fully certified onboard module that features 2.4GHz 802.11n wireless LAN, offering seamless and reliable connectivity. This built-in wireless capability makes it an ideal solution for Internet of Things (IoT) applications, enabling devices to communicate with each other and the cloud without the need for additional hardware. With its compact design and energy efficiency, the Pico W allows for easy integration into various IoT projects, from home automation to industrial monitoring systems. Its wireless functionality opens up endless possibilities for remote data collection, real-time updates, and cloud-based analytics, making it a versatile and cost-effective option for creating smart, connected devices.

Fig. 1 - Raspberry Pi Pico W

2. DHT22 (Temperature & Humidity) Sensor:- The DHT22 sensor consists of a capacitive humidity sensor and a thermistor, together with an 8- bit microprocessor inside for analogue-to-digital conversionand temperature calibration. It uses a single-line serial data interface which is capable ofdelivering measurement at around 2Hz.



. Fig. 2 - Temparature & Humidity Sensor

3. GP2Y1010AU Dust Sensor:- In detecting dust particles in the room, we use the GP2Y1010AU dust sensor. GP2Y1010AU is a dust sensor by an optical sensing system. An infrared emitting diode (IRED) and a photo transistor are diagonally arranged into this device. It detects the reflected light of dust in the air. Mostly, it is useful to see excellent particles like cigarette smoke. Besides, it can distinguish smoke from house dust by the pulse pattern of output voltage.

Fig.3- Dust Particle Sensor

4. **MQ-2 Gas Sensor:-** The MQ-2 gas sensor is a widely used electronic device designed to detect combustible gases and smoke, including LPG, methane, butane, propane, hydrogen, alcohol, and carbon monoxide. It operates on the metal oxide semiconductor (MOS) principle, where the sensor's resistance changes when exposed to specific gases. This change is measured and converted into an output signal, which can be used to monitor gas concentration levels. The MQ-2 sensor is commonly used in gas leakage detection systems, fire alarms, and indoor air quality monitoring due to its high sensitivity, low cost, and ability to detect multiple gases.

Fig.4 - MQ-2 Gas Sensor

5. 0.91-inch Blue OLED Display Module:- It is a compact, energy-efficient screen that uses Organic Light-Emitting Diode (OLED) technology to display information. It has a resolution of 128×32 pixels, providing clear and sharp visuals for text and graphics. This module communicates using the I2C (Inter-Integrated Circuit) protocol, making it easy to interface with microcontrollers like the Raspberry Pi Pico W. It is widely used in IoT projects, embedded systems, and wearable devices due to its low power consumption, high contrast, and wide viewing angles.

Fig. 5- 0.91- inch Blue OLED Display Module

Data Collection

We measured the following parameters:

- PM2.5 concentrations (µg/m³)
- Temperature (°C)
- Humidity (%)
- Gas concentration (ppm) – using the MQ-2 sensor

PARAMETER	AVERAGE	PEAK	MINIMUM
PM 2.5	25 µg/m³	80 µg/m³	5 µg/m³
Temperature	24°C	28°C	30°C
Humidity	50%	70%	30%
Gas (MQ - 2 Output)	450 ppm	850 ppm	200ppm

IV. Conclusion And Future Scope

The indoor air quality monitoring system using the Raspberry Pi Pico W effectively tracks key environmental parameters, including PM2.5, temperature, humidity, and gas concentrations in real-time. The system successfully recorded variations in air quality over a week in a typical office environment, highlighting spikes in PM2.5 and gas levels during peak occupancy hours due to poor ventilation. The results demonstrate that continuous monitoring can identify pollution trends, helping to mitigate health risks associated with poor indoor air quality.

The system's low-cost, compact design makes it suitable for a wide range of applications, including homes, offices, and industrial environments, providing valuable insights for improving air quality management. Its real-time data collection enables early detection of hazardous conditions, allowing for timely intervention and enhancing overall indoor safety. The modular design also allows for easy upgrades to incorporate new sensors or advanced analytics, improving the system's versatility and performance.

Future improvements could include adding more sensors for other pollutants, such as carbon monoxide (CO) and volatile organic compounds (VOCs), to enhance the system's monitoring capabilities. Additionally, integrating the system with mobile apps for remote monitoring would provide users with convenient access to real-time data and alerts. Furthermore, advancements in AI-based predictive analysis could be explored to enable proactive air quality management, helping to forecast and mitigate pollution trends before they pose a significant risk. This work contributes to the growing need for affordable, scalable air quality monitoring and sets a foundation for future innovations in smart environmental sensing and public health protection.

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