Comparative Analysis of Particulate Matter (PM $_{2.5}$ and PM$_{10}$) Pollutant levels between Low-Income and High-Income Residential Areas in Yola Metropolis, Adamawa State, Nigeria.

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Abstract

Many households using solid fuels burn them in open fires or simple stoves that release most of the smoke into the home. The effect this has on them is the release of pollutants into their houses which is detrimental to health. Particulate Matter$_{2.5}$ and Particulate Matter$_{10}$ were collected in four buildings each at Low-Income residential area and High-Income residential area in Yola metropolis. The low-income residential area was Zango at Limawa ward while the high-income residential was army barracks road. The data collected in February 2024 were done when cooking was happening and when cooking was not happening, and analysis showed higher pollutant concentration in low-income residential buildings. This was primarily due to the type of cooking fuel (coal) used at the low-income residential buildings while at high-income residential buildings, the usage of cooking gas was observed. Considering PM$_{2.5}$, The mean value at Gas House (during cooking time) which was at 7.2 ug/M^3 was lesser than Coal house (when not cooking) which was 7.6ug/M^3. This clearly shows there is higher concentration of PM$_{2.5}$ at coal fuelled building than Gas fuelled building. Moreover, the maximum concentration value of PM$_{2.5}$ was 25ug/M^3 at Coal fuelled building while it was 9ug/M^3 at Gas fuelled building which is even lesser than the value of 11ug/M^3 measured when cooking was not ongoing at coal fuelled building. PM$_{10}$ also showed the same pattern where the mean value was as high as 42.03ug/M^3 at Coal fuelled building while cooking but 14.8ug/M^3 at Gas fuelled building while cooking which was just 35% of that of coal fuelled building while cooking. The maximum concentration of PM$_{10}$ at the Coal fuelled building was 59ug/M^3 during the cooking period while 20ug/M^3 with Gas fuelled also during the cooking period. This clearly shows that there is higher PM concentration at the low-income residential buildings, and this was due to the fuel used in cooking. Hence, the study recommends that there is a need to educate the residents of low-income communities on the health implication of the type of fuel they use; the government should also help provide cleaner fuel for the people of the community. This will go a long way to improve the air quality of their environment.

Keywords: Cooking fuels, Environment Indoor Pollutants concentration, High-Income Residential Buildings & Low-Income Residential Buildings

Introduction

Many households using solid fuels burn them in open fires or simple stoves that release most of the smoke into the home. The resulting indoor air pollution (IAP) is a major threat to health, particularly for women and young children, who may spend many hours close to the fire (Bruce, 2023). Saksena, Thompson and Smith (2004) have recently compiled data on several of the main pollutants associated with various household fuels from studies of homes in a wide range of developing countries. Consideration of PM_{10}, averaged over 24-hour periods, was in the range of 300 to 3,000 (or more) micrograms per cubic meter. Particulate Matter refers to small particles suspended in the air, including dust, pollen, pet dander and smoke (EPA, 2019). Indoor PM sources can be cooking, cleaning, smoking, candles, fireplaces and outdoor air infiltration (Chen *et al.*, 2020). According to Chen *et al* (2020), average indoor $PM_{2.5}$ levels in developing countries is between 5-15ugm^3 while Wallace *et al* (2015) confirmed $PM_{2.5}$ levels to be up to 100 ugm^3 during cooking or smoking. Yola Metropolis has recorded an increasing population figure over the years. In terms of population, according to the 2006 national census, Yola had a population of 196,197 (National Population Commission [NPC], 2006) and as at 2018, Yola had a projected population of 282,785 with population density of 2,528 per km^2 and has witnessed some significant growth in recent times with an increasing population and urban development. However, recent estimates (2021) put the population over 400,000 (Citypopulation.de, 2021).

The increasing population of Yola Metropolis indicates an increase in higher number of residents per house among other things. Hence, considering the effect of the increasing number of people in Yola Metropolis, the probability of greater air quality pollution is higher which also will have negative health effect on greater number of people since the population has increased. It is therefore important to investigate the indoor pollutant concentration status to come up with ways to curb indoor pollution growth in the metropolis. The indoor air quality has become one of the most important topics of air pollution study since people spend more than 85% of their time in various indoor environments such as homes, schools, offices and restaurants (Diffey, 2011). Particulate matter has recently become recognized as a concern in indoor air quality since it is small enough to be respired by people (Mohamed *et al*., 2012). It has been observed that the use of biomass fuels as an energy source is a major cause of indoor air pollution in Pakistan (Colbeck *et al.*, 2008). Data was collected during cooking time and at the time cooking was not happening at both sampled locations. This was to reflect the variation in pollutant concentration at the two different periods as well as to examine the variation among residential buildings in Yola metropolis.

Literature Review

Since the industrial revolution and widespread urbanization, air pollution has risen to the top of the environmental concerns list in both developed and developing nations (Anwar *et al.,* 2021; Wei *et al.,* 2021; Zhang *et al.,* 2022). The key source of pollutants that contribute to the degradation of air quality are various human activities, such as fossil fuel combustion to drive production processes, motor vehicles, and industrial plants (Pachon *et al,* 2018; Rajput *et al.,* 2021; Munsif *et al.,* 2021; Molina *et al.,* 2021). This implies that many urban inhabitants are continually exposed to an unhealthy amount of air pollution (Chen *et al.*, 2020). It has been recently found out that the traffic (25%), combustion and agriculture (22%), domestic fuel burning (20%), natural dust and salt (18%), and industrial activities (15%) are the main sources of particulate matter contributing to cities air pollution all over the world with domestic burning being responsible for 20% (EU Science Hub, 2016). A study by Balakrishnan *et al* (2019) measures $PM_{2.5}$ levels in low-income households in India and found high levels of exposure during cooking. Also, Clark *et al* (2013) found high levels of $PM_{2.5}$ and CO in low-income homes in Guatemala due to indoor cooking. The households where biomass fuels were used for cooking in Kenya also recorded high concentration of $PM_{2.5}$ (Riojas-Rodriguez *et al.,* 2016). A comparative analysis will be done between high and low-income residential buildings in Yola metropolis to check their level of particulate matter concentration variations.

Description of Study Area

Yola metropolis is the capital of Adamawa State, Nigeria and it covers Yola North (Jimeta) and Yola South local government areas. It is situated on the bank of the Benue River. Yola Metropolis, being the capital city is also the administrative center of Adamawa State and is an economic hub for the region. It is located between latitude 9^0 13' – 9^0 19'N and longitude 12^0 19' – 12^0 28'E and has a population of 282,785 as at 2018 with population density of 2,528 per km^2. As a metropolis, Yola has witnessed some significant growth in recent times with an increasing population and urban development. In terms of population, according to the 2006 national census, Yola had a population of 196,197 (National Population Commission [NPC], 2006). However, recent estimates (2021) put the population over 400,000 (Citypopulation.de, 2021). The increasing population of Yola Metropolis indicates an increase in commercial activities, automobile movements, Increase in industrial activities, more waste and higher number of residents per house among other things. It should be noted that this will have some influence in gas emission in Yola if not well managed.

Methodology

Data Types and Sources

To capture the indoor pollutants concentration, two major locations were considered in Yola Metropolis between the low-income residential area (Zango Limawa Ward) and high-income residential area (Army Barracks Road) in Yola Metropolis. The selection was based on access granted into the building premises. Four buildings were purposively sampled per location with seven different readings taken per building. However, it was discovered that the sampled buildings at Zango ward used coal for their cooking while the sampled buildings at Barracks Road use gas cookers for their cooking. Hence, each building was tested when residents were cooking and when they were not cooking to assess the variability in pollutants concentration. For this study, buildings in Zango ward were categorized as coal cooking houses while the houses at barracks road were categorized as gas cooking houses. Moreover, due to the limited availability of data collection tools, residential data were taken during harmattan season only and this was done in February 2024 with measurements majorly taken for $PM_{2.5}$ and PM_{10}.

Data Collection Instruments

Hinaway CW-HAT200 Handheld Portable Particulate Counter $PM_{2.5}$ and PM_{10} unit Microgram Cubic Meter air quality instrument was used to collect particulate matter data (2.5 and 10 diameter).

Data Analysis

The central tendencies were measured between low-income buildings and high-income buildings by comparing the average pollutant concentration values of the dataset between both groups and by comparing the maximum and the minimum values between both groups. This obviously helped to summarize the large datasets, identify patterns and of both samples and compare datasets to identify the more polluted buildings between both residential building types.

Result of findings

In Table 1 below where the highest mean value of $PM_{2.5}$ was 19.3ug/M^3 for coal house during cooking and the least was 3.1ug/M^3 at Gas house (non-cooking). The mean value at Gas House (Cooking) which was at 7.2 ug/M^3 was even lesser than Coal house (non-cooking) which was 7.6ug/M^3. This clearly shows there is a significantly higher concentration of $PM_{2.5}$ at coal fuelled building than Gas fuelled building. Moreover, the maximum concentration value of $PM_{2.5}$ was 25ug/M^3 at Coal fuelled building while it was 9ug/M^3 at Gas fuelled building which is even lesser than the value of 11ug/M^3 measured when cooking was not ongoing at coal fuelled building. The same pattern was observed on PM_{10} in Table 2 below, where the mean value was as high as 42.03ug/M^3 at Coal fuelled building while cooking but 14.8ug/M^3 at Gas fuelled building while cooking which is just 35% of that of coal fuelled building while cooking. Also, maximum concentration of PM_{10} at the Coal fuelled building was 59ug/M^3 during the cooking period while 20ug/M^3 with Gas fuelled also during the cooking period.

i. Coal Fuelled House was represented by CFH
ii. Gas Fuelled House was represented by GFH

Table 1: Indoor Pollutants Concentration of $PM_{2.5}$ in the sampled Residential Building Types

Building Types	**N**	**Mean**	**SD**	**Min**	**Max**
CFH (Cooking)	28	19.3	2.7	10	25
CFH (non-cooking)	28	7.6	4.1	2	11
GFH (Cooking)	28	7.2	1.2	4	9
GFH (non-cooking)	28	3.1	0.9	2	5

Table 2: Indoor Pollutants Concentration of PM_{10} in the sampled Residential Building Types

Building Types	**N**	**Mean**	**SD**	**Min**	**Max**
CFH (Cooking)	28	42.03	5.4	32	59
CFH (non-cooking)	28	14.6	6.2	4	28
GFH (Cooking)	28	14.8	2.5	8	20
GFH (non-cooking)	28	4.7	1.1	3	7

Discussion

In areas where solid fuels are the primary source of household cooking, particulate emissions from household cooking with solid fuels contribute significantly to ambient (outdoor) air pollution (Smith, 2006). The ambient exposure assessment prepared for Global Burden of Disease (GDB) 2010 shows substantial exposures occurring in rural areas (Brauer et al. 2012). The research carried out by Vivian and Mynepalli (2017) at Ibadan, where 37.7% of the respondents used firewood, 17.7% used coal, 33.1% used kerosene and 11.5% used gas, showed that the least PM concentration was from gas users while highest PM concentration came from those that used firewood followed by those that used coal. This is apparently due to the high emission observed with the coal cooking which generated large amounts of ash and soot.

While collecting data for this study, a lot of dark spots from coal cooking were already observed on the walls of Coal Fuelled Houses unlike the Gas Fuelled Houses which was with a reduced environmental footprint, and which contributes to a cleaner and healthier environment. Moreover, a study done in Ibadan by Vivian *et al* (2017) where 186 households were monitored for PM_{10} with Air monitoring carried out both in dry (December through January) and rainy (May through July) season and monitoring done in the morning between 4am to 9am and in the evening between 6pm and 9pm. The study chose these periods considering the cooking practices observed in the households. Those that used firewood had a mean value of 1,640ug/M^3, charcoal was 1,159 ug/M^3, Kerosene was 909.3 ug/M^3 and gas was 300.9 ug/M^3. The ambient particulate matter value was 250 ug/M^3. This clearly showed that gas fuelled residential buildings was the least polluted of all the sampled buildings. The findings of the study further showed that charcoal users had lowest lung function value while gas users had the highest lung function value. Combustion of cooking fuels has been identified as one of the major factors that contribute to indoor air pollution (Li *et al,* 2015). According to WHO global estimates, 4.3 million people died prematurely in 2012 due to indoor air pollution (Xiao *et al,* 2015). The above references corroborate the findings in this study that the buildings where gas is used for cooking have cleaner air than the buildings where coals are used.

Conclusion

Particulate Matter concentration analysis that was conducted among residential buildings, precisely the coal fuelled houses, and the Gas fuelled houses, showed that the Coal Fuel Houses (CFH) had $PM_{2.5}$ as high as 19.3ug/M^3 with a low value of 7.2ug/M^3 in Gas Fuelled Houses (GFH) while cooking. This clearly shows that the concentration $PM_{2.5}$ at GFH was only 37% of the concentration at CFH. Moreover, PM_{10} was assessed with the value at CFH yielding 42.032ug/M^3 and GFH yielding 14.82ug/M^3. GFH here also represents 35% of the concentration at CFH. We will have a better indoor air quality if the use of coal fuel is discouraged by educating people on the health benefits of using cleaner fuels for their cooking.

Recommendations

The following recommendations in line with findings of the study are made;

i. **Conduct of Public Awareness Campaigns:** The government should organize public awareness campaigns to educate citizens about the benefits of gas fuel over coal fuel for cooking.
ii. **Provision of incentives:** Offer incentives, such as subsidies or tax breaks, to encourage residents to switch from coal fuel to gas fuel for cooking.
iii. **Installation of Gas Infrastructure:** Invest in installing gas pipelines and infrastructure in residential areas to make gas fuel more accessible.
iv. **Implementation of Policies:** Develop and implement policies that encourage the use of gas fuel over coal fuel for cooking in residential buildings.

v. **Provision of Financial Assistance:** Offer financial assistance to low-income households to help them switch from coal fuel to gas fuel.
vi. **Research and Development:** Continuously fund research and development to improve gas fuel technology and make it more accessible and affordable

Benefits of implementing the recommendations

i. Reduced greenhouse gas emissions
ii. Improved indoor air quality
iii. Enhanced energy efficiency
iv. Increased safety
v. Economic benefits (e.g job creation, reduced healthcare costs)

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