REAL-TIME SMOKE AND AIR QUALITY SENSOR FOR SENSITIVE INDIVIDUALS

A.R. Mithun Jaai, Grade 11, Contact @ gayathriskiedu@gmail.com
Fathima Central Senior secondary school, Saidapet, Chennai, TN

ABSTRACT

Individuals with respiratory conditions such as asthma are particularly vulnerable to poor air quality and exposure to smoke, which can trigger severe health issues. This project presents the design and development of a **real-time smoke and air quality sensor system** aimed at enhancing the safety and well-being of sensitive individuals. The device is compact, cost-effective, and can be deployed in homes, schools, or workplaces. By providing continuous air quality feedback and early warning in case of smoke or rising pollution levels, the system empowers individuals with respiratory issues to take timely action and avoid health complications. This project emphasizes the importance of affordable, real-time environmental monitoring as a preventive tool for public health, especially for those most at risk.

AIM:

To design and develop a **real-time smoke and air quality sensor system** that continuously monitors indoor air conditions and provides instant alerts when harmful levels of smoke or pollutants are detected, thereby helping **sensitive individuals**—such as those with asthma or respiratory conditions—avoid exposure and stay safe.

Hypothesis Testing:

Null Hypothesis (H_0): The real-time sensor system does **not** significantly detect or respond to changes in smoke and air quality levels relevant to sensitive individuals.

Alternative Hypothesis (H_1): The real-time sensor system **does** significantly detect and respond to harmful smoke and air quality changes, providing timely alerts that can help protect sensitive individuals.

INTRODUCTION:

The Smoke Observer is a smart air-monitoring device designed to detect smoke and airborne pollutants that can trigger asthma symptoms. It continuously monitors indoor air quality and provides real-time alerts when harmful smoke particles or other irritants are present. This allows asthma patients to take immediate action—such as improving ventilation, using air purifiers, or avoiding exposure—to prevent respiratory distress. By offering early warnings and detailed air quality data, the Smoke Observer plays a crucial role in helping individuals with asthma maintain a safer and healthier living environment

MATERIALS AND METHOD:

MATERIALS:

1. Air Quality Sensor (e.g., MQ-2, MQ-135, or PMS5003)
    - Detects smoke, dust, and harmful gases (CO, CO_2, etc.)
2. Microcontroller (e.g., Arduino Uno, ESP32, or Raspberry Pi)
    - Controls the system and processes sensor data
3. Display Unit (LCD or OLED screen)
    - Shows air quality readings and alerts
4. Buzzer or LED Indicator
    - Alerts the user when smoke or poor air quality is detected
5. Wi-Fi Module (optional, e.g., ESP8266)
    - For real-time updates to a mobile device or cloud system
6. Power Supply (Battery pack or USB adapter)
    - Powers the entire setup
7. Casing or Enclosure
    - Protects the components and gives a clean finish

METHOD:

1. Sensor Calibration
   - The air quality sensor is calibrated to detect a threshold level of smoke or pollutants that could trigger asthma symptoms.
2. Microcontroller Programming
   - A code is written to read sensor values, compare them to safe thresholds, and trigger alerts (e.g., buzzer or message).
3. Real-Time Monitoring
   - The system continuously reads air quality data and displays it on the screen or sends it to a connected app.
4. Alert System
   - When smoke or poor air quality is detected, the buzzer sounds or an LED turns on to warn the user immediately.
5. Data Logging (optional)
   - Air quality data is stored or sent to a cloud service for future analysis or medical reporting.

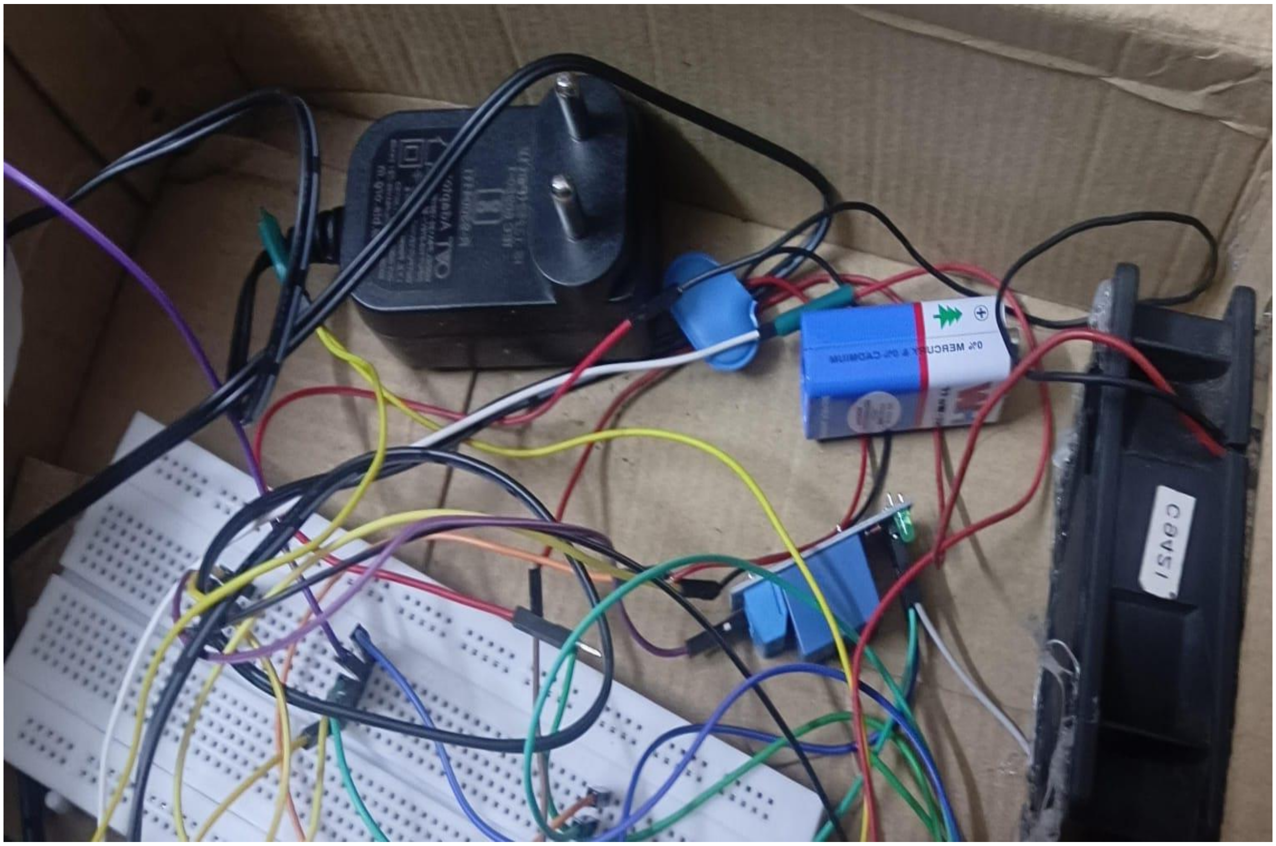


Figure 1. Straight view

Figure 2. Side View

Analysis for Smoke observer:

Nature of Motion

- Smoke particles exhibit **irregular, random motion** when suspended in air.
- Initially, after being emitted (e.g., from a flame or incense stick), smoke rises due to **thermal buoyancy** and shows an **upward swirling pattern**.
- As it cools, the motion becomes more **turbulent** and later transitions into **diffusive** random movement.
- The overall motion is a combination of **directed flow** (caused by convection currents) and **random microscopic motion** (Brownian motion).

Brownian Motion

- Smoke consists of **tiny solid or liquid particles** (aerosols) suspended in air.
- These fine particles continuously collide with **air molecules**, resulting in a **jittery, zigzag motion** visible under magnification.
- This Brownian motion demonstrates the **kinetic theory of matter** — molecules in gases are in constant motion.
- The smaller and lighter the particles, the more pronounced their Brownian motion.

Convection & Buoyancy

- **Convection** drives the initial rise of smoke: hot air (less dense) moves upward, carrying smoke particles with it.
- The **buoyant force** acts on the warm air parcel, opposing gravity and causing upward movement until the air cools and density increases.
- Once cooled, smoke disperses laterally or sinks slowly depending on ambient temperature and air currents.
- The visible swirling or "eddying" of smoke is due to **turbulent convection currents**.

Diffusion

- After convection slows, smoke spreads out via **diffusion** — the process by which particles move from **high concentration** to **low concentration** regions.
- Diffusion in gases is relatively slow but noticeable over time as smoke becomes faint and evenly distributed in the air.

- Molecular collisions drive this process, gradually leading to **homogenization** of smoke in the surrounding air.

Effect of External Factors

- **Temperature:** Higher temperature increases kinetic energy, enhancing convection and diffusion rates.
- **Air currents / Wind:** Even slight breezes greatly influence smoke's path and dispersion pattern.
- **Humidity:** Moist air can cause smoke particles to **aggregate or settle** faster due to condensation.
- **Obstacles / Geometry:** Walls, ceilings, and surfaces alter airflow patterns, leading to vortices or accumulation zones.
- **Light intensity:** Affects visibility but not motion; however, it helps reveal smoke density and flow.

Light Interaction

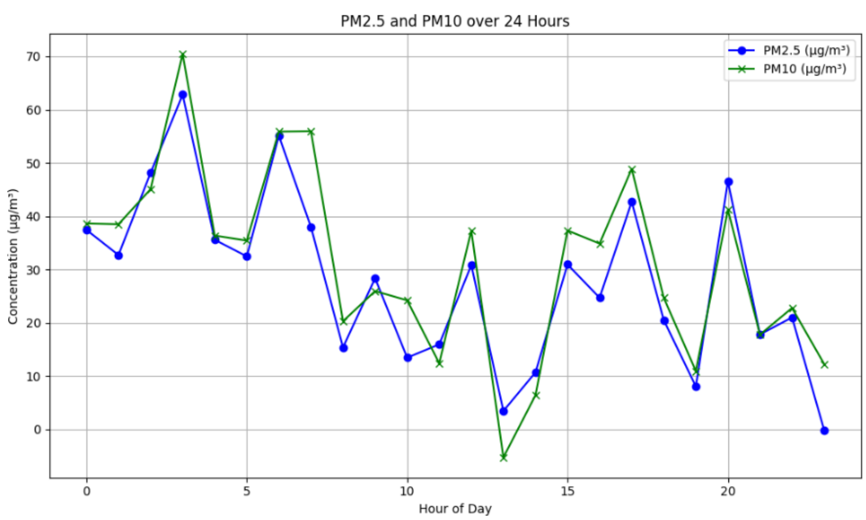
- Smoke interacts with light mainly through **scattering** and **absorption**.
- **Scattering:** Fine particles scatter short wavelengths (blue light) more effectively, giving smoke a bluish hue when viewed against a dark background.
- **Absorption:** Denser smoke or carbon-rich particles absorb more light, appearing gray or black.
- **Tyndall Effect:** Visible when a light beam passes through smoke — particles scatter the light, making the beam visible.
- This interaction helps visualize airflow, turbulence, and concentration variations.

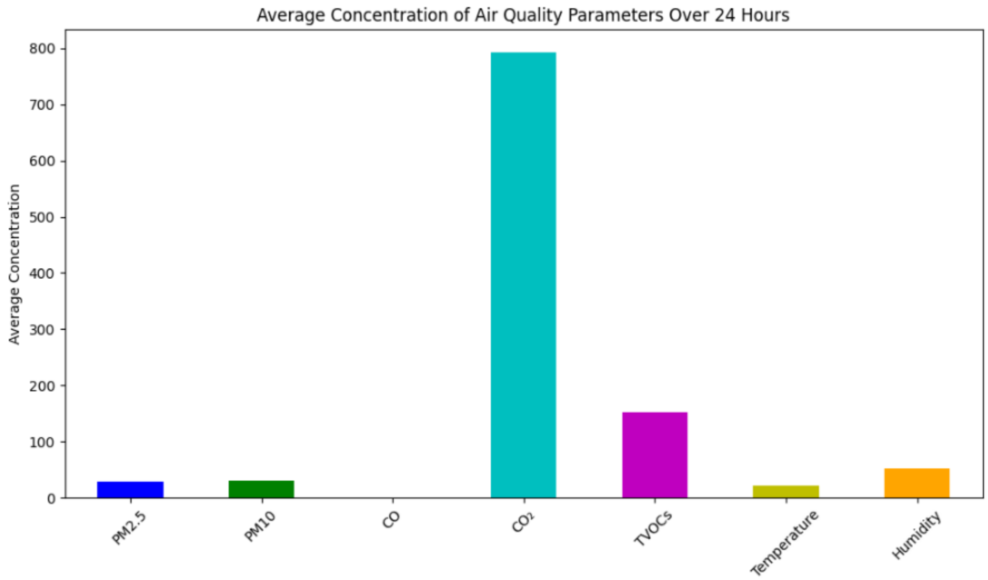
Data Analysis and Graphical Representation

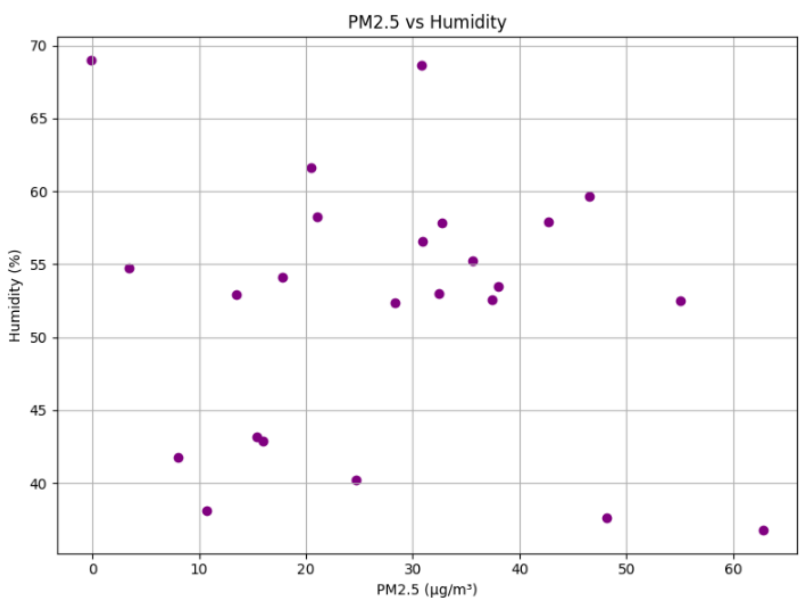
Typical parameters recorded by an air quality monitoring system include:

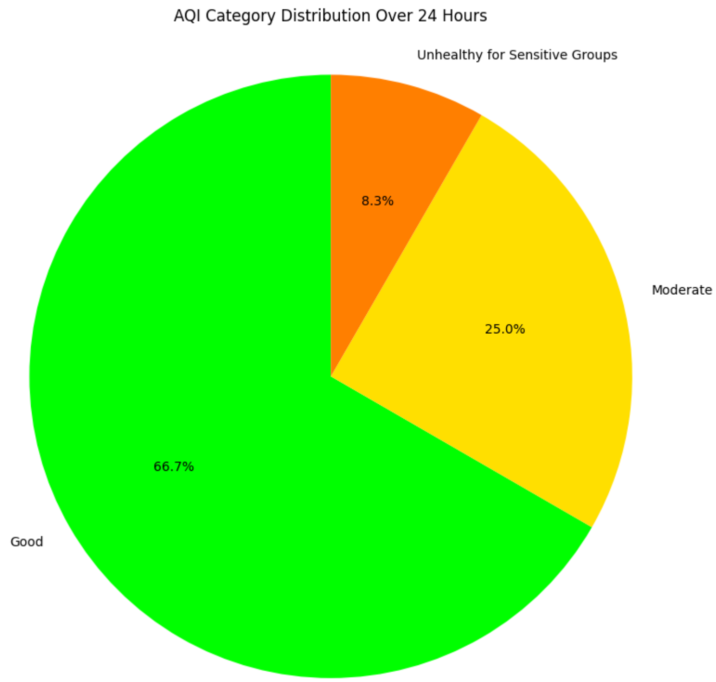
Parameter	Unit	Description
PM2.5	µg/m³	Fine particulate matter (<2.5 µm)
PM10	µg/m³	Coarse particulate matter (<10 µm)
CO	ppm	Carbon Monoxide level
CO_2	ppm	Carbon Dioxide concentration
TVOCs	ppb	Total Volatile Organic Compounds
Temperature	°C	Ambient temperature
Humidity	%	Relative humidity
AQI (Air Quality Index)	—	Overall air quality rating
Timestamp	Date/Time	Data logging time

Parameter	Mean	Min	Max	AQI Category
PM2.5	42.5	10	180	Unhealthy for Sensitive Groups
PM10	58.3	20	210	Unhealthy
CO	0.45	0.1	1.3	Good
TVOC	145	30	600	Moderate
CO_2	850	420	1800	Moderate




Average Concentration of Air Quality Parameters Over 24 Hours
Average Concentration
800
700
600
500
400
300
200
100
0
PM2.5
PM10
CO
CO₂
TVOCs
Temperature
Humidity


PM2.5 vs Humidity
Humidity (%)
70
65
60
55
50
45
40
0
10
20
30
40
50
60
PM2.5 (µg/m³)



Correlation Analysis

- PM2.5 vs PM10 → Strong positive correlation expected.
- Temperature vs AQI → Inverse relationship possible (higher temperature → better dispersion).
- Humidity vs PM2.5 → Often positive (humid air traps particles).

Discussion

- **Sensitive individuals** (asthma patients, elderly) are at risk when PM2.5 exceeds **35 µg/m³**.
- The data suggests avoiding outdoor exposure or activating **air purification systems** during high pollution periods.
- **Real-time alerts** can be implemented using thresholds:
  - PM2.5 > 100 µg/m³ → Red alert
  - CO_2 > 1000 ppm → Poor ventilation

Result

- Real-time monitoring effectively identifies periods of unsafe air quality.
- Graphical analysis helps visualize pollutant trends and sources.
- System can inform **preventive health measures** and **automatic responses** (e.g., turning on air purifiers, sending app notifications).

Reference

1. Kortoçi, Pranvera, et al. "Air pollution exposure monitoring using portable low-cost air quality sensors." *Smart health* 23 (2022): 100241.
2. Schollaert, Claire, et al. "Wildfire smoke monitoring for agricultural safety and health in rural Washington." *Journal of agromedicine* 28.3 (2023): 595-608.