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Research Article

Effect of Cooking Fuel Choice on the Typology of Indoor Pollutants in Port Harcourt Metropolis: Implications for the incidence of Sick Building Syndrome

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ABSTRACT

The study examined the effect of cooking fuel choice on indoor air quality and its implication for the incidence of sick building syndrome in different residential land use areas of Port Harcourt metropolis. Questionnaire survey and measurement of indoor air pollutants in residential areas were undertaken. The residential areas were stratified into high, middle and low income residential land use. Purposive sampling and random sampling techniques were used to select two residential areas and two streets from each selected residential land use. The questionnaire survey exercise that features respondents' types of cooking fuel choices were accessed by given identification numbers to buildings. The odd numbers were enumerated for each area (residential land use). Based on consent and approval, 15 residential buildings (5 from each residential area) were selected for air quality measurements. Composite sampling technique was deployed for the collection of air quality data from the 15 households at a distance of 2m away from source of cooking fuel. The air quality parameters measured were Carbon dioxide (CO_2), Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Nitrogen oxide (NO), Nitrogen IV oxide (NO_2) and Particulate matter ($PM_{2.5}$). Both Descriptive statistics and Inferential statistics were deployed (Spearman Rank Correlation and ANOVA. Findings revealed that LP Gas (38.6%) was mostly used by residents. The concentration of gaseous pollutants of CO, CO_2, SO_2, NO and $PM_{2.5}$ were all highest under low income residential area with mean concentrations of CO, =3.56(mg/m^3), CO_2 =539.5(mg/m^3), SO_2 =1.48(mg/m^3), NO= 0.72 (mg/m^3), and $PM_{2.5}$=16.4 ug/mg^3 respectively; except NO_2 with concentration of 1.02 mg/m^3 during the morning cooking periods. Findings revealed that measured air quality especially in the low income residential area failed to meet the perfect conditions of fresh air due to the heavy use of firewood, kerosene and charcoal as choice of cooking fuel. Thus, cooking fuel choice has direct effect on indoor air quality and the risk of Sick Building Syndrome. The study recommends that choices for cooking fuel should not be based on cost but on low health implications as this will help reduce the associated health risk factors of indoor air pollution in the study area.

Keywords: Cooking fuel, Choice of fuel, Kitchen, Households, Indoor pollutants

INTRODUCTION

Long-term exposure to indoor air pollution from cooking fuel combustion is a major contributor to indoor air quality of residential buildings and a risk factor for several health-related issues especially respiratory disease and sick building syndrome (SBS), which is an increasingly prevalent contributor to morbidity and mortality in low- and middle-income countries of the world.

The World Health Organization posits that about 3 billion people worldwide use kerosene, biomass (wood, animal dung and crop waste) and coal as domestic fuels [1]. Their incomplete combustion produces harmful pollutants. These pollutants have adverse effects on both human health and the climate [2]. Around 20% of black carbon emissions globally result from traditional solid fuel stoves and open cooking fires, especially when biomass is the fuel source. In low- and middle-income countries in Africa and Asia, household solid fuel use contributes 60–80% of black carbon emissions, while kerosene use contributes 270 Gg of black carbon annually [3]. Products of incomplete combustion like black carbon and methane contribute to climate change, while carbon monoxide, Sulphur dioxide, nitrous oxide and particle mass with aerodynamic diameter less than 2.5μm ($PM_{2.5}$) have been linked to adverse health

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outcomes including cardiovascular disease, respiratory diseases, the incidence of sick building syndrome and lung cancer [4-10].

In many homes in developing countries, a major source of air pollutants is cooking smoke, caused by burning unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking and space heating [11,12]. According to some known estimates, approximately half of the worlds' population is reliant on biomass fuels (wood, agriculture residues, and charcoal) for cooking and heating as the primary source of domestic energy, and nearly 2 billion kilograms of biomass are burned every day in developing countries [11,13].

However, the distribution of indoor air quality is extremely difficult to describe on a geographic scale, because indoor air quality is determined by complex dynamic relationships that depend heavily on occupant activity and highly variable structural characteristics of buildings [14,15]. Weather, which has a regional character, influences indoor air concentrations of some chemicals, such as formaldehyde, and biologic contaminants, such as bacteria and molds [16].

A cursory look at recent scientific studies, concerns and findings reveals that the impact of cooking fuel choice on indoor air quality is not new, but there is dearth of empirical examination of the interplay of the influence of relative humidity and other weather-related conditions affecting indoor environmental quality especially its implications for the incidence of Sick Building Syndrome (SBS) among building occupants in a sub-humid tropical industrial coastal city of Port Harcourt. This is the gap in the literature which this study intends to provide.

The Study Area

Port Harcourt is the capital of Rivers State. It is the main city in the state and has one of the largest seaport in the Niger Delta region of Nigeria. It is the hub of industrial, commercial, administration and other activities in the state. The city lies between latitude 0^0 23^1 -7^0 30^1 E and 5^0 45^1 - 40^0 15^1 N (fig 1). It covers an estimated area of 1811.6 square kilometers. The city is bounded in the north by Imo and Abia States east by Akwa-Ibom State, West by Bayelsa State and south by the Atlantic Ocean. Weather systems particularly rainfall in city are primarily a result of the interplay between two major pressure and wind systems. These are the two dynamically generated sub-tropical high pressure cells centered over Azores Archipelago (off the west coast of North Africa) and St. Hellena Islands (off the coast of Namibia). These high-pressure centers (or anticyclones) which are permanent generate and drive respectively the North-East trade winds and the South-West winds, which are the northward extension of the re-curved South-East trade winds of the South Atlantic Ocean. The major rainfall controls over the region are, apart from the seasonal location of the ITD, the distance inland from the coast and relief. Generally, rainfall over Nigeria diminishes with increasing distance from the moisture source in the South Atlantic. Thus, coastal areas like the Port Harcourt region, receive heavier and more persistent rainfall because the South-West wind is strong. The strength of the air mass is reduced as it penetrates inland. This also affects temperature. Ascent of air over high ground produces cooling which can lead to condensation and precipitation. This phenomenon described as orography, does not control any weather system in the region in that the area is devoid of any high lands. Pollution in the atmospheric medium travels the farthest and industrial emissions are one of the most important sources of air pollution. The implications of the location pattern of industries for pollution are many. The dominant air mass over Port Harcourt is the South West Trade Wind. Detailed wind flow characteristics over the city include periodic doses of emission from the major industrial locations around the city. The incidence of land breeze, as well as, the Harmattan factor actually transfers emissions into the city [16].

Theoretical Framework and Methodology

The conceptual framework upon which this study is rooted is the concept is the Ecological Modernization theory. The Ecological Modernization theory asserts that economic development policies and environmental protection can work together for synergy and create positive-sum game between ecology and economy. [17] explained that the Ecological Modernization theory promote the application of stringent environmental policies as a positive influence on economic efficiency and technological innovation, and a resolution of ecological problems for economic growth can, in principles, be reconciled. Additionally, they cited [18] who identified four exclusive features of Ecological Modernization theory. The first one is technological adjustment for emission reduction and efficient resource management, the second one is belief system which reflects an ideology centered on the understanding of environmental protection as a precondition of long term development. The third feature is policy discourses that transform change in environmental policies in a broad framework of modernity and promote discourse about environmental policy making that emphasized role definition and identification of social factors that influence environmental policy formulation and implementation. One basic assumption of ecological modernization relates to environmental re-adaptation of economic growth and industrial development. On the basis of enlightened self-interest, economy and ecology can be favorably combined: Environmental productivity, i.e. productive use of natural resources and environmental media (air, water, soil, ecosystems), can be a source of future growth and development in the same way as labour productivity and capital productivity. This includes increases in energy and resource efficiency as well as product and process innovations such as environmental management and sustainable supply chain management, clean technologies, benign substitution of hazardous substances, and product design for environment. Radical innovations in these fields can not only reduce quantities of resource turnover and emissions, but also change the quality or structure of the industrial metabolism. In the co-evolution of humans and nature, and in order to upgrade the environment's carrying capacity, ecological modernization gives humans an active role to play, which may entail conflicts with nature conservation [19-21].

There are different understandings of the scope of ecological modernization - whether it is just about techno-industrial progress and related aspects of policy and economy, and to what extent it also includes cultural aspects (ecological modernization of mind, value orientations, attitudes, behavior and lifestyles). Similarly, there is some pluralism as to whether ecological modernization would need to rely mainly on government, or markets and entrepreneurship, or civil society, or some sort of multi-level governance combining the three. Some scholars explicitly refer to general modernization theory as well as non-Marxist world-system theory; others don't [22-24].

The research design for the study is cross-sectional and correlational because the study seeks to sample respondents that cut across a defined residential class within a study population and to examine the relationships between variables of interest from a comparison point of view in order to determine the nature of relationships and make right conclusions for the purpose of the study. This study made use of both primary and secondary data. The primary data were acquired from the fieldwork through questionnaire survey and measurements of indoor air quality in sampled residential areas. On the other hand, the secondary data were acquired from relevant journals, books and magazines found in the libraries and internet. Indoor air quality parameters investigated included Carbon dioxide (CO_2), Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Nitrogen oxide (NO), Nitrogen IV oxide (NO_2) and Particulate matter ($PM_{2.5}$). The air quality parameters were recorded using air quality equipment. Standards of air quality by World Health Organization (WHO) were obtained for comparison purposes for the study.

The population of study includes all residential areas and buildings in Port Harcourt. However, since dealing with the entire number of residential areas in Port Harcourt will be very tasking and time consuming and in order to obtain a sample size for the study; the field exercise therefore stratified the residential zones into high, middle and low income residential zones. The sample size for the study was therefore obtained by given all residential buildings in each selected residential area identification numbers, whereby all the odd numbers were enumerated in sampled streets as sample size of the study.

The sampling technique adopted in this study was composite sampling technique. The technique emphasizes taking records at a point in different times. The households' residential apartments were reference points at which indoor air quality parameters were taken. Indoor air quality parameters were collected at a distance of 2m from source of cooking fuel utilized in the sampled household. Based on the need to obtain permission and informed consent from household owners; time and financial constraints involved as regards the expensive nature of instrument to be used for sampling and data collection, purposive and convenient sampling methods were employed to limit the sample size to 15 randomly selected households for indoor air quality measurements based on cooking fuel choices (like electricity, gas, in each type of residential areas: high income; middle income and low income areas in Port Harcourt Metropolis as delineated by the Rivers State Ministry of Lands and Housing. The data on gaseous pollutants were collected four times daily (cooking periods and non-cooking periods between 7 and 10 am in the morning and afternoon periods between 4 and 7 pm periods) at a measured distance of 2m away from point of cooking fuel being utilized at the household level. The research was carried out between January and February, 2019 and it lasted for 3 weeks with the aid of two (2) field assistants. The indoor air quality instruments used for measurement were calibrated in parts per million (ppm) but the results were converted to mg/m^3 for gaseous pollutants and $\mu g/m^3$ for particulate matter. Purposive sampling technique was used to select two streets from two locations in each type of residential areas. For instance for high, middle and low income residential areas, two streets each were selected from old GRA and Peter Odili; Rumuigbo and Ada George axis and Choba and Diobu respectively. Stratified sampling technique was used to determine the sample size for questionnaire administration. This was achieved by given each building within each selected residential street identification numbers whereby odd numbers (1, 3, 5, 7, 9…) were selected and counted and totaled as sample size for the study (details on Table 1 and Figure.1). A total of 300 copies of the questionnaire were administered among selected residential areas based on the sample size of 293 houses enumerated. However, a total of 272 copies of the questionnaire were retrieved for analysis (including questionnaire administered at households sampled for indoor air quality).

Table 1: Sampled Residential Areas and Sample Size

For appropriate representation of the study population, questionnaire survey was employed based on types of residential areas: high income residential areas; middle income residential areas; and low income residential areas. A total of 300 copies of the questionnaire were administered to respondents based on the targeted sample size for the study in order to obtain information on types of cooking fuel utilized and factors responsible for choice of cooking fuels in the study area. The questionnaire instrument was divided into two parts: part A and B. The part A was on respondents' socio-economic status while the part B focused on factors responsible for choice of cooking fuel among sampled respondents. The cooking fuel choices usually range from the use of gas, electricity, kerosene, firewood, charcoal, saw dust, animal dung and so on. For this study, the Gas, electricity and animal dung cooking choice are tagged as "clean fuel", while on the other hand the rest of the listed cooking fuel choice are tagged as "unclean fuel". This is because of the possibility of incomplete combustion from the unclean fuel and their ability to produce dangerous gases that may be injurious to human health [25]. Thus, ranking was done on the basis of low carbonaceous fuel substances, the cooking fuels were ranked as: Electricity (7), Gas (6), others (like animal dung - Biogas) (5), Kerosene (4), Saw dust (3), Charcoal (2), and Firewood (1).

Both descriptive and inferential statistics were used for this study. The data collected were presented in tables and charts. Descriptive statistics was used to explain the mean values of the indoor air quality parameters. It was also used to explain the comparison between the observed mean values of pollutants and the WHO and USEPA standards of indoor air pollutants. Pair-wise t-test statistics was used to compare the measured data obtained for indoor air quality between morning periods and evening periods in the study area. The first hypothesis stated for the study was tested using Pearson Correlation Statistics. Pearson Correlation Statistics (Equ.1) was used to test the hypothesis 1. Student's t-test was used to test the level of significance of the hypothesis (Equ. 2). Hypothesis 2 and 3 which states that no statistically significant variation exists in the concentration of gaseous pollutants at different cooking periods and the third that states that no significant variation exists among sampled residential apartments in the study area were tested using the One-way analysis of variance (ANOVA). The One-way ANOVA is a veritable tool for analysing the level of variation among, within and between variables of interest. The Spearman Rank Correlation Analysis was employed because it can be used to determine relationships between observations obtained through the questionnaire survey. Thus, the ranked data here were the types of cooking fuel against measured gaseous pollutants at household levels.

The formulae for Pearson Correlation Statistics used were represented as:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad (1)$$

Where;

r = correlation coefficient

Table 1: Sampled Residential Areas and Sample Size.

S/n	Type of residential areas	Sampled locations (sampled streets)	Total odd nos. Counted from buildings	Total copies of questionnaire distributed	Total copies of questionnaire returned
1	High Income Residential Areas	Old GRA (William Jumbo)	38	39	35
		Peter Odili	42	43	40
		Total	**80**	**82**	**75**
2	Middle Income Residential Areas	Ada George	47	48	45
		Rumuigbo	49	50	44
		Total	**96**	**98**	**89**
3	Low Income Residential Areas	Choba (Rumuochakara and Okocha)	61	62	58
		Diobu	56	58	50
		Total	**117**	**120**	**108**
Overall Total			**293**	**300**	**272**

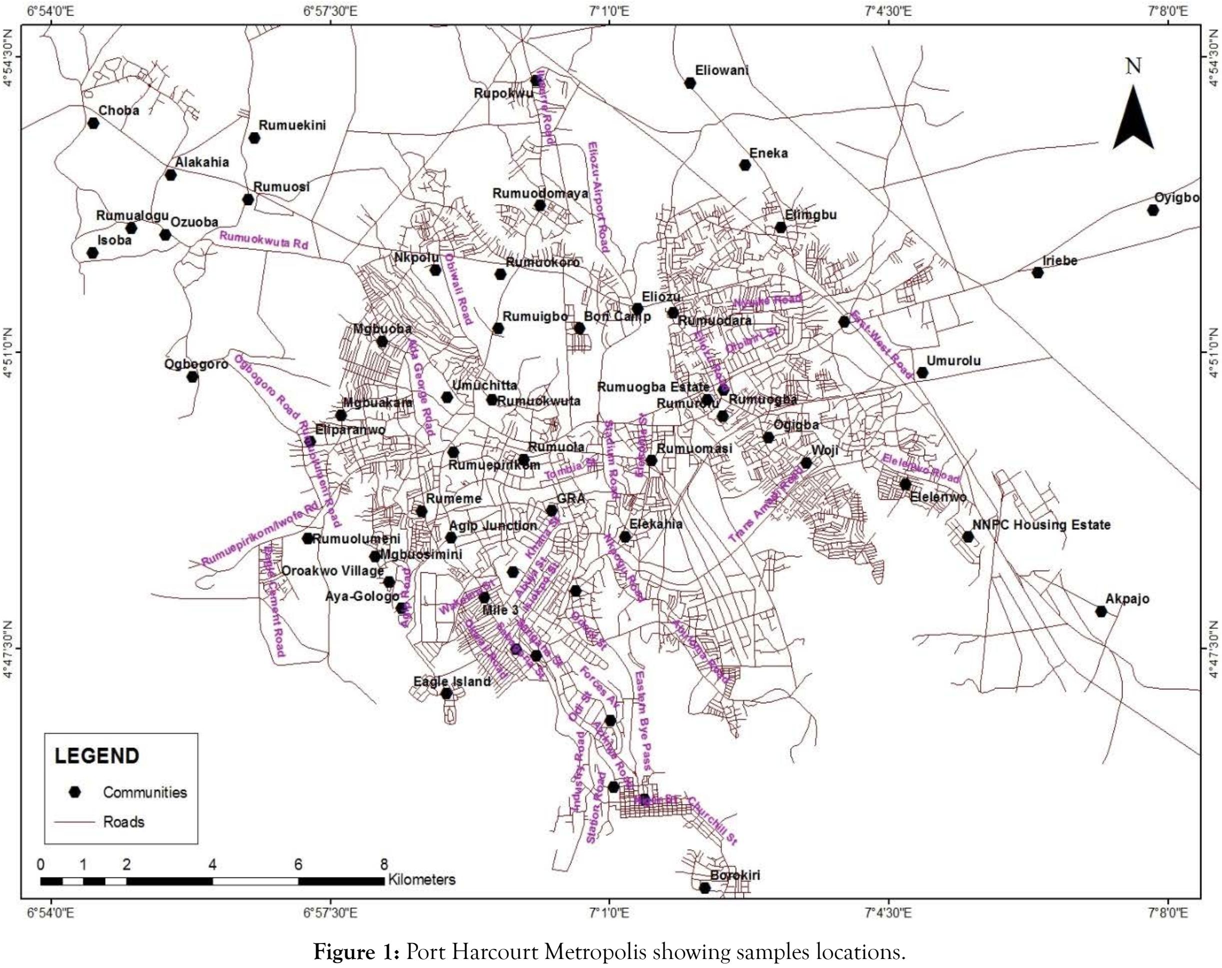

Figure 1: Port Harcourt Metropolis showing samples locations.

X = Independent variable

Y = Dependent variable

X = Mean of X

Y = Mean of Y

$$t = r\sqrt{\frac{n-2}{1-r^2}} \quad (2)$$

Where;

t- Calculated value

n- Number of samples

r- Correlation coefficient

Discussion of Findings

Socio-Economic Characteristics of Sampled Respondents

The information on Table 2 revealed that more females of 58.8% were sampled for the study more than the males of 41.2%. This was because most times females are responsible for cooking and spent more time in the kitchen more than the males. The marital status of sampled respondents revealed that 72.2% were married, 14.3% were single, and 13.6% are widowed while no sampled respondents have been divorced. The age structure of sampled respondents showed that 42.3% are between 21-40 years, 45.2% of sampled respondents are between 41-60 years while the 12.5% of sampled respondents are above 61 years of age. The occupational

Table 2: Socio-economic Characteristics of Sampled Respondents.

Description	Characteristics	High Income Residential Area	Middle Income Residential Area	Low Income Residential Area	Total
Gender	Male	23 (8.5%)	48 (17.6%)	41 (15.1%)	**112 (41.2%)**
	Female	52 (19.1%)	41 (15.1%)	67 (24.6%)	**160 (58.8%)**
Marital Status	Single	19 (7.0%)	14 (5.1%)	6 (2.2%)	**39 (14.3%)**
	Married	52 (19.1%)	70 (25.7%)	74 (27.2%)	**196 (72.2%)**
	Widow	4 (1.5%)	5 (1.8%)	28 (10.3%)	**37 (13.6%)**
Age	21-40 years	31 (11.4%)	49 (18.0%)	35 (12.9%)	**115 (42.3%)**
	41-60 years	40 (14.7%)	31 (11.4%)	52 (19.1%)	**123 (45.2%)**
	61 years and above	4 (1.5%)	9 (3.3%)	21 (7.7%)	**34 (12.5%)**
Occupation	Wage/Salary only	8 (2.9%)	40 (14.7%)	45 (16.5%)	**93 (34.2%)**
	Salary/Self employed	41 (15.1%)	18 (6.6%)	7 (2.6%)	**66 (24.3%)**
	Self-employed only	26 (3.6%)	22 (8.1%)	17 (6.3%)	**65 (23.9%)**
	Unemployed	0 (0.0%)	9 (3.3%)	39 (14.3%)	**48 (17.6%)**
Academic Level	Primary	0 (0.0%)	0 (0.0%)	13 (4.8%)	**13 (4.8%)**
	Secondary	8 (2.9%)	21 (7.7%)	45 (16.5%)	**74 (27.2%)**
	Tertiary	67 (36.2%)	68 (36.8%)	50 (27.0%)	**185 (68.0%)**
Average Monthly income	#41,000-#60,000	0 (0.0%)	0 (0.0%)	54 (19.9%)	**54 (19.9%)**
	#61,000-#80,000	0 (0.0%)	4 (1.5%)	48 (17.6%)	**52 (19.1%)**
	#81,000-#100,000	0 (0.0%)	58 (21.3%)	6 (2.2%)	**64 (23.5%)**
	Above #100,000	75 (27.6%)	27 (9.9%)	0 (0.0%)	**102 (37.5%)**
Household size	1-2	33 (12.1%)	4 (1.5%)	9 (3.3%)	**46 (16.9%)**
	3-4	34 (12.5%)	51 (18.8%)	41 (15.1%)	**126 (46.3%)**
	5-6	8 (2.9%)	25 (9.2%)	23 (8.5%)	**56 (20.6%)**
	6-8	0 (0.0%)	9 (3.3%)	23 (8.5%)	**32 (11.8%)**
	Above 8	0 (0.0%)	0 (0.0%)	12 (4.4%)	**12 (4.4%)**
Length of Stay	0-5 years	0 (0.0%)	10 (3.7%)	18 (6.6%)	**28 (10.3%)**
	6-10 years	33 (12.1%)	23 (8.5%)	23 (8.5%)	**79 (29.0%)**
	11-15 years	34 (12.5%)	44 (16.2%)	41 (15.1%)	**119 (43.8%)**
	16-20 years	12 (4.4%)	8 (2.9%)	12 (4.4%)	**32 (11.8%)**
	Above 20 years	2 (0.7%)	2 (0.7%)	10 (3.7%)	**14 (5.1%)**
House ownership	Landlord	48 (17.6%)	34 (12.5%)	40 (14.7%)	**122 (44.9%)**
	Tenant	27 (9.9%)	55 (20.2%)	68 (25.0%)	**150 (55.1%)**
Dwelling unit type	Single room	0 (0.0%)	9 (3.3%)	54 (19.6%)	**63 (23.2%)**
	Bed Room and sitting room	15 (5.5%)	35 (12.9%)	48 (17.6%)	**98 (36.0%)**
	2X3 Bedroom	41 (15.1%)	40 (14.7%)	6 (2.2%)	**87 (32.0%)**
	Duplex	12 (4.4%)	0 (0.0%)	0 (0.0%)	**12 (4.4%)**
	Detached house	7 (2.6%)	5 (1.8%)	0 (0.0%)	**12 (4.4%)**

status revealed that 34.2% of sampled respondents are on wage and salary only, 24.3% of sampled respondents are on salary and are also self-employed, 23.9% of the respondents are self -employed only, while the remaining 17.6% of sampled respondents are unemployed in the study area. The educational status of sampled respondents revealed that 4.8% belong to the primary level, 27.2% of sampled respondents belong to the secondary educational level, while the remaining 68.0% belong to the tertiary level of education. The information obtained for the average monthly income of sampled respondents showed that 19.9% of respondents earn between #41,000 and #60,000; another 19.1% of respondents earn between #61,000 and #80,000; 23.5% of respondents earn between #81,000 and #100,000; while the remaining 37.5% are earning above #100,000 in the study area. The household sizes for the sampled respondents showed that 16.9% have between 1 and 2 household size, 46.3% recorded between 3 and 4 household sizes, another 20.6% of sampled respondents recorded household sizes of between 5 and 6, 11.8% of sampled respondents recorded between 6 and 8 household number while the remaining 4.4% of sampled respondents recorded above 8 individuals as household size. Thus, majority of sampled respondents for the study recorded household numbers that falls between 3 and 4. The number of years lived (length of stay) in respondents' residential area was examined and the findings showed that 10.3% of sampled respondents have lived in their residential apartment between one to five years; 29.0% of sampled respondents have lived between six and ten years; 43.8% of sampled respondents have lived between eleven and fifteen years; 11.8% of sampled respondents have lived between sixteen and twenty years; while the remaining 5.1% of sampled respondents have lived in their residence for more than twenty

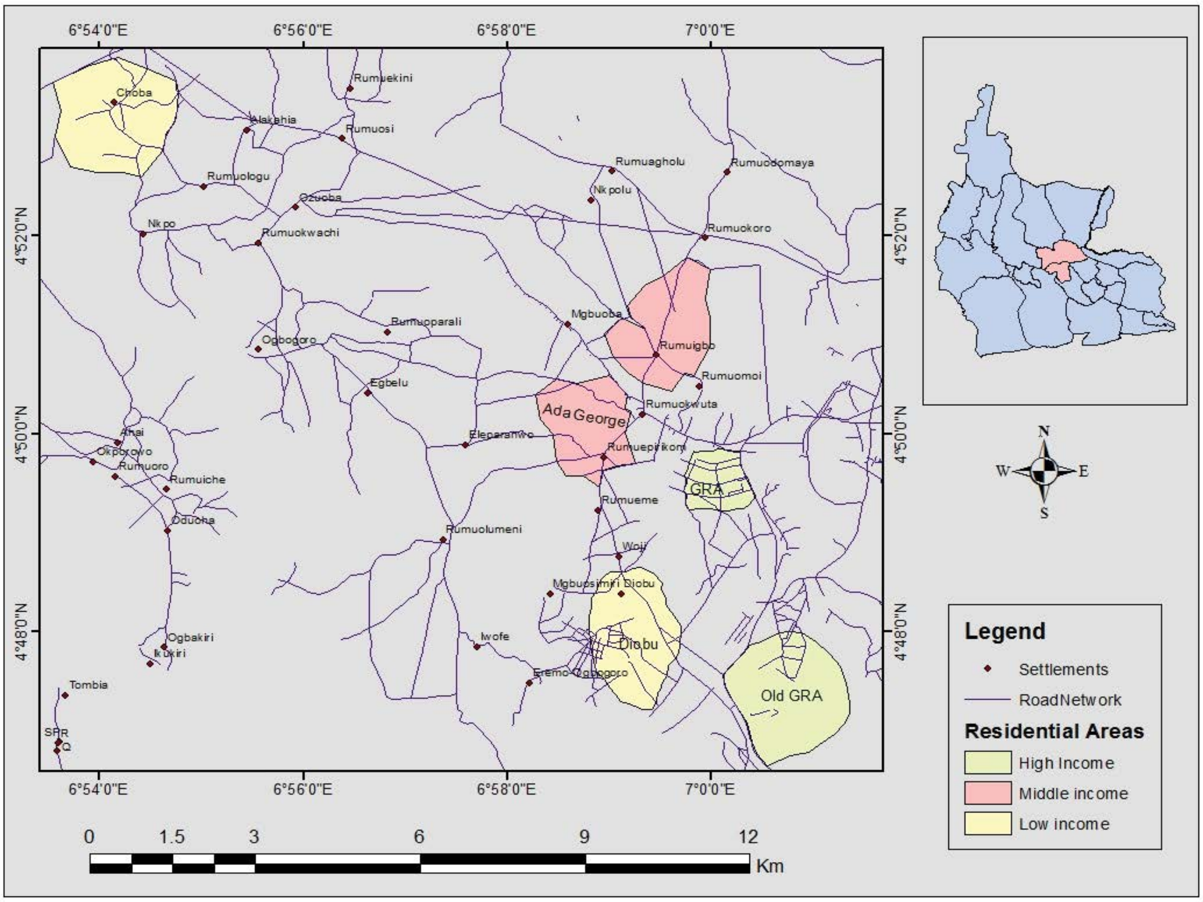

Figure 2: Sampled Locations in the Study Area.

years. The information for the status of sampled respondents in their residential apartments revealed that 44.9% are landlords while the remaining 55.1% of sampled respondents are tenants. The dwelling types of sampled respondents showed that 23.2% of sampled respondents lived in single rooms; 36.0% of sampled respondents live in a room and parlor house settings; 32.0% of sampled respondents lives in a 2 or 3 bedroom apartments; 4.4% of sampled respondents are living in duplexes; while the remaining 4.4% of sampled respondents lives in detached houses.

Indoor Air Quality in High Income Residential Areas

The spatial distributions for gaseous pollutants recorded in high income residential households were displayed on Table 3. The results revealed that during the morning periods the recorded concentration of CO mg/m^3 during cooking period ranged between 0.24 mg/m^3 and 2.06 mg/m^3 with a mean of 1.09 mg/m^3; while during the non-cooking periods the concentration of CO mg/m^3 ranged between 0.13 mg/m^3 and 0.69 mg/m^3 with a mean value of 0.33 mg/m^3. The evening periods recorded slightly varied values, as CO mg/m^3 concentration ranged between 0.25 mg/m^3 and 2.29 mg/m^3 with a mean value of 1.30 mg/m^3 during the cooking hours. The non-cooking periods had range values of 0.13 mg/m^3 and 0.57 mg/m^3 with mean value of 0.26 mg/m^3. For the concentration of CO_2 mg/m^3, it ranged between 459 mg/m^3 and 584 mg/m^3 with mean value of 521 mg/m^3 during the cooking periods in the morning. In the morning period for non-cooking time, the minimum value of CO_2 mg/m^3 was 212 and 432 mg/m^3 for maximum value and a mean value of 340 mg/m^3. The evening periods recorded range values of 460.8 mg/m^3 and 588 mg/m^3 and a mean value of 523 mg/m^3 during the cooking hour and range values of 288 mg/m^3 and 396 mg/m^3 with a mean value of 340.5 mg/m^3 for non-cooking periods.

The mean concentration of SO_2 mg/m^3 during the cooking hour was 0.13 mg/m^3 and with range values of 0.05 mg/m^3 and 0.21 mg/m^3. For non-cooking periods the mean value was 0.08 mg/m^3 of range values of 0.03 mg/m^3 and 0.16 mg/m^3. In the evening, the concentration of SO_2 mg/m^3 ranged from 0.08 mg/m^3 to 0.24 mg/m^3 with a mean value of 0.15 mg/m^3 for cooking periods; while the concentration of SO_2 mg/m^3 during non-cooking periods in the evening ranged from 0.03 mg/m^3 to 0.11 mg/m^3 with a mean value of 0.07 mg/m^3. The concentration of NO mg/m^3 recorded mean value of 0.07 mg/m^3 and minimum and maximum values of 0.03 mg/m^3 and 0.11 mg/m^3 during cooking hour in the morning. However, the concentration was lower in the morning during non-cooking hour and it recorded range values of 0.04 mg/m^3 and 0.09 mg/m^3 and a mean value of 0.06 mg/m^3. In the evening periods the concentration of NO mg/m^3 also varied and the range values recorded was 0.04 mg/m^3 and 0.15 mg/m^3 with a mean value of 0.08 mg/m^3 during cooking hours; while its range values were 0.06 mg/m^3 and 0.013 mg/m^3 during non-cooking hours with mean values of 0.06 mg/m^3. The level of air quality with respect to NO_2 mg/m^3 during morning cooking hours showed minimum and maximum range values of 0.02 mg/m^3 and 0.13 mg/m^3 and a mean value of 0.07 mg/m^3. In the non-cooking period, it ranged between 0.02 mg/m^3 and 0.09 mg/m^3 and a mean value of 0.06 mg/m^3. However, in the evening cooking hours, the range values of NO_2 was 0.04 mg/m^3 and 0.15 mg/m^3 with mean value of 0.08 mg/m^3 while in the non-cooking periods the range values of NO_2 was 0.06 mg/m^3 and 0.08 mg/m^3 with mean values of 0.07 mg/m^3. The particulate matter concentration in indoor air quality also

Table 3: Temporal Pollutant characterization and Cooking Fuel Choices in High Income Residential Areas.

Parameters	Morning						Evening					
	Cooking Periods			Non Cooking Periods			Cooking Periods			Non Cooking Periods		
	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
CO (mg/m^3)	0.24	2.06	1.09±0.824	0.13	0.69	0.33±0.241	0.25	2.29	1.3±0.961	0.13	0.57	0.26±0.19
CO_2 (mg/m^3)	459	584	521±56.97	212	432	340.6±81.9	460	588	523±46.99	288	396	340.5±46.9
SO_2 (mg/m^3)	0.05	0.21	0.13±0.06	0.03	0.16	0.08±0.05	0.08	0.24	0.16±0.06	0.03	0.18	0.12±0.06
NO (mg/m^3)	0.03	0.11	0.08±0.03	0.04	0.086	0.06±0.36	0.05	0.11	0.08±0.02	0.01	0.061	0.03±0.26
NO_2 (mg/m^3)	0.02	0.13	0.07±0.04	0.02	0.094	0.06±0.40	0.04	0.15	0.08±0.05	0.06	0.08	0.07±0.55
$PM_{2.5}$ (ug/m^3)	12.2	16.8	14.6±1.95	8.20	10.8	9.28±1.15	10.8	16.2	13.32±2.01	4.80	8.40	6.44±1.29

Min–Minimum; Max-Maximum; SD-Standard Deviation

showed that $PM_{2.5}$ ranged between 12.2 ug/m^3 and 16.8 ug/m^3 with mean concentration value of 14.6 ug/m^3 during the cooking hours. The non-cooking hour period for the same morning showed mean concentration of 9.3 from ug/m^3 minimum and maximum values of 8.20 and 10.8 ug/m^3. The concentration of $PM_{2.5}$ during evening cooking periods recorded minimum and maximum concentration of 10.8 and 16.2 ug/m^3 with a mean concentration value of 13.3 ug/m^3. However, during non-cooking periods it was 4.80 ug/m^3 and 8.40 ug/m^3 with mean concentration value of 6.4 ug/m^3.

Indoor Air Quality in Middle Income Residential Areas

In the analysis presented for distribution of gaseous pollutants for the indoor air quality of middle income residential apartments was displayed on Table 4. The morning periods recorded that the concentration of CO mg/m^3 during cooking period ranged between 0.82 mg/m^3 and 8.90 mg/m^3 with a mean of 5.7 mg/m^3; while during the non-cooking periods the concentration of CO mg/m^3 ranged between 0.14 mg/m^3 and 0.26 mg/m^3 with a mean value of 0.20 mg/m^3. The evening periods recorded concentration values, as CO mg/m^3 concentration ranged between 0.84 mg/m^3 and 8.94 mg/m^3 with a mean value of 5.6 mg/m^3 during the cooking hours. The non-cooking periods had range values of 0.16 mg/m^3 and 0.27 mg/m^3 with mean value of 0.22 mg/m^3. For the concentration of CO_2 mg/m^3, it ranged between 483.10 mg/m^3 and 626.80 mg/m3 with mean value of 545.80 mg/m^3 during the cooking periods for morning periods. In the morning period for non-cooking time, the minimum value of CO_2 mg/m^3 was 298.80 and 378 mg/m^3 for maximum value and a mean value of 336.24 mg/m^3. The evening periods recorded range values of 505.1 mg/m^3 and 591.10 mg/m^3 and a mean value of 538 mg/m^3 during the cooking hour and range values of 338.4 mg/m^3 and 442.8 mg/m^3 with a mean value of 391.7 mg/m^3 for non-cooking periods.

The mean concentration of SO_2 mg/m^3 during the cooking hour was 1.49 mg/m^3 and with range values of 1.36 mg/m^3 and 1.7 mg/m^3. For non-cooking periods the mean value was 0.58 mg/m^3 of range values of 0.47 mg/m^3 and 0.71 mg/m^3. In the evening, the concentration of SO_2 mg/m^3 ranged from 1.36 mg/m^3 to 1.73 mg/m^3 with a mean value of 1.51 mg/m^3 for cooking periods; while the concentration of SO_2 mg/m^3 during non-cooking periods in the evening ranged from 0.29 mg/m^3 to 0.60 mg/m^3 with a mean value of 0.39 mg/m^3. The concentration of NO mg/m^3 recorded mean value of 0.70 mg/m^3 and minimum and maximum values of 0.63 mg/m^3 and 0.81 mg/m^3 during cooking hour in the morning. However, the concentration was lower in the morning during non-cooking hour and it recorded range values of 0.28 mg/m^3 and 0.52 mg/m^3 and a mean value of 0.41 mg/m^3. In the evening periods the concentration of NO mg/m^3 also varied and the range values recorded was 0.61 mg/m^3 and 0.82 mg/m^3 with a mean value of 0.70 mg/m^3 during cooking hours; while its range values were 0.25 mg/m^3 and 0.38 mg/m^3 during non-cooking hours with mean values of 0.32 mg/m^3. The level of air quality with respect to NO_2 mg/m^3 during morning cooking hours showed minimum and maximum range values of 0.96 mg/m^3 and 1.05 mg/m^3 and a mean value of 1.0 mg/m^3. In the non-cooking period it ranged between 0.23 mg/m^3 and 0.66 mg/m^3 and a mean value of 0.46 mg/m^3. However, in the evening cooking hours, the range values of NO_2 mg/m^3 was 0.98 mg/m^3 and 1.07 mg/m^3 with mean value of 1.02 mg/m^3 while in the non-cooking periods the range values of NO_2 mg/m^3 were 0.34 mg/m^3 and 0.62 mg/m^3 with mean values of 0.52 mg/m^3. The particulate matter concentration in indoor air quality also showed that $PM_{2.5}$ ranged between 14.80 ug/m^3 and 18.4 ug/m^3 with mean concentration value of 17.2 ug/m^3 during the cooking hours. The non-cooking hour period for the same morning showed mean concentration of 5.3 ug/m^3 from minimum and maximum values of 4.20 ug/m^3 and 6.40 ug/m^3. The concentration of $PM_{2.5}$ during evening cooking periods recorded minimum and maximum concentration of 12.60 ug/m^3 and 16.80 ug/m^3 with a mean concentration value of 14.5 ug/m3. However, during non-cooking periods the minimum and maximum values were 4.20 ug/m^3 and 6.60 ug/m^3 respectively with a mean concentration value of 5.4 ug/m^3.

Indoor Air Quality in Low Income Residential Apartments

The indoor air quality of measured in sampled households in low income residential apartments was displayed on Table 5. The distribution showed that the cooking during the morning periods recorded that the concentration of CO mg/m^3 during cooking period ranged between 0.83 mg/m^3 and 8.90 mg/m^3 with a mean of 4.03 mg/m3; while during the non-cooking periods the concentration of CO mg/m3 ranged between 0.16 mg/m^3 and 0.27 mg/m^3 with a mean value of 0.21 mg/m^3. The evening periods measured air quality values, as CO mg/m3 concentration ranged between 0.81 mg/m3 and 9.1 mg/m3 with a mean value of 5.58 mg/m^3 during the cooking hours. The non-cooking periods had range values of 0.14 mg/m^3 and 0.26 mg/m^3 with mean value of 0.20 mg/m^3. For the concentration of CO_2 mg/m^3, it ranged between 630.9 mg/m^3 and 684 mg/m^3 with mean value of 652.8 mg/m^3 during the cooking periods for morning periods. In the morning period for non-cooking time, the minimum value of CO_2 mg/m^3 was 298.8 and 378 mg/m^3 for maximum value and a mean value of 336.2 mg/m^3. The evening periods measured range values of 632.7 mg/m^3 and 681.3 mg/m^3 and a mean value of 647.1 mg/m^3 during the cooking hour and range values of 388.4 mg/m^3 and 460.8 mg/m^3 with a mean value of 397.4 mg/m^3 for non-cooking periods.

Table 4: Temporal Pollutant characterization and Cooking Fuel Choices in Middle Income Residential Areas.

Parameters	Morning Periods						Evening Periods					
	Cooking Periods			Non Cooking Periods			Cooking Periods			Non Cooking Periods		
	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
CO (mg/m^3)	0.82	8.90	5.65±4.39	0.14	0.26	0.20±0.04	0.84	8.94	5.64±4.38	0.16	0.27	0.22±0.05
CO_2 (mg/m^3)	483.1	626.8	545.8±56.3	298.8	378	336.2±32.9	505.1	591.1	538±32.3	338.4	442.8	391.7±48.8
SO_2 (mg/m^3)	1.36	1.70	1.5±0.14	0.47	0.71	0.58±0.10	1.36	1.73	1.50±0.17	0.29	0.60	0.40±0.13
NO (mg/m^3)	0.63	0.81	0.7±0.075	0.28	0.52	0.41±0.12	0.61	0.82	0.70±0.08	0.25	0.38	0.32±0.05
NO_2 (mg/m^3)	0.96	1.05	1.0±0.04	0.23	0.66	0.47±0.18	0.98	1.07	1.02±0.04	0.34	0.62	0.52±0.11
$PM_{2.5}$ (ug/m^3)	14.8	18.4	17.2±1.56	4.20	6.4	5.28±0.97	12.6	16.8	14.6±1.92	4.20	6.60	5.4±1.07

Min–Minimum; Max-Maximum; SD-Standard Deviation

Table 5: Temporal Pollutant characterization and Cooking Fuel Choices in Low Income Residential Areas.

Parameters	Morning Periods						Evening Periods					
	Cooking Periods			Non-Cooking Periods			Cooking Periods			Non-Cooking Periods		
	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD
CO (mg/m^3)	0.83	8.90	4.03±4.34	0.16	0.27	0.22±0.04	0.81	9.1	5.58±0.12	0.14	0.26	0.20±0.05
CO_2 (mg/m^3)	630.9	684	652.8±25.8	298.8	378	336.2±32.9	632.7	681.3	647.1±19.59	338.4	460.8	397.4±55.3
SO_2 (mg/m^3)	1.34	1.74	1.48±0.15	0.29	1.36	0.55±0.46	1.36	1.62	1.48±0.12	0.47	0.66	0.58±0.34
NO (mg/m^3)	0.54	0.81	0.70±0.07	0.24	0.38	0.32±0.61	0.65	0.82	0.72±0.07	0.28	0.52	0.41±0.12
NO_2 (mg/m^3)	0.96	1.05	1.01±0.04	0.34	0.62	0.52±0.11	0.95	1.05	1.00±0.04	0.23	0.66	0.47±0.18
$PM_{2.5}$ (ug/m^3)	16.80	20.2	18.6±1.22	6.20	8.20	6.92±0.76	14.80	18.20	16.4±1.65	6.20	6.80	6.44±0.26

Min–Minimum; Max-Maximum; SD-Standard Deviation

The mean concentration of SO_2 mg/m^3 during the cooking hour was 1.49 mg/m^3 with range values of 1.34 mg/m^3 and 1.70 mg/m^3. For non-cooking periods the mean value was 0.55 mg/m^3 of range values of 0.29 mg/m^3 and 1.36 mg/m^3. In the evening, the concentration of SO_2 mg/m^3 ranged from 1.36 mg/m^3 to 1.62 mg/m^3 with a mean value of 1.48 mg/m^3 for cooking periods; while the concentration of SO_2 mg/m^3 during non-cooking periods in the evening ranged from 0.47 mg/m^3 to 0.66 mg/m^3 with a mean value of 0.58 mg/m^3. The concentration of NO mg/m^3 recorded mean value of 0.70 mg/m^3 with minimum and maximum values of 0.64 mg/m^3 and 0.81 mg/m^3 respectively during cooking hour in the morning. However, the concentration was lower in the morning during non-cooking hour and it recorded range values of 0.24 mg/m^3 and 0.38 mg/m^3 and a mean value of 0.32 mg/m^3. In the evening periods the concentration of NO mg/m^3 also varied and the range values recorded was 0.65 mg/m^3 and 0.82 mg/m^3 with a mean value of 0.72 mg/m^3 during cooking hours; while its range values were 0.28 mg/m^3 and 0.52 mg/m^3 during non-cooking hours with mean values of 0.41 mg/m^3. The level of air quality with respect to NO_2 mg/m^3 during morning cooking hours showed minimum and maximum range values of 0.96 mg/m^3 and 1.05 mg/m^3 and a mean value of 1.01 mg/m^3. In the non-cooking period, it ranged between 0.34 mg/m^3 and 0.62 mg/m^3 and a mean value of 0.52 mg/m^3. However, in the evening cooking hours, the range values of NO_2 mg/m^3 was 0.96 mg/m^3 and 1.05 mg/m^3 with mean value of 1.0 mg/m^3 while in the non-cooking periods the range values of NO_2 mg/m^3 were 0.23 mg/m^3 and 0.66 mg/m^3 with mean values of 0.47 mg/m^3. The particulate matter concentration for indoor air quality also showed that $PM_{2.5}$ ranged between 16.8 ug/m^3 and 20.2 ug/m^3 with mean concentration value of 18.6 ug/m^3 during the cooking hours. The non-cooking hour period for the same morning showed mean concentration of 6.92 ug/m^3 from minimum and maximum values of 6.20 ug/m^3 and 8.20 ug/m^3. The concentration of $PM_{2.5}$ during evening cooking periods measured minimum and maximum concentration of 14.8 ug/m^3 and 18.2 ug/m^3 with a mean concentration value of 16.4 ug/m^3. However, during non-cooking periods it was 6.20 ug/m^3 and 6.80 ug/m^3 with mean concentration value of 6.44 ug/m^3.

Difference in Indoor Air Quality between Cooking Periods and Non-Cooking Periods In Sampled Residential Areas

High Income Residential Area

The analysis for the difference in CO (mg/m^3) between morning periods ($t=2.916$; $p<0.05$) was significant while the there was no significant difference in the concentration of CO (mg/m^3) at evening periods ($t=2.612$; $p<0.05$). For the concentration of CO_2 (mg/m^3) it was significant in the morning ($t=7.584$; $p<0.05$) and evening ($t=5.790$; $p<0.05$) between cooking and non-cooking periods. For the concentration of SO_2 (mg/m3) it was significant in the morning ($t=9.000$; $p<0.05$) and evening ($t=6.532$; $p<0.05$) periods between cooking and non-cooking periods. The concentration of NO (mg/m^3) was not significant in the morning periods ($t=-0.959$; $p<0.05$) between cooking and non-cooking periods and also not significant in the evening ($t=-0.555$; $p<0.05$) between cooking and non-cooking periods. The difference in the concentration of NO_2 (mg/m3) for both morning and evening periods were not significant ($t=-0.916$; $p<0.05$) and ($t=-1.113$; $p<0.05$) between their cooking periods and non-cooking periods. However, $PM_{2.5}$ (mg/m3) showed that the difference was significant for morning ($t=6.881$; $p<0.05$) and evening ($t=6.020$; $p<0.05$) between cooking and non-cooking periods.

Middle Income Residential Area

The analysis for the difference in CO (mg/m^3) between morning periods ($t=2.782$; $p<0.05$) was significant while it was also significantly different in the concentration of CO (mg/m^3) at evening periods ($t=2.778$; $p<0.05$). For the concentration of CO_2 (mg/m^3) it was significant in the morning ($t=4.550$; $p<0.05$) and evening ($t=4.620$; $p<0.05$) between cooking and non-cooking periods. For the concentration of SO_2 (mg/m^3) it was significant in the morning ($t=9.940$; $p<0.05$) but not significant in the evening ($t=1.042$; $p<0.05$) periods between cooking and non-cooking periods. The concentration of NO (mg/m3) were significant in the morning periods ($t=-10.052$; $p<0.05$) between cooking and non-cooking periods and also significant in the evening ($t=-7.466$; $p<0.05$) between cooking and non-cooking periods. The difference in the concentration of NO_2 (mg/m^3) for both morning and evening periods were significant ($t=-7.049$; $p<0.05$) ($t=-8.723$; $p<0.05$) between their cooking periods and non-cooking periods. The result of the analysis also showed that $PM_{2.5}$ (µg/m^3) were also significantly different in the morning hours ($t=13.235$; $p<0.05$) and evening hours ($t=17.454$; $p<0.05$) between cooking and non-cooking periods.

Low Income Residential Area

The indoor air quality between cooking periods and non-cooking periods was displayed on Table 7. It was revealed that the comparison in CO (mg/m^3) in the morning ($t=1.984$; $p<0.05$) and evening periods ($t=1.292$; $p<0.05$) between cooking periods and non-cooking periods was not significant. For CO_2 (mg/m^3) it was significant in the morning (($t=52.952$; $p<0.05$) and evening ($t=13.363$; $p<0.05$) between cooking and non-cooking periods. For SO_2 (mg/m3) the comparison was significant in the morning ($t=6.235$; $p<0.05$) but not significant in the evening ($t=0.920$; $p<0.05$) between cooking and non-cooking periods. The comparison of NO (mg/m^3) was significant in the morning periods ($t=-0.7.618$; $p<0.05$) between cooking and non-cooking periods; and also, significant in the evening ($t=10.058$; $p<0.05$) between cooking and non-cooking periods. The comparison between NO_2 (mg/m3) for both morning and evening periods were significant (($t=8.253$; $p<0.05$) ($t=7.072$; $p<0.05$) between their cooking periods and non-cooking periods. Similarly, $PM_{2.5}$ (mg/m3) also showed that the comparison was significant for morning ($t=22.418$; $p<0.05$) and evening ($t=12.021$; $p<0.05$) between cooking and non-cooking periods

Implications of the result and the risk of the incidence of Sick Building Syndrome (SBS)

The term "sick building syndrome" (SBS) is used to describe situations in which building occupants experience acute health

Table 6: Indoor Air Quality Comparison between Cooking Periods and Non-Cooking Periods (High Income Residential Area)

Parameters	Mean	Std. Deviation	t-cal	Significant at p<0.05
CO (mg/m^3) Morning Periods	0.67300	0.54672	*2.916	0.044
CO (mg/m^3) Evening Periods	0.91300	0.77587	2.612	0.058
CO_2 (mg/m^3) Morning Periods	272.30010	80.17750	*7.584	0.002
CO_2 (mg/m^3) Evening Periods	281.01000	111.20112	*5.790	0.004
SO_2 (mg/m^3) Morning Periods	0.01800	0.00447	*9.000	0.001
SO_2 (mg/m^3) Evening Periods	0.01600	0.00548	*6.532	0.003
NO (mg/m^3) Morning Periods	-0.11800	0.27517	-0.959	0.392
NO (mg/m^3) Evening Periods	-0.05000	0.20137	-0.555	0.608
NO_2 (mg/m^3) Morning Periods	-0.08000	0.19570	-0.916	0.414
NO_2 (mg/m^3) Evening Periods	-0.13400	0.27181	-1.113	0.362
$PM_{2.5}$ (ug/m^3) Morning Periods	4.700020	1.61679	*6.881	0.001
$PM_{2.5}$ (ug/m^3) Evening Periods	3.61010	1.34164	*6.020	0.003

N=30; *Correlation Significant

Table 7: Indoor Air Quality Comparison between Cooking Periods and Non-Cooking Periods (Middle Income Residential Areas).

Parameters	Mean	Std. Deviation	t-cal	Significant at p<0.05
CO (mg/m^3) Morning Periods	4.76600	3.83049	*2.782	0.050
CO (mg/m^3) Evening Periods	4.73800	3.81420	*2.778	0.050
CO_2 (mg/m^3) Morning Periods	290.11000	142.56095	*4.550	0.010
CO_2 (mg/m^3) Evening Periods	267.91600	129.67390	*4.620	0.010
SO_2 (mg/m^3) Morning Periods	0.35200	0.07918	*9.940	0.001
SO_2 (mg/m^3) Evening Periods	10.72200	23.01362	1.042	0.356
NO (mg/m^3) Morning Periods	0.24000	0.05339	*10.052	0.001
NO (mg/m^3) Evening Periods	0.31800	0.09524	*7.466	0.002
NO_2 (mg/m^3) Morning Periods	0.28600	0.09072	*7.049	0.002
NO_2 (mg/m^3) Evening Periods	0.26800	0.06870	*8.723	0.001
$PM_{2.5}$ (ug/m^3) Morning Periods	28.20000	4.76445	*13.235	0.000
$PM_{2.5}$ (ug/m^3) Evening Periods	35.60000	4.56070	*17.454	0.000

N=30; *Correlation Significant

Table 8: Indoor Air Quality Comparison between Cooking Periods and Non-Cooking Periods (Low Income Residential Areas).

Parameters	Mean	Std. Deviation	T-cal	Significant at p<0.05
CO (mg/m^3) Morning Periods	3.82200	4.30765	1.984	0.118
CO (mg/m^3) Evening Periods	20.31800	35.17477	1.292	0.266
CO_2 (mg/m^3) Morning Periods	316.62000	13.37038	*52.952	0.000
CO_2 (mg/m^3) Evening Periods	249.66000	41.77784	*13.363	0.000
SO_2 (mg/m^3) Morning Periods	0.93800	0.33641	*6.235	0.003
SO_2 (mg/m^3) Evening Periods	-9.98400	24.25964	0.920	0.410
NO (mg/m^3) Morning Periods	0.38800	0.11389	*7.618	0.002
NO (mg/m^3) Evening Periods	0.31000	0.06892	*10.058	0.001
NO_2 (mg/m^3) Morning Periods	0.49200	0.13330	*8.253	0.001
NO_2 (mg/m^3) Evening Periods	0.52800	0.16694	*7.072	0.002
$PM_{2.5}$ (ug/m^3) Morning Periods	11.64000	1.16103	*22.418	0.000
$PM_{2.5}$ (ug/m^3) Evening Periods	10.00000	1.86011	*12.021	0.000

N=30; *Correlation Significant

and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. It is also described as a condition in which people in a building suffer from symptoms of illness or become infected with chronic disease from the building in which they work or reside [26-30]. Certain symptoms tend to increase in severity with the time people spend in the building; often improving over time or even disappearing when people are away from the building. Exposure to toxic black mold might be a problem [31]. The main identifying observation is an increased incidence of complaints of symptoms such as headache, eye, nose, and throat irritation, fatigue, and dizziness and nausea. The World Health Organization has revealed that SO_2 ranging from 0.05-0.6 mg/m^3 (24 hours period) is implicated for health issues like respiratory problems affecting the lungs. $PM_{2.5}$ (0-30 µg/m^3) is implicated for causing mucus and irritants as a result of dust. In the low income, residential areas which showed that $PM_{2.5}$ (µg/m^3) concentration was significant for morning (t=22.418; p<0.05) and evening (t=12.021; p<0.05) between cooking and non-cooking periods has a high risk of experiencing sick building syndrome. For the middle income, residential areas, the concentration of SO_2 (mg/m^3) was significant in the morning (t=9.940; p<0.05) but not significant in the evening (t=1.042; p<0.05). This is suggestive of the fact that the middle income residential areas are also at high risk of sick building syndrome build up especially in the morning hours.

Summary

The cooking fuel choices differs among sampled respondents with reference to their income level, familiarity, dwelling place type, level of effectiveness and other reasons like lack of electricity. Cooking fuel choices among sampled households have direct impact on the level of air pollution. The findings of the study revealed that residential types and dwelling place directly influence cooking fuel types among sampled households in the study area. Findings corroborates with that determines patterns of cooking among rural and urban households in southwest Nigeria. The study discovers that pattern of cooking fuel choices was significantly influenced by household dwelling types: most households in rural areas choice of cooking fuels are firewood, charcoal or saw dust and this have several implications on their health.

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