



A Comparative Study of Indoor Kitchen Air Quality and Outdoor Ambient Air Quality

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Abstract: The Cooking activity makes a substantial contribution to indoor pollution. Indoor air pollution (IAQ) has become a significant environmental and public health concern in recent years in countries like India, where 48.5% of the Indian population i.e. women cooks daily. In this paper an Internet of Things (IoT) based model is developed to compare the air quality outside and inside the kitchen while cooking. The proposed model measures the level of key harmful gases like Carbon Monoxide (CO), Carbon Dioxide (CO₂) inside the kitchen while cooking and outside the building. The proposed model comprises ESP8266 microcontroller, MQ series gas sensors, Liquid Crystal Display (LCD) and jumper wires. The collected data reveals that there is a significant impact of cooking on the key pollutants gases, and there is a spike in the level of gas concentration while cooking inside the kitchen.

Keywords: Indoor Air Quality (IAQ), Internet of Things (IoT), Women Health, Pollution, Air Quality

(Article history: Selected papers from NIELIT's International Conference on Communication, Electronics and Digital Technologies (NICE-DT'26), 29-30 Jan, 2026, Gorakhpur, India)

1. Introduction

In highly dense societies, air quality (IAQ) has become a critical health concern of the public [1]. In India, the most common mess facilities or kitchen areas where daily food preparation activities produce significant levels of indoor pollutants or harmful gases. These gases are Particulate matter (PM_{2.5}), CO₂, CO, VOCs, and other combustion byproducts are examples of these indoor pollutants. As a function of fuel type, ventilation efficiency and cooking intensity the concentrations of these pollutants tend to fluctuate significantly during the day Abdullahi et. al [2]. Cooking-related emissions can rapidly accumulate in enclosed or semi-ventilated spaces, leading to short-term pollution surges that pose both immediate and long-term health risks, according to numerous studies.

The present study focuses on the temporal behavior of IAQ markers specifically VOCs, CO₂, and overall Air Quality Index (AQI) —in shared kitchen environments. This study investigates the time- dependent changes in IAQ indicators—specifically VOCs, CO₂, and the overall Air Quality Index (AQI)—within shared kitchen spaces Ahmad et. al [3]. The results from the recorded environment indicate distinct pollutant peaks during morning and evening cooking sessions. The peaks are generated by inadequate exhaust systems or user-neglected ventilation practices, such as leaving windows and chimney units closed during frying or boiling stages, and they have a strong correlation with high-activity cooking intervals. This time varying analysis provides deeper insight into how everyday cooking patterns influence indoor pollutant accumulation.

Existing literature strongly supports these observations. Indoor environments are routinely exposed to elevated concentrations of VOCs, PAHs, and fine particulate matter which are therefore derived from frying, grilling, and heating. Inadequate ventilation further aggravates pollutant buildup [4]. Who determined the severe IAQ deterioration in Ethiopian households relying on biomass cooking with poor airflow? Additional research by Xu. et al [5] establishes direct links between prolonged exposure to PM_{2.5} and VOCs with chronic respiratory illnesses, cardiovascular complications, and reduced cognitive performance. These results highlight how urgent it is to increase environmental health treatments in community kitchens and create IAQ monitoring regimes.

The development of technological solutions is ongoing. The availability of real-time IAQ monitoring systems that can precisely measure changes in pollutants has increased (Ahmad et al., 2013). According to Abdullahi et al. [2], contemporary kitchen ventilation technologies, such as integrated stovehoods, heat-recovery ventilators, and automated exhaust control mechanisms, show great promise in reducing the buildup of indoor pollutants. However, because of financial limitations, inadequate upkeep, and user ignorance, these devices are still not widely used in hostel and shared living settings.

2. Literature Review

From the standpoint of human health, IAQ has acquired increasing attention within the research community especially in kitchens with regular cooking activities. As per WHO consideration, in some instances, the concentration of pollutants in the indoor environment exceeds that of outdoor air, specifically happening where there is poor ventilation in the kitchens. Combustion oriented cooking (using LPG, kerosene, or electric stove) emits harmful pollutants like carbon monoxide, nitrogen oxide, nitrogen dioxide, formaldehyde and volatile organic compounds as stated by numerous studies. According to a research by Balakrishnan et al. (2013) emissions from traditional biomass cooking results in indoor PM_{2.5} concentrations that surpass outdoor air quality standards by several orders of magnitude. Similarly, a research also conducted by Smith et al.

(2014) implies that kitchens utilising LPG stoves nevertheless highlight much higher levels of CO and NO₂ during higher cooking hours, stating that even “clean fuels” contribute appreciably to indoor air pollution when ventilation is too poor. Researches conducted in village environments also depict that worn out fans and chimney-based ventilation systems reduces the pollutant emissions, but their impact is subject to variation depending upon kitchen orientation and air ventilation patterns.

On the other hand, indoor pollution shows a sharp increase while cooking and remains elevated for extended periods due to slow pollutant dissipation. Kirchner et al. (2017) emphasized that indoor PM levels are strongly influenced by factors like stove type, oil used for frying, cooking method (deep frying vs. boiling), and ventilation efficiency. In contrast to this outdoor air is affected by macro-level emission sources and meteorological conditions.

Numerous studies, including those by Smith et al. (2017) and Johnson et al. (2019), illustrates that prolonged exposure to elevated concentrations of pollutants generated in the kitchen raises the risk of respiratory infections, chronic obstructive pulmonary disease (COPD), cardiovascular disorders, and ocular problems. Women and children who spend more time near domestic cooking environments are affected to a greater extent. Research by Bruce et al. (2018) emphasizes the need for systematic monitoring of indoor environments, paired with the implementation of cleaner cooking technologies and stronger ventilation measures, highlighting the potential challenges in adoption due to socioeconomic factors. Indoor air quality has emerged as a critical focus of research due to its substantial impact on human health. Most of it is found particularly in households marked by regular culinary activities conducted in the kitchen. The WHO warns that indoor settings can sometimes host pollutant amounts which are significantly greater than those found in outdoor air, especially found in improperly ventilated cooking areas. An appreciable amount of data indicates that combustion-based cooking methods which are utilizing LPG, biomass, kerosene, or electric stoves releases a wide range of undesirable pollutants like PM_{2.5} and PM₁₀, CO, NO₂, formaldehyde, and VOCs. The restricted nature of these confined areas and limited pollutant dispersion, plays a major role in increasing the accumulation of these pollutants indoors.

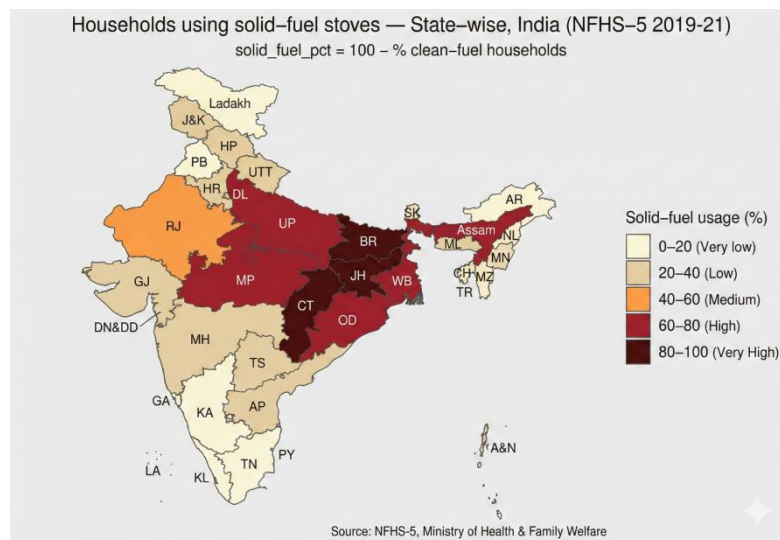


Fig.1 Solid-fuel usage in India

A Research by Balakrishnan and his team in 2013 shows that the old biomass burning stoves affect the indoor air really badly. These stoves can accumulate a lot of particles that are not good for us and the levels of these particles can be much higher than what is allowed outside. For example, Smith and his team found out in 2014 that households using LPG stoves still had a lot of air during the times when people were cooking a lot. They found levels of CO and NO₂ in these homes. This means that even if we use what we think are fuels like LPG we can still have bad air inside our homes if the ventilation is not good. So, the research by Balakrishnan and Smith and their teams tells us that indoor air pollution is a problem even with clean fuels, like LPG. Studies conducted in urban environments demonstrate that the use of exhaust fans and chimney-based ventilation systems substantially mitigates pollutant concentrations; however, their efficacy is contingent upon kitchen design and air circulation patterns. The air we breathe outside is mostly affected by the pollution from cars, factories, construction sites and people burning trash. The air quality is also influenced by the weather like when the temperature gets stuck in a pattern during different times of the year. The Central Pollution Control Board notes that cities with a lot of traffic have high levels of bad things in the air like tiny particles, nitrogen oxides and ozone especially when it is winter.

What is really interesting is that even with all this outdoor pollution, the air inside our homes especially, in the kitchen can be even worse when we are cooking a lot. For example a study by Latha and Venkatesan that was done in 2018 found out that the amount of carbon monoxide inside homes during cooking is a lot higher than the amount. This is true in cities that are really polluted. The carbon monoxide levels inside homes are three to five times higher than the levels. This is what Latha and

Venkatesan discovered in their research, about carbon monoxide levels.

When we look at the differences in dynamics we can see some big differences. Outdoor pollution usually goes up and down depending on the time of day, the weather and how many cars are on the road. On the other hand indoor pollution goes up really fast when we are cooking and stays too high for a long time because the pollutants do not go away quickly..

According to several studies, extended exposure to high levels of pollutants emitted in kitchens increases the risk of having respiratory infections, chronic obstruct pulmonary disease (COPD), cardiovascular problems, and eye discomfort. Women and children, who are majorly affected by the emission of pollutants in the kitchen.

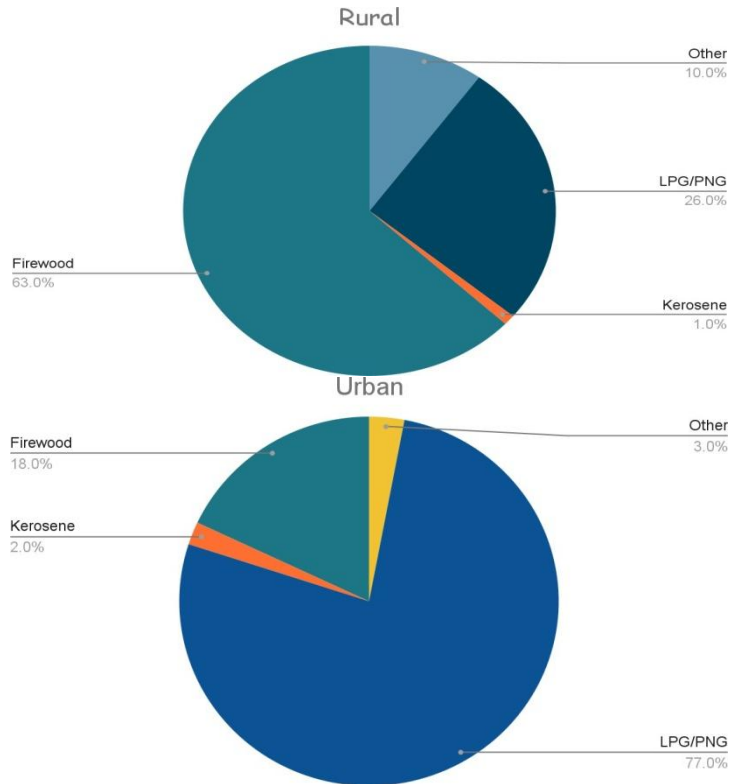


Fig.2 Rural vs Urban Fuel Consumption

3. Overview

CO ₂ Level (ppm)	Effect on Health
400–600	Fresh air, no effects
600–1,000	Slight stuffiness
1,000–2,000	Headaches, reduced focus
2,000–5,000	Drowsiness, fatigue, nausea
5,000	Unsafe for long exposure
10,000+	Dangerous, severe symptoms
40,000+	Life-threatening

Table 1: Carbon Dioxide (CO₂) and Its Effects on Humans

The Earth's atmosphere normally contains 400–420 parts per million of CO₂, a colourless, odourless, and nonflammable gas. It is crucial to both the respiratory cycle of living things and the greenhouse effect, which keeps the world's temperature stable. As a consequence of cellular respiration, humans constantly exhale CO₂, which builds up inside when ventilation is inadequate. The incomplete combustion of carbon-based fuels like petrol, wood, LPG, charcoal, or natural gas is the main source of CO, a colourless, odourless, tasteless, and extremely poisonous gas. Stoves, water heaters, fireplaces, and cars running in enclosed areas are common indoor sources.

Because of its great affinity for haemoglobin, the protein in red blood cells that carries oxygen, CO is extremely hazardous.

The inhaled CO binds with haemoglobin to create **carboxyhaemoglobin**(COHb), therefore hampering the binding of oxygen. So this reduces oxygen delivery to organs and tissues which is a condition known as **hypoxic stress**. With the increasing concentrations of COHb in the bloodstream, the body is effectively suffocated, despite the air appearing normal. So this is the reason why CO poisoning is so hazardous: one doesn't feel a lack of air because your lungs are working fine. Instead, you feel vague symptoms like a headache, dizziness, or confusion as your vital organs start to run on empty, resulting in a silent deficiency of oxygen due to the molecule's exceptionally strong affinity for haemoglobin.

CO Level (ppm)	Health Impact
0–9	Safe
10–35	Mild symptoms after long exposure
35–100	Headache, dizziness
100–200	Nausea, fatigue
200–400	Severe headache, confusion
400–800	Life-threatening
800–1600	Fatal with prolonged exposure
1600+	Fatal in minutes

Table 2: Carbon Monoxide (CO) and Its Effects on Humans

By binding to mitochondrial enzymes, CO can interfere with the electron transport chain and lower the body's capacity to generate energy. This contributes to the neurological symptoms such as confusion, dizziness, and loss of consciousness because CO has no detectable smell or color, exposure is often **unknowingly prolonged**, making it one of the leading causes of accidental poisoning worldwide. Therefore, it is essential for safety to keep an eye on CO levels in homes, businesses, and enclosed spaces. Because of their sensitivity to reducing gases, semiconductor sensors like MQ-9 and MQ-7 are frequently employed for CO detection; nevertheless, electrochemical CO sensors are used in high-precision settings for precise results.

I. Impact of IAQ on Women Health

The WHO reports that 2.6 billion people, or one-third of the world's population, still deplete to clean cooking and continue to use inefficient technologies and polluting fuels (wood, coal, charcoal, animal dung, and agricultural residues). These pollutants pose a health hazard and are a leading cause of disease as well as mortality, especially for Indian women and kids growing in developing countries [3], [21]. While 41.5% of households in urban areas cook with gas or biogas, most households still cook with biomass fuels, namely charcoal and firewood [21] [13]. Finding the risk variables is crucial for improved illness prevention. In this paper, the objective is to examine the connection between COPD and indoor pollution exposure in Ouagadougou, Burkina Faso. Measuring the levels of PM_{2.5}, CO, and volatile organic compounds (VOCs), or pollutants produced during cooking, in home kitchens was one of the specific goals. To evaluate the correlation between vulnerability to PM_{2.5}, VOCs and Carbon mono-oxide in the kitchen and COPD, the mean concentrations between the patient and control groups were compared.

Research on CO Emissions and Cognition

- **Reduced IQ:** According to research, children who were chronically exposed to smoke emissions from solid biomass fuels had arithmetic IQ scores that were on an average 5.5 points lower than those children residing in households that used cleaner LPG fuel for cooking.
- **Neuropsychological Impact:** Carbon monoxide from sources like kerosene stoves are associated with significant negative neuropsychological impacts which can be due to prolonged exposure in poorly ventilated environments, affecting components of intelligence scales like digit span caused by the disruption of oxygen delivery to the brain.
- **Brain Development:** Epidemiological and neuro imaging have reported such associations between these types of exposure including pathological abnormalities found in brain imaging studies.
- **Cognitive Function in Adults:** Research also suggests that dependence on polluting cooking fuels is associated with worse performance across various cognitive tasks in adults.
- **Compounding Factors:** The negative effects of air pollution on children's IQ are magnified by co-exposure to social stress, material hardship, and insufficient nutrition, which are often correlated with the use of polluting fuels

4. Methodology

For finding what is the safe range limit of pollutant gases for women. We developed a system to collect data we used the following components:

- Arduino Uno
- ESP-12E Module
- Gas sensor: MQ9 and MQ135

- LCD16x12I2Cdisplay
- Type-BMicroUSBCable
- Jumper Wires
- Bread Board

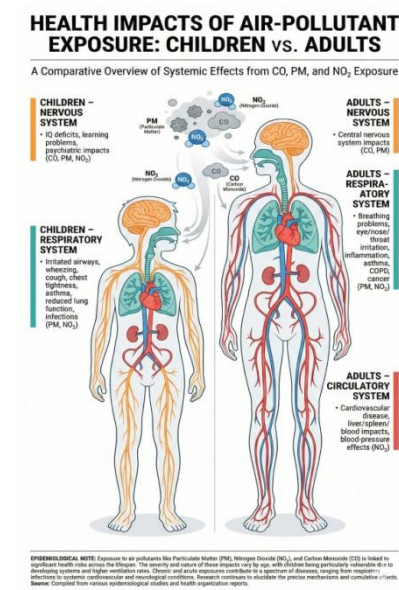


Fig.3 A Comparative Overview of Systematic Effects from CO,PM, and NO₂ Exposure

I. ArduinoUno

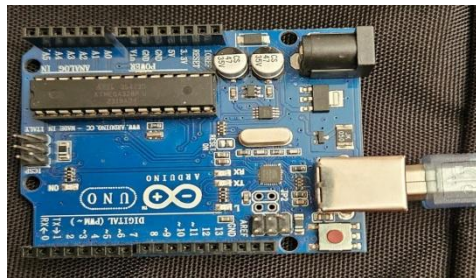


Fig.4ArduinoUno

ArduinoUno R3 is versatile, easy-to-use microcontroller board for building interactive electronic projects.

II. NodeMCUESP-12EModule

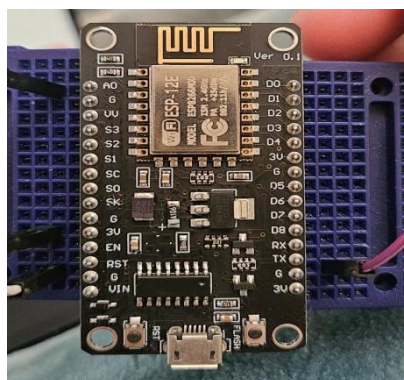


Fig.5NodeMcuESP12-EModule

NodeMCU is an extended open source version of ESP8266 Wi-Fi module that facilitates seamless network connectivity for IoT applications.

III. MQ9gassensor



Fig.6MQ9sensor

MQ9isaGasSensor(MQ9)modulethat is important for identifying gas leaks (in home and industry). Identifying LPG, CO, and CH₄ is effective

IV. MQ135 gas sensor

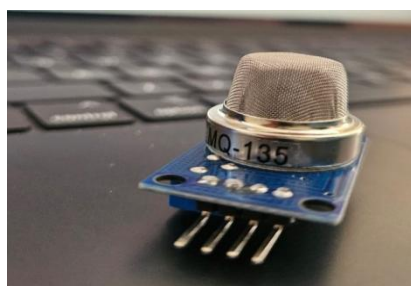


Fig.7MQ135sensor

MQ135 Sensor, the sensor is used for the detection of various gases such as CO₂, NH₃ and some other pollutants. The sensor provides analog outputs proportional to the concentration of these gases in parts per million (ppm).

V. Type-B Micro USB Cable



USB type-B Cable to give power to NodeMcu ESP Module

VI. Jumper Wires

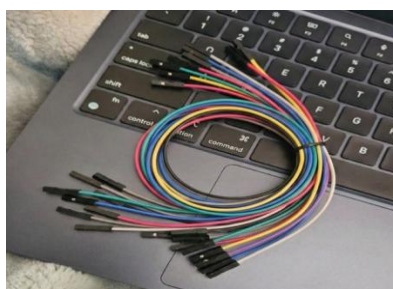


Fig.8Jumperwires

Jumper wires are used to create temporary or permanent electrical connections between circuit points, essential for electronics prototyping, testing, and connecting components like Arduinos, sensors, and breadboards without soldering, acting as simple

conduits for power and signals.

VII. BreadBoard



Fig.9 BreadBoard

After all the connections, our system will look like as in the above figure Connections:-

ESP A0 → Sensor A0, ESP GND → Sensor GND, ESP VCC → Sensor VCC, ESP D2 → LCD I2C SDA, ESP D1 → LCD I2C SCL, ESP GND → Arduino UNO GND, Arduino UNO GND → LCD I2C GND

Code

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266HTTPClient.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// LCD
LiquidCrystal_I2C lcd(0x27, 16, 2);

// ----- WiFi 1 (Primary) -----
const char* ssid1 = "Saksham's S23";
const char* pass1 = "52111980";

WiFiClient client;
HTTPClient http;
String api_key = "87KKGGA3NQV6Q7W0Y";

int mq135_pin = A0; // CO2, NH3
int mq9_pin = A0; // For analog reading of MQ-9

// MQ135 constants
float R0_135 = 10.0;

// MQ-9 constants
float R0_9 = 10.0;

// Calculate Rs
float getRs(float adcValue) {
    return (1023.0 / adcValue - 1.0);
}

// MQ135 conversions
float getCO2(float ratio) {
    return 116.6828682 * pow(ratio, -2.769034857);
}

float getNH3(float ratio) {
    return 102.2 * pow(ratio, -2.473);
}

// MQ9 conversions
float getCO(float ratio) {
    return 100 * pow(ratio, -1.2);
}

float getCH4(float ratio) {
    return 500 * pow(ratio, -2.0);
}

// ----- FUNCTION: CONNECT TO WIFI USING TWO NETWORKS -----
void connectWiFi() {
    lcd.clear();
    lcd.print("WiFi 1 Connecting");
    WiFi.begin(ssid1, pass1);

    unsigned long start = millis();
    while (WiFi.status() != WL_CONNECTED && millis() - start < 5000) {
        delay(300);
    }

    if (WiFi.status() == WL_CONNECTED) {
        lcd.clear();
        lcd.print("WiFi1 Connected");
        delay(1000);
        return;
    }

    // Try WiFi 2
    lcd.clear();
    lcd.print("WiFi1 Failed!");
    delay(1000);

    lcd.clear();
    lcd.print("WiFi2 Connecting");
    // WiFi.begin(ssid2, pass2);

    start = millis();
    while (WiFi.status() != WL_CONNECTED && millis() - start < 5000) {
        delay(300);
    }

    if (WiFi.status() == WL_CONNECTED) {
        lcd.clear();
        lcd.print("WiFi2 Connected");
    } else {
        lcd.clear();
        lcd.print("No WiFi!");
    }

    delay(1200);
}

void setup() {
    Serial.begin(9600);
    Wire.begin(D2, D1);
    lcd.init();
    lcd.backlight();
    connectWiFi(); // connect using 2 WiFi system
}
```

```
void loop() {
    // ----- MQ135 (CO2, NH3) -----
    int adc135 = analogRead(mq135_pin);
    float rs_135 = getRs(adc135);
    float ratio135 = rs_135 / R0_135;

    float co2_ppm = getCO2(ratio135);
    float nh3_ppm = getNH3(ratio135);

    // ----- MQ9 (CO, CH4) -----
    int adc9 = analogRead(mq9_pin);
    float rs_9 = getRs(adc9);
    float ratio9 = rs_9 / R0_9;

    float co_ppm = getCO(ratio9);
    float ch4_ppm = getCH4(ratio9);

    // ----- Display 1: CO2 + CO -----
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("CO2: ");
    lcd.print((int)co2_ppm);

    lcd.setCursor(0, 1);
    lcd.print("CO : ");
    lcd.print((int)co_ppm);
    delay(5000);

    // ----- Display 2: NH3 + CH4 -----
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("NH3: ");
    lcd.print((int)nh3_ppm);

    lcd.setCursor(0, 1);
    lcd.print("CH4: ");
    lcd.print((int)ch4_ppm);
    delay(5000);

    // ----- ThingSpeak Upload -----
    String url = "http://api.thingspeak.com/update?api_key=" + api_key;
    url += "&field1=" + String(co2_ppm);
    url += "&field2=" + String(co_ppm);
    url += "&field3=" + String(nh3_ppm);
    url += "&field4=" + String(ch4_ppm);

    http.begin(client, url);
    http.GET();
    http.end();
}
```

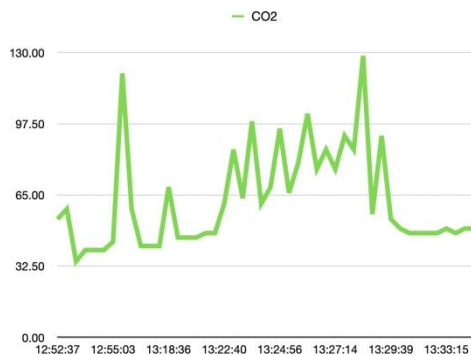


Fig.10Readings(inppm)ofCO₂gasfromthesensor

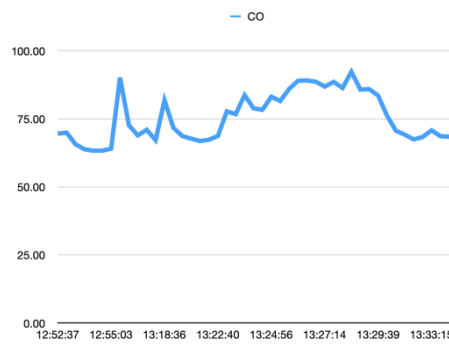


Fig.11Readings(inppm)ofCOgasfromthesensor

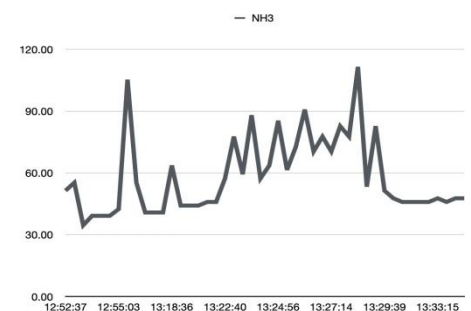


Fig.12Readings(inppm)ofNH₃gasfromthesensor

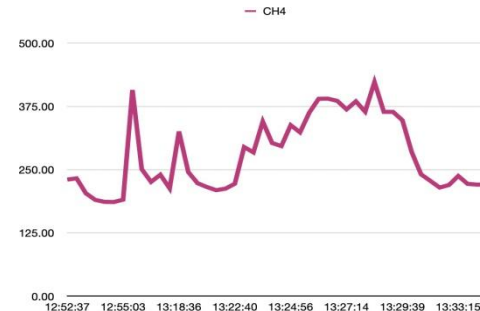


Fig.13Readings(inppm)ofCH₄gasfromthesensor

5. Observations

It has been observed in our experiment that A person may experience symptoms similar to the flu after breathing in little amounts of carbon monoxide for a few hours. Headaches and eye discomfort are possible symptoms. A runny nose may also occur if an individual is exposed to levels greater than 35 ppm for the duration of a workday.

It has also been observed that flu-like symptoms, including headaches and sore eyes can be brought on by a modest exposure lasting more than two to three hours, such as a CO level between 35 and 200 parts per million.[19] On the other hand, a runny nose occurs at higher concentrations of more than 35 ppm when exposed continuously for eight hours [19]

In as little as an hour, a medium exposure (a CO level between 200 and 800 parts per million) will cause lightheadedness, sleepiness, and vomiting.[20] After around three hours, this level of exposure is considered potentially fatal. In as little as a few minutes, extreme exposure (a CO level of 800 ppm and above) will cause unconsciousness, brain damage, and ultimately death. According to guidelines, the maximum exposure should not exceed 35 parts per million over eight hours.[16]

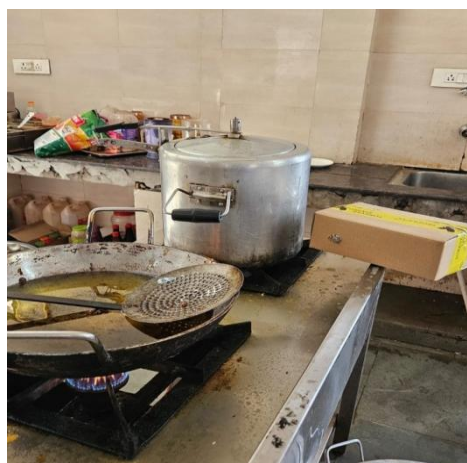


Fig. 14 Taking readings from the sensor while keeping it in the kitchen near the gas stove

6. Study Limitations

- **Sample Size:** Sample size is small and contains 9 cases and 9 controls measured.
- **Statistical Power:** As far as sample size is concerned lack of statistical significance despite observed differences in raw numbers.
- **Measurement Duration (Averaging Effect):** Data should be relied on an average 24-hour, which leads to inaccurately captured peak exposure intensity during specific meal preparation times.
- **Variability in Ventilation:** The study reflects significant differences in pollution based on kitchen type (external separate vs. internal vs. open-air). If the proportion of kitchen types was not perfectly matched between cases and controls, the physical structure of the cooking area could act as a confounding variable, influencing the results independent of fuel type.
- **Lack of Personal Exposure Monitoring:** The study measured concentrations *in the kitchen* (stationary monitoring). Since the women's real intake relies on how much time they spend in the kitchen compared to other parts of the house over the 24-hour period, it could not be an accurate representation of their personal exposure.

7. Conclusion

Indoor air pollution from the cooking environment forms a serious threat to human health, especially in shared and poorly ventilated kitchens or the communal GOATELS. During the fuel combustion, pre-heating, food preparation, and even after cooking ends, various harmful pollutants, like CO, CO₂, and fine particulate matter (PM_{2.5}), are released. These pollutants majorly affect indoor air quality and lead to high societal and public health costs (as said by WHO).

There is a severe need for strategies that address emissions at their source rather than relying solely on behavioral modifications or conventional ventilation techniques reflected in this study. Regulators should initiate guidelines that help in reducing indoor pollution levels, mandate real-time air quality monitoring in high-risk regions, and promote the use of improved ventilation systems and cleaner cooking methods. There must be a use of emission-free cooking techniques and switching to electrical kitchen appliances which can significantly lower indoor pollution.

Albeit modern electric systems can sufficiently lower harmful emissions, but their progress is slow due to economic challenges, infrastructure issues, and low awareness in the population. So in order to accelerate the change to cleaner cooking techniques and practices, national and municipal policy must prioritise incentives, subsidies, and educational initiatives. Therefore the primary issues related to IAQ cannot be resolved by investing in experimental solutions like hydrogen or inefficient ventilation alteration.

So it is of utmost importance to eliminate emissions before, during, and after cooking to protect people, especially women and children from long-term exposure who spend more time in the kitchen. However, moving to low-emission and emission-free cooking environments can provide lasting health benefits, reduce environmental impacts, and ensure our kitchens are safe.

8. References

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