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Estimation of Indoor Air Pollutants and Health Implications Due to Biomass Burning in Rural Household Kitchens in Jos, Plateau State, Nigeria †

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Abstract: Household air pollution was responsible for an estimated 3.2 million deaths per year in 2020, including over 237,000 deaths of children under the age of 5. A large number of these death cases was particularly recorded in developing countries where many people rely heavily on biomass for energy. Burning biomass emits carbon monoxide and other pollutants resulting in indoor air pollution, exacerbations of asthma, hospitalizations for heart attacks and respiratory illness, birth defects, neurological diseases, and even mortality, which are all brought on by indoor air pollution. Because women and children typically do most of the cooking, they are most affected by indoor air pollution. In this research, an active sampling technique was adopted in estimating the amount of three major criteria gaseous pollutants (CO, H_2S, and SO_2) in the air in rural household kitchens within the Jos metropolis. The Attair 5X gas detector was used. The power button was pressed and the equipment was allowed to initialize for few minutes while the readings were taken downwind in-situ at a distance of 1 m, 2 m, 3 m, 4 m, and 5 m respectively from the emission source at the expiration of one (1) minute for each distance to check the impact of emissions on the environment and people in such areas. The results obtained shows that CO, H_2S, and SO_2 were higher from firewood emission sources when compared with charcoal emission sources from the 14 different rural kitchens in the Bauchi ring road, Jos, Plateau State, Nigeria. Hence, this study serves as a ready reference for environmentalists to make target decisions on air pollution reduction.

Keywords: indoor; biomass; firewood; pollution

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1. Introduction

Indoor Air Pollution (IAP) is a grave concern, encompassing toxic gases and particles that can accumulate at alarming levels within households, posing severe health risks [1]. This study delves into the estimation of IAP in rural household kitchens within Jos, Plateau State, Nigeria, where biomass burning serves as the primary fuel source due to economic constraints [2].

Biomass combustion, often utilizing wood, charcoal, animal dung, and agricultural residues, yields a spectrum of hazardous pollutants, including particulate matter (SPM), carbon monoxide (CO), and nitrogen dioxide (NO_2) [3]. In 2020 alone, household air pollution led to an estimated 3.2 million deaths worldwide, with a significant toll on children under 5 years old [4].

Rural areas in developing countries, such as Jos North, face acute threats from indoor air pollution, with approximately 95% of the population relying on biomass for cooking and heating [5]. The study area presents an environmental conundrum, characterized by numerous unplanned kitchens that emit pollutants severely compromising the health of nearby communities.

This research aims to estimate the emissions of gaseous pollutants, notably carbon monoxide (CO), hydrogen sulfide (H_2S), and sulfur dioxide (SO_2), within these kitchen environments, establishing a vital baseline for assessing health hazards [6]. By doing so, it contributes to addressing a critical global environmental issue, ultimately improving the quality of life for those dependent on biomass as a primary fuel source.

2. Materials and Methodology

2.1. Description of Study Area

Seven (7) different kitchens located in Bauchi Road, Rusau, Farin-Gada Round About, Opposite Student village hostel, Opposite University of Jos Main Campus, Farin-Gada Junction, and Student Village Hostel were selected for monitoring in this work. This study areas are located in the Jos North Local Government Area, Plateau State. Jos North has a population of 643,200. It has an annual temperature of 28.41 °C. The major activities of people that generate particulate pollution are usually combustion of solid fuels and vehicular activities.

2.2. Method

In this study, we utilized active sampling with the Altair 5X Multi-Gas detector to measure CO, H_2S, and SO_2 concentrations at selected biomass sources in seven (7) different kitchens. The detector was initiated after a self-check and calibration procedure.

Readings were recorded downwind at distances of 1 m, 2 m, 3 m, 4 m, and 10 m from the emission source for one minute at each distance, enabling the assessment of pollutant concentrations at varying distances.

The collected data, which include pollutant concentrations at different distances, underwent analysis and interpretation to draw conclusions and provide recommendations concerning the impact of biomass emissions on air quality.

2.3. Air Quality Index

The AQI is based on the five "criteria" pollutants regulated under the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The AQI has also been developed into an electronic mode called the AQI calculator. However, the AQI is compared with standards for pollutants in the environment as provided by both global and regional organizations. These standards are used to check the emission status of activities in the world today.

The pollutant's index is its concentration expressed as a percentage of the relevant air standard, as outlined in Table 1. In the present study, AQI was calculated by using the equation given by the US. EPA (2017) as follows:

$$\text{AQI} = \frac{\text{pollutant concentration}}{\text{pollutant standard level}} \times 100 \quad (1)$$

Table 1. Air Quality Rating Table (Source: USEPA, 2014).

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51 to 100	Moderate
101 to 150	Unhealthy for Sensitive Groups
151 to 200	Unhealthy
201 to 300	Very Unhealthy
301 to 500	Hazardous

2.4. Statistical Analysis

The monitored data of CO, H_2S, and SO_2 were analyzed using descriptive statistics (mean, standard mean error, standard deviation) for all the seven different kitchens. The daily means for all the seven locations were also computed. These data were analyzed using Microsoft Excel Version 2016.

The Overall Mean Concentration of the pollutants (CO, H_2S, SO_2) is presented in Table 2, the Standard Deviation, which tells us about the shape of the distribution and how close the individual data values are to the mean value, and Standard Error, which explains how close the sample mean is to the true mean of the overall population.

Table 2. Overall Mean Concentration of the pollutants (CO, H_2S, SO_2).

Sample Locations	Pollutants	Mean	Standard Deviation	Standard Error
Bauchi Road (Beans cake frying spot)	CO	11.215	10.500	5.248
	H_2S	0.053	0.071	0.036
	SO_2	0.023	0.008	0.004
Rusau (Beans cake frying spot)	CO	51.75	16.537	8.993
	H_2S	0.060	0.066	0.030
	SO_2	0.030	0.016	0.007
Farin-Gada Roundabout (Beans cake frying spot)	CO	9.537	4.780	2.145
	H_2S	0.205	0.134	0.054
	SO_2	0.018	0.008	0.003
Opposite Student Village Hostel (Meat barbecue spot)	CO	43.383	45.221	31.976
	H_2S	0.140	0.104	0.074
	SO_2	0.030	0.008	0.004
Opposite University of Jos Main Campus (Rice cake frying spot)	CO	38.625	29.895	12.205
	H_2S	0.015	0.022	0.009
	SO_2	0.134	0.058	0.024
Farin-Gada Junction (Meat barbecue spot)	CO	6.520	4.464	2.578
	H_2S	0.00	0.000	0.000
	SO_2	0.009	0.008	0.005
Student Village Hostel (Meat barbecue spot)	CO	4.737	5.78685	3.341
	H_2S	0.043	0.075	0.043
	SO_2	0.030	0.016	0.006
Overall Mean Concentration of polutants	CO	26.650		
	H_2S	0.074		
	SO_2	0.051		

3. Air Quality Measurements

Using the formula of the Air Quality Index present in equation 1, the Air Quality Index was calculated and compared with the WHO. The result obtained is shown in Table 3.

Table 3. Air Quality Index.

Sample Location	Pollutants	Air Quality Index (AQI)	Level of Health Concern
Bauchi Road (Beans cake frying spot)	CO	124.60	Unhealthy for Sensitive Groups
	H_2S	53.25	Moderate
	SO_2	23.35	Good—No health implications
Rusau (Beans cake frying spot)	CO	575.00	Extremely hazardous
	H_2S	60.33	Moderate
	SO_2	30.33	Good—No health implications
Farin-Gada Roundabout (Beans cake frying spot)	CO	105.96	Unhealthy for Sensitive Groups
	H_2S	205.00	Very unhealthy—Serious health impact
	SO_2	17.67	Good—No health implications
Opposite Student Village Hostel (Meat barbecue spot)	CO	482.04	Hazardous
	H_2S	140.00	Unhealthy for sensitive groups
	SO_2	30.00	Good—No health implications
Opposite University of Jos Main Campus (Rice cake frying spot)	CO	492.20	Hazardous
	H_2S	14.67	Good—No health implications
	SO_2	134.30	Unhealthy for sensitive groups
Farin-Gada Junction (Meat barbecue spot)	CO	72.44	Moderate
	H_2S	0.00	Good—No health implications
	SO_2	9.00	Good—No health implications
Student Village Hostel (Meat barbecue spot)	CO	52.63	Moderate
	H_2S	43.33	Good—No health implications
	SO_2	30.00	Good—No health implications

4. Discussion

Our study conducted a comprehensive assessment of indoor air quality at selected biomass emission sources in Jos, Nigeria. We aimed to understand the impact of gaseous pollutants from traditional firewood-based cooking. Active sampling was employed to measure in-situ emissions of CO, H_2S, and SO_2.

The Air Quality Index (AQI) was calculated based on WHO standards for CO, H_2S, and SO_2 concentrations as shown in Table 3.

For the concentration of CO as shown in Figure 1, Rusau had extremely hazardous levels, while the university campus and Student Village Hostel had hazardous levels. Bauchi Road and Farin-Gada Roundabout had unhealthy levels of emission for sensitive groups, and Farin-Gada Junction and Student Village Hostel had moderate levels.

In Figure 2, SO_2 levels were generally acceptable except near the University of Jos Main Campus which had impact on sensitive groups.

For the concentration of H_2S in Figure 3, Farin-Gada Roundabout records the worst case emission scenario, while Farin-Gada junction showed the least emission scenario.

From the overall mean concentration of pollutants, Rusau emerged as having the worst-case emission scenario, posing significant health risks to its residents. Variations in emitted gases were influenced by factors like biomass burning intensity, seasonal patterns, and meteorological conditions. The efficiency of biomass burning directly affected CO and byproduct emissions, with diurnal and seasonal variations linked to human activities and weather dynamics. Meteorological factors, including wind patterns and atmospheric stability, played a role in shaping observed trends, highlighting the complex interplay of human practices and natural processes on air quality outcomes.

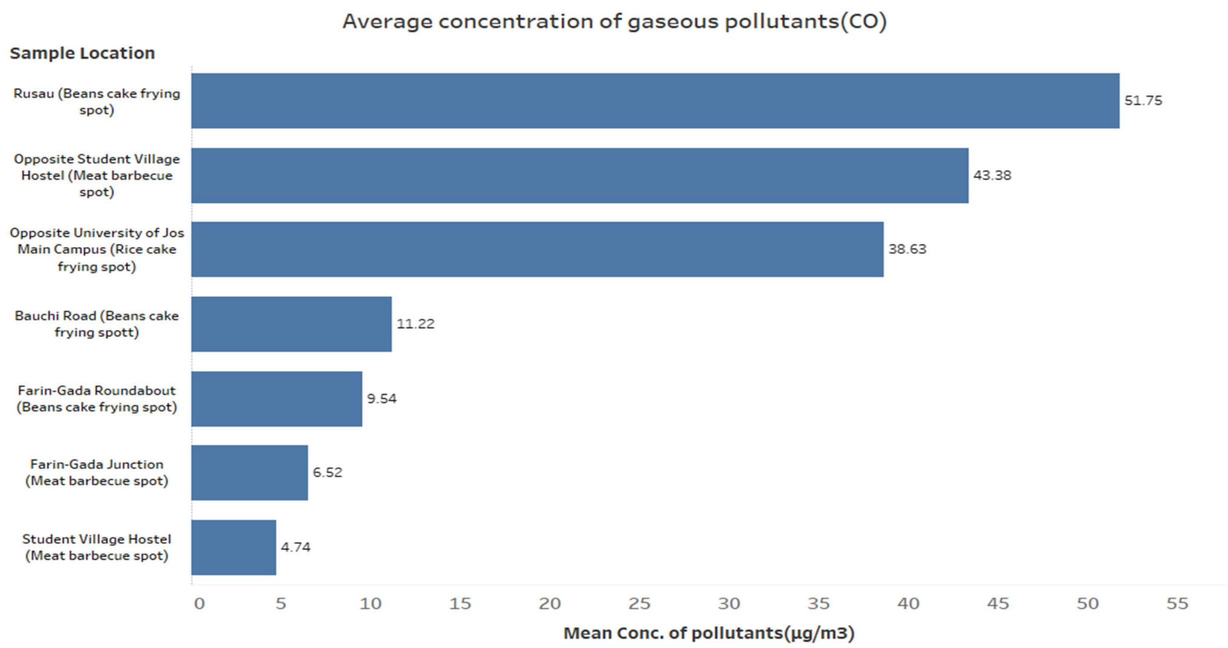

Figure 1. Concentration of gaseous pollutants (CO).

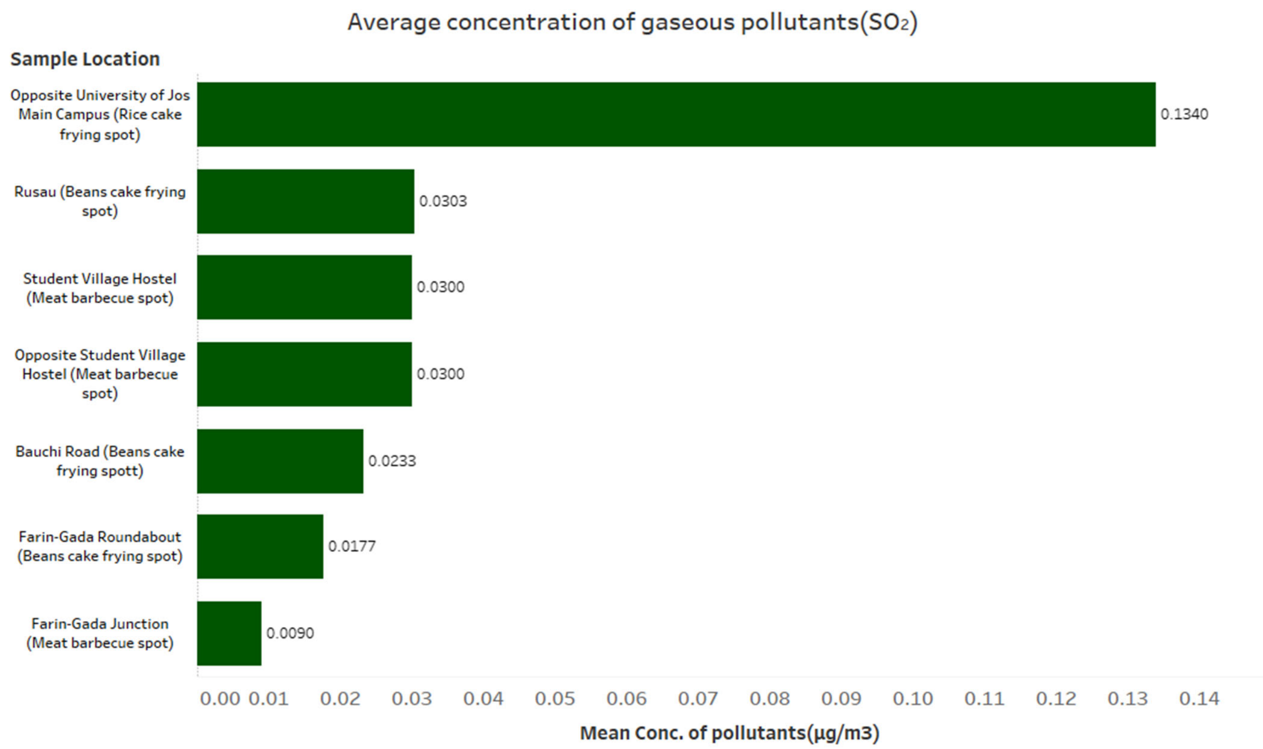

Figure 2. Concentration of gaseous pollutants (SO_2).

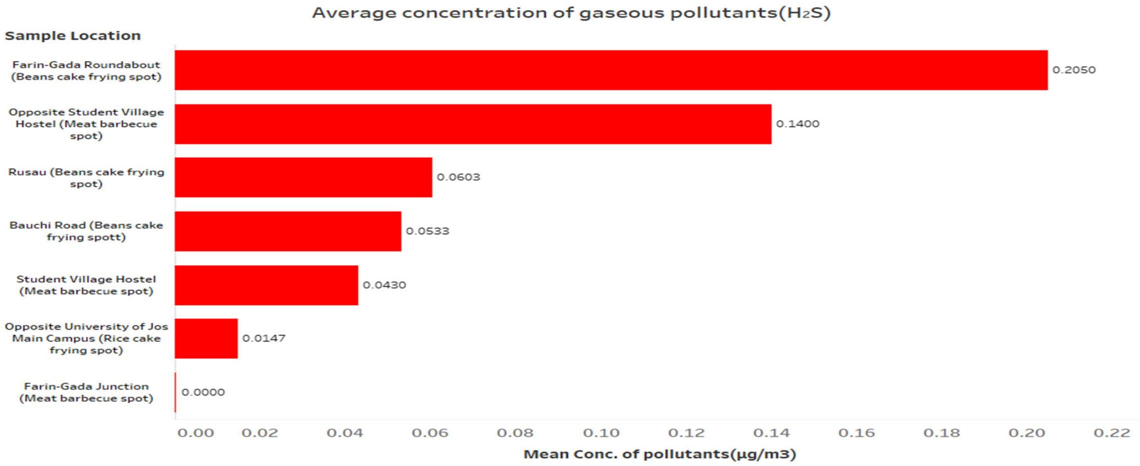

Figure 3. Concentration of gaseous pollutants (H_2S).

5. Conclusions

In conclusion, our assessment of indoor gaseous pollutants from firewood burning at food frying and barbecue sites reveals concerning pollutant levels exceeding air quality standards. Urgent action is needed to mitigate these emissions, promoting healthier cooking practices, public awareness, and stronger air quality regulations. Collaborative efforts among communities, businesses, and policymakers are crucial for achieving cleaner air and sustainability. Embracing cleaner technologies and sustainable practices can lead to a healthier, greener future for generations to come.

Author Contributions: T.D. conceptualized the study, designed the research methodology, and contributed to data analysis. A.J.A. conducted experiments, collected data, and performed statistical analysis. D.U.A. contributed to data interpretation, manuscript writing, and critically reviewed the final version. All authors have read and approved the manuscript.

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