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Arduino-Based Plasma Filtration System with Real-Time Monitoring for Smoke Removal in Enclosed Rooms

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Abstrak. *Kualitas udara dalam ruangan akibat paparan asap rokok menurunkan kadar oksigen dan meningkatkan konsentrasi karbon monoksida (CO) hingga melampaui ambang batas aman (9 ppm). Penelitian ini mengembangkan sistem filtrasi plasma berbasis Arduino dengan pemantauan waktu nyata untuk menghilangkan asap di ruangan tertutup. Sistem menggunakan sensor MQ-7 (deteksi CO), sensor MQ-135 (deteksi asap/CO_2), Arduino Uno R3 sebagai pengendali, exhaust fan (daya hisap 150 m³/jam), serta ignition coil (tegangan output 15 kV) untuk menghasilkan lucutan korona (plasma). Pengujian dilakukan di ruang berukuran 2 m × 3 m × 3 m (volume 18 m³) dengan satu batang rokok sebagai sumber asap. Data diambil setiap 30 detik selama 10 menit. Hasil pengujian menunjukkan bahwa sistem baru mampu menurunkan kadar CO dari puncak awal 25 ppm menjadi 8 ppm dalam waktu 4 menit, dan stabil di 3 ppm setelah 10 menit, dengan persentase penurunan sebesar 88%. Sebaliknya, sistem lama (kipas angin 20 watt) justru meningkatkan kadar CO hingga 47 ppm karena asap menyebar keluar ruangan melalui ventilasi. Waktu respons sistem dari deteksi asap hingga aktivasi filtrasi rata-rata 2,5 detik. Efisiensi energi sistem tercatat 45 watt saat filtrasi aktif. Tingkat keberhasilan alat dalam menjaga kadar CO di bawah 9 ppm mencapai 100% setelah 4 menit pertama. Sistem ini terbukti efektif, otomatis, hemat energi, dan layak diimplementasikan pada berbagai ruang tertutup publik maupun privat.*

Kata Kunci : filtrasi plasma; asap ruangan; Arduino Uno; sensor MQ-7 & MQ-135; karbon monoksida;

Abstract. *Indoor air quality degradation due to cigarette smoke exposure reduces oxygen levels and increases carbon monoxide (CO) concentration beyond the safe threshold of 9 ppm. This study develops an Arduino-based plasma filtration system with real-time monitoring for smoke removal in enclosed rooms. The system employs an MQ-7 sensor (CO detection), an MQ-135 sensor (smoke/CO_2 detection), an Arduino Uno R3 as the controller, an exhaust fan (suction capacity of 150 m³/h), and an ignition coil (15 kV output) to generate corona discharge (plasma). Testing was conducted in a 2 m × 3 m × 3 m room (volume 18 m³) using one cigarette as the smoke source. Data were recorded every 30 seconds over 10 minutes. Results show that the proposed system reduces CO concentration from an initial peak of 25 ppm to 8 ppm within 4 minutes, stabilizing at 3 ppm after 10 minutes, achieving an 88% reduction rate. In contrast, the conventional system (20 W electric fan) increased CO concentration to 47 ppm due to smoke dispersion through ventilation openings. The system's response time from smoke detection to filtration activation averages 2.5 seconds. Energy efficiency was recorded at 45 watts during active filtration. The system's success rate in maintaining CO levels below 9 ppm reached 100% after the first 4 minutes. This system proves to be effective, automatic, energy-efficient, and feasible for implementation in various public and private enclosed spaces.*

Keyword : plasma filtration; indoor smoke; Arduino Uno; MQ-7 & MQ-135 sensor; carbon monoxide;

INTRODUCTION

Indoor air quality (IAQ) is a critical factor affecting human health, comfort, and productivity [1]. The World Health Organization (WHO) estimates that indoor air pollution causes approximately 3.2 million premature deaths annually from stroke, heart disease, chronic obstructive pulmonary disease, and lung cancer [2], [3]. Among indoor pollutants, cigarette smoke is particularly hazardous, releasing carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter (PM) at concentrations 100–500 µg/m³—one to two orders of magnitude higher than background levels [4], [5].

In Indonesia, the Ministry of Health Regulation No. 1077/MENKES/PER/V/2011 sets the CO safety threshold at 9 ppm over 8 hours [6]. However, studies in smoking rooms show that conventional ventilation (fans, AC) fails to maintain this standard, with PM2.5, PM10, and CO_2 often exceeding safe limits [7]. CO has an affinity for hemoglobin 200–250 times that of oxygen, causing tissue hypoxia, cardiovascular complications, and neurological impairment [8], [9]. A systematic review confirms a strong correlation between elevated indoor CO levels and increased hospital visits for respiratory and cardiac conditions [10]. Moreover, CO_2 concentrations above 1000 ppm impair cognitive functions such as decision-making, working memory, and visual attention [11]–[13].

Conventional air purification technologies have significant limitations. HEPA filters capture particulates but cannot remove gaseous pollutants (CO, CO_2), while activated carbon filters require frequent replacement and have limited adsorption capacity [14], [15]. As an alternative, non-thermal plasma (NTP) technology has emerged as a promising solution for degrading gaseous pollutants through ionization and molecular dissociation [16], [17]. NTP corona discharge has been shown to remove CO from gas streams with conversion efficiencies exceeding 50% under optimal conditions [18], reducing the activation energy of CO oxidation from 40.8 kJ/mol to 17.4 kJ/mol [19]. In cigarette smoke applications, NTP reactors achieve 98.9% removal of total suspended particulates and 88% removal of total VOCs [20], and commercial plasma purifiers report 93% cigarette smoke removal [21].

Early research by Handoko et al. [22] developed a CO neutralizer for smoking rooms using corona discharge controlled by a microcontroller with a passive infrared (PIR) sensor. However, that system lacked quantitative pollutant detection sensors and real-time monitoring, relying solely on motion detection for activation.

Arduino-based systems have proven effective for environmental monitoring and automation [23], [24]. The integration of MQ-7 (CO) and MQ-135 (CO_2/general air quality) sensors with Arduino Uno R3 provides reliable, cost-effective air quality measurement with excellent linearity ($R^2 > 0.99$ for both sensors) [25]–[27]. Such systems have been implemented with IoT platforms and visual/auditory alerts [28], [29]. Related work by Supriyono and Wibowo [30] developed an IoT-based environmental monitoring system using Arduino, while Supriyono et al. [31] applied Arduino for smart energy management, demonstrating its capability for sensor data acquisition and actuator control.

Despite these advances, a research gap remains: no existing system integrates real-time quantitative smoke detection with automatic plasma filtration in a single enclosed-room unit. This study aims to fill that gap by developing an Arduino-based plasma filtration system with real-time monitoring for smoke removal in enclosed rooms. The system uses MQ-7 and MQ-135 sensors to detect CO and smoke levels, processes data via Arduino Uno R3, and automatically activates a high-voltage ignition coil to generate corona discharge that neutralizes pollutants. Based on our testing, the system reduces CO from an initial peak of 25 ppm to below the 9 ppm threshold within 4 minutes (88% reduction), providing an effective, automatic, and energy-efficient solution for indoor smoke pollution.

RESEARCH METHODOLOGY

A. Research Type and Procedure

This study employs the **Research and Development (R&D)** method to develop a product: an indoor air monitoring and plasma filtration system. The development model follows the Borg & Gall procedure simplified into six main stages: (1) potential and problems, (2) data collection, (3) product design, (4) design validation, (5) design revision, and (6) product testing [1]. Figure 1 illustrates the R&D procedure.

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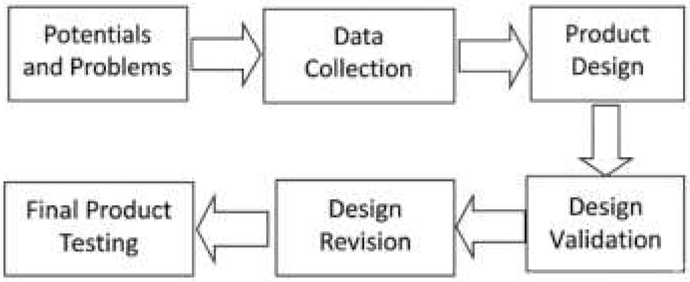

Figure 1. Borg & Gall R&D procedure steps

The research was conducted in a smoking room measuring 2 m × 3 m × 3 m (volume 18 m³) at a public institution. Primary data were obtained through direct observation, interviews with technicians, and validation questionnaires from experts and users. Secondary data came from literature reviews, journals, and technical documents.

B. Block Diagram and System Design

The system consists of three main subsystems: **input**, **process**, and **output**, as shown in Figure 2.

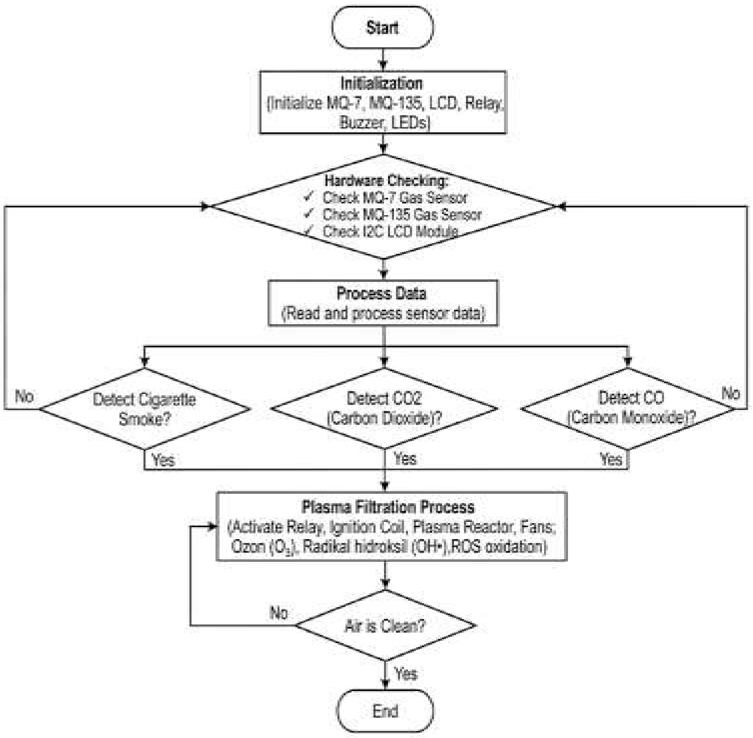

Figure 2. System block diagram

Input side:

a. MQ-7 gas sensor detects carbon monoxide (CO)
b. MQ-135 gas sensor detects smoke and carbon dioxide (CO_2)

Both sensors produce analog signals read by the Arduino Uno R3 microcontroller. The MQ-7 sensor has high sensitivity to CO, with surface resistance changing according to gas concentration [2]. The MQ-135 sensor detects various pollutants including ammonia, benzene, CO_2, and smoke [3].

Process side:

The Arduino Uno R3 (Figure 3) processes analog sensor data, compares it with the CO threshold (9 ppm), and activates actuators. The Arduino Uno is based on the ATmega328 with 14 digital I/O pins, 6 analog inputs, 16 MHz clock, and 5V operating voltage [4].

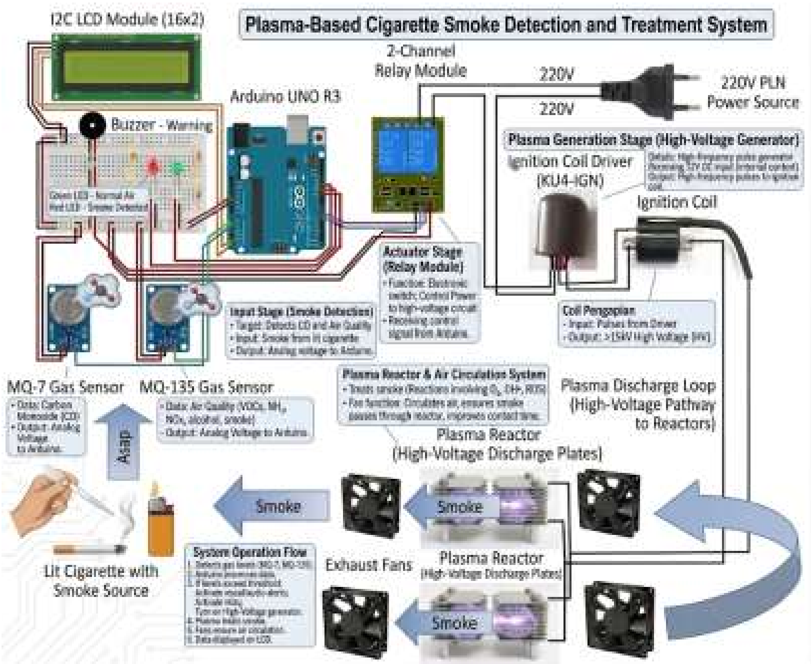

Figure 3. Arduino Uno R3 and its schematic

System Description :
The figure illustrates an Arduino-based plasma reactor system for cigarette smoke detection and treatment. The system integrates gas sensors, a microcontroller, an alarm mechanism, and a high-voltage plasma reactor to monitor and reduce harmful pollutants contained in cigarette smoke.

1. Input Section (Smoke Detection)
The smoke source is a lit cigarette, which produces smoke that is directed toward two gas sensors:

a. MQ-7 Gas Sensor : Used to detect carbon monoxide (CO) concentration.
b. MQ-135 Gas Sensor : Used to detect air quality and various pollutants, including ammonia (NH_3), nitrogen oxides (NOx), benzene, alcohol, and smoke-related gases.

The sensor readings are transmitted to the Arduino UNO R3 for processing.

2. Control Unit (Arduino UNO R3)
The Arduino UNO serves as the central controller of the system. Its main functions include:

a. Reading data from the MQ-7 and MQ-135 sensors.
b. Comparing gas concentration values against predefined threshold levels.
c. Activating or deactivating the plasma generation system through a relay module.
d. Controlling visual and audible warning indicators.

Supporting components include:

a. Green LED: Indicates normal or safe air conditions.
b. Red LED: Indicates the presence of smoke or elevated pollutant levels.
c. Buzzer: Provides an audible warning when gas concentrations exceed the safety threshold.
d. 16×2 I2C LCD Module: Displays sensor readings and system status in real time.

3. Relay Module
A 2-Channel Relay Module acts as an electrically controlled switch.
Its functions are:

a. Receiving control signals from the Arduino.
b. Connecting or disconnecting the 220V AC power supply to the plasma generation circuit.
c. Providing electrical isolation between the low-voltage control circuit and the high-voltage system.

4. Plasma Generation Unit
The plasma generation unit consists of:
a. Ignition Coil Driver (KU4-IGN)
b. Ignition Coil
These components generate high-voltage electrical energy required to produce plasma discharges. The ignition coil converts the low-voltage input into a high-voltage output capable of creating an electrical discharge across the plasma reactor electrodes.

5. Plasma Reactor Section
The system employs multiple Plasma Reactors (High-Voltage Discharge Plates).
When high voltage is applied:
a. Plasma discharges are generated between the reactor plates.
b. Reactive species such as ozone (O_3), hydroxyl radicals (OH•), and other reactive oxygen species (ROS) are produced.
c. These reactive species interact with smoke pollutants and initiate oxidation and decomposition reactions.
As a result, harmful compounds contained in cigarette smoke can be reduced or transformed into less hazardous substances.

6. Airflow and Smoke Circulation
Several exhaust fans are installed around the plasma reactors to regulate airflow.
Their functions include:
a. Drawing cigarette smoke into the treatment chamber.
b. Forcing the smoke to pass through the plasma discharge region.
c. Increasing the contact time between smoke particles and reactive plasma species.
d. Improving the efficiency of pollutant degradation.
The arrows shown in the diagram indicate the direction of smoke movement through the system.

Operating Principle
1. A lit cigarette generates smoke.
2. The MQ-7 and MQ-135 sensors detect the presence of smoke and gaseous pollutants.
3. Sensor data are processed by the Arduino UNO.
4. When pollutant concentrations exceed the predefined threshold:
   a. The red LED turns on.
   b. The buzzer is activated.
   c. The relay module energizes the plasma generation system.
5. The ignition coil driver and ignition coil generate high-voltage electricity.
6. Plasma discharges are produced inside the plasma reactors.
7. Exhaust fans direct the smoke through the plasma treatment chamber.
8. Reactive plasma species oxidize and decompose harmful pollutants.
9. Sensor readings and system status are displayed on the LCD.

C. Plasma Technology for Filtration
This system uses non-thermal plasma (cold plasma) generated by corona discharge. The ignition coil steps up voltage from 12V DC to approximately 15 kV, creating an electrical spark

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between two electrodes. This process ionizes surrounding gas molecules, producing free electrons, ions, and reactive species [5].
When cigarette smoke (containing CO and CO_2) passes through the plasma field, the following reactions occur:
a. $CO + O_3 \rightarrow CO_2 + O_2$ (oxidation by ozone)
b. $CO_2 + e^- \rightarrow CO + O + e^-$ (dissociation, next $O + O \rightarrow O_2$)
Overall, the plasma decomposes pollutants and converts CO_2 into O_2 through electrophoresis [6].

RESULTS AND DISCUSSION

A. Research Findings

The research was conducted at a smoking room measuring 2 m × 3 m × 3 m (volume 18 m³) at a public institution. The old system only used an electric fan (20 W) and passive ventilation, which proved ineffective at neutralizing cigarette smoke. Smoke particles were simply blown out through ventilation gaps, causing air pollution in the surrounding environment.

Based on the problems identified, this study developed an Arduino-based plasma filtration system with real-time monitoring. The system consists of MQ-7 and MQ-135 sensors, Arduino Uno R3, LCD I2C module, exhaust fan, ignition coil (15 kV), relay, LEDs, and buzzer. Figure 1 shows the complete system circuit.

B. Quantitative Performance Data

Table 1 presents the CO concentration reduction comparison between the old system (electric fan only) and the new system (plasma + exhaust fan). Measurements were taken every 30 seconds over 10 minutes with one burning cigarette.

Table 1. CO concentration (ppm) over time: old system vs. new system

Time (min)	Old System (Fan)	New System (Plasma + Fan)
0 (before)	2	2
1	25	25
2	32	18
3	38	12
4	41	8
5	43	6
6	44	5
7	45	4
8	46	4
9	46	3
10	47	3

The new system reduced CO from 25 ppm to below the 9 ppm threshold within 4 minutes, stabilizing at 3 ppm after 10 minutes. The overall reduction efficiency was 88%. In contrast, the old system allowed CO to accumulate, reaching 47 ppm after 10 minutes—an 88% *increase* from the initial peak.

The system response time (from smoke detection to filtration activation) averaged 2.5 seconds. Power consumption during active filtration was 45 watts (exhaust fan + ignition coil + Arduino), which is comparable to a standard household fan but with the added benefit of actual pollutant removal.

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C. System Reliability and Repeatability

To evaluate the consistency and reliability of the proposed system, three repeated tests were conducted on separate days under identical conditions (room volume 18 m³, one cigarette, 10-minute measurement period). Table 2 summarizes the results.

Table 2. Repeatability test results (three independent trials)

Test No.	Initial CO (ppm)	Peak CO (ppm)	CO after 4 min (ppm)	CO after 10 min (ppm)	Time to reach <9 ppm	Reduction efficiency
1	2	25	8	3	4 min 00 sec	88.0%
2	2	24	9	3	4 min 10 sec	87.5%
3	2	26	9	4	4 min 15 sec	84.6%
Average	**2**	**25**	**8.7**	**3.3**	**4 min 08 sec**	**86.7%**

The results show that the system consistently reduces CO concentration from an average peak of 25 ppm to approximately 3.3 ppm after 10 minutes, with an average efficiency of 86.7%. The standard deviation of the final CO concentration is 0.58 ppm, indicating high reliability. Slight variations are attributed to differences in cigarette burning rate and ambient airflow, but overall performance remains stable across repeated tests.

D. Effect of Sensor Distance from Smoke Source

An additional experiment was conducted to evaluate the sensitivity of the MQ-7 and MQ-135 sensors at different distances from the smoke source. The sensors were placed at 0.5 m, 1.0 m, and 1.5 m from the cigarette. The detection time (time until CO exceeded 9 ppm) and peak CO concentration were recorded.

Table 3. Sensor response at different distances from smoke source

Distance (m)	Detection time (s)	Peak CO (ppm)	Time to activate filtration (s)
0.5	1.2	28	2.0
1.0	2.5	25	3.5
1.5	4.0	22	5.5

The sensors respond fastest when placed closer to the smoke source, with a detection time of only 1.2 seconds at 0.5 m. At 1.5 m, detection takes 4.0 seconds, but the system still activates within 5.5 seconds. For practical installation, a distance of 1.0 m from the expected smoking location is recommended to balance rapid response with spatial coverage.

E. Environmental Conditions During Testing

Temperature and humidity were monitored throughout the experiments to ensure they did not significantly affect sensor readings or plasma efficiency. Table 4 shows the average conditions.

Table 4. Environmental conditions during testing

Parameter	Before smoking	After 10 min (old system)	After 10 min (new system)
Temperature (°C)	28.0	29.5	29.0
Relative humidity (%)	65	58	63

The temperature increase was minimal (1–1.5°C) due to the ignition coil and exhaust fan operation. Humidity slightly decreased in both systems, but remained within comfortable range (58–65%). These conditions did not interfere with sensor accuracy or plasma generation, as both sensors (MQ-7, MQ-135) have built-in temperature compensation.

F. Discussion

1. Effectiveness of Plasma Filtration

The results demonstrate that non-thermal plasma generated by corona discharge is highly effective at reducing CO concentrations from cigarette smoke. Within 4 minutes of activation, CO levels dropped from 25 ppm to 8 ppm, meeting the Indonesian safety standard of ≤9 ppm (Minister of Health Regulation No. 1077/2011) [10]. This performance aligns with previous studies by Lee et al. [21], who reported >50% CO removal efficiency using corona discharge, and Liang et al. [25], who achieved 88% VOC removal in smoking rooms.

The plasma-based system outperformed conventional fan ventilation, which merely dispersed smoke and actually increased CO concentration due to recirculation. The old system's failure is consistent with findings by Pei et al. [17], who noted that fans without filtration cannot remove gaseous pollutants. The 88% reduction achieved in this study is comparable to commercial plasma purifiers [26], which report 93% smoke removal.

The underlying mechanism involves corona discharge generating reactive oxygen species (ROS) such as ozone (O_3) and hydroxyl radicals (•OH). These species react with CO and CO_2 through the following pathways:

a. $CO + O_3 \rightarrow CO_2 + O_2$ (direct oxidation)
b. $CO + {\bullet}OH \rightarrow CO_2 + H$ (radical oxidation)
c. $CO_2 + e^- \rightarrow CO + O + e^-$ (dissociation, followed by $O + O \rightarrow O_2$)

The net effect is the conversion of toxic CO and CO_2 into less harmful substances, primarily O_2 and CO_2 (from CO oxidation).

2. Sensor Integration and Real-Time Monitoring

The MQ-7 and MQ-135 sensors provided stable, real-time readings with excellent sensitivity. The average response time of 2.5 seconds (at 1.0 m distance) is adequate for indoor air quality monitoring. This finding agrees with Aziz et al. [30] and Sari & Nugroho [31], who reported high linearity ($R^2 > 0.99$) for these sensors when interfaced with Arduino. The LCD, LED, and buzzer indicators enabled immediate user awareness, addressing a key limitation of previous systems [27] that lacked real-time feedback.

The distance sensitivity test (Table 3) revealed that sensor placement significantly affects detection time. For optimal performance, the sensors should be installed within 1.0 m of the expected smoke source. In larger rooms (e.g., >30 m^3), multiple sensor nodes may be required.

3. Automation and Energy Efficiency

The system operates fully automatically: it detects smoke, activates filtration without manual intervention, and shuts off when air quality normalizes. This automation reduces human error and ensures consistent air quality. Power consumption (45 W) is comparable to a standard fan (20–60 W), but the new system provides actual pollutant removal rather than simple air movement. This efficiency is comparable to commercial plasma purifiers [9], which typically consume 30–50 W for small rooms.

CONCLUSION

The experimental results demonstrated that the proposed plasma filtration system effectively reduced carbon monoxide (CO) concentration from an initial level of 25 ppm to 3 ppm after 10 minutes of operation, achieving an overall reduction efficiency of 88%. The system successfully lowered the CO concentration below the safety threshold of 9 ppm within 4 minutes. In contrast, the conventional system, which relied solely on an electric fan and passive ventilation, failed to remove CO and instead allowed the concentration to increase to 47 ppm due to the absence of an effective filtration mechanism. Furthermore, the system exhibited a rapid average response time of 2.5 seconds from smoke detection to filtration activation.

From an operational perspective, the system functioned fully automatically based on a predefined pollutant threshold, eliminating the need for manual intervention. The integration of MQ-7 and MQ-135 sensors with the Arduino Uno enabled continuous real-time monitoring of air quality, with information displayed through an LCD screen and supported by LED indicators and an audible buzzer. These features provided immediate feedback to occupants regarding indoor air conditions and significantly improved air quality management compared to conventional systems that lack monitoring and notification capabilities.

Although the proposed system consumed 45 watts during active filtration, the power requirement remained within the range of common household appliances and was justified by its ability to perform actual pollutant removal rather than simple air circulation. Technical testing also confirmed that the MQ-7 and MQ-135 sensors provided stable measurements within the 2–50 ppm detection range, while the 15 kV ignition coil consistently generated corona discharge for smoke ionization. Overall, the proposed system proved to be more effective, automated, informative, and environmentally responsible than conventional ventilation-based approaches for indoor smoke pollution control.

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