

PM₁₀ Emissions from Cooking Fuels in Nigerian Households and Their Impact on Women and Children

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Abstract

A study was carried out on the type of fuels being used by households in Ibadan, a highly populated city in south-west Nigeria. Ekotedo, Agbeni, Bodija and Agbowo communities were selected through stratified random sampling, keeping in view of their socioeconomic background and population density. The study monitored 186 households for the type of fuel used for cooking and measured PM₁₀ and the lung function of the respondents. The study population involved 130 women and 130 children. In addition, a community nurse carried out a physical and clinical examination of both the mothers and the children for respiratory and non-respiratory symptoms. The results showed that 37.7% used firewood, 33.1% used kerosene, 17.7% used charcoal and 11.5% used liquefied natural gas. Firewood use followed by charcoal emitted high PM₁₀ at a level of 1640 µg/m³ and 1159 µg/m³, respectively. Charcoal users showed the lowest lung function values and gas users the highest value. A majority (78.5%) of the respondents complained of having cough during and after cooking. Some of them reported breathing problems, eyes and skin irritations. It is recommended that the communities be advised to switch over from the use of biomass fuels to natural gas so as to sustained the natural resources and again, reduced the health impacts of these cooking fuels on the population.

Keywords

Cooking Fuels, PM₁₀, Smoke, Lung Function, Women, Children, Nigeria

1. Introduction

Combustion of cooking fuels has been identified as one of the most important factors that contribute to indoor air pollution [1]. Approximately half of the world's population and up to 90% rural households and urban poor in developing countries rely solely on primarily unprocessed biomass fuels (wood, dung, crop residues) as sources of domestic cooking and heating [2] [3]. In many of the households, fuels are burned inefficiently on open fires on poorly functioning stoves in rooms poorly ventilated or without a chimney [4]. As a result, a large number of women who do the cooking, as well as young children and infants in the vicinity of the cooking area are exposed to high levels of pollutants. Exposure to cooking fuels smoke, ascertained by type of fuel used for cooking has been reported in developing countries to have an impact on the health of the population [5] [6] [7] [8].

According to the World Health Organization (WHO) global estimates, 4.3 million people died prematurely in 2012 due to indoor air pollution from traditional stoves, fueled by coal, wood, dung or crop waste. Outdoor air pollution has been linked to 3.7 million deaths [9]. A study in Ibadan [10], reported an indoor air quality of daycare centres, with mean PM_{10} readings of $73.4 \pm 54.4 \mu\text{g}/\text{m}^3$ and $296.3 \pm 61.6 \mu\text{g}/\text{m}^3$ for the wet and dry season, respectively. These exceeded the guideline limit of a $50 \mu\text{g}/\text{m}^3$. Another study in Korea reported mean CO_2 levels from selected Korean restaurants where gas stoves were used for food cooking, with an exceeded range of 40% to 60% compared to places where other fuels were used. Average levels of PM_{10} and $PM_{2.5}$ at the Korean barbecue style restaurant has been showed to be as high as 1442 and 1167 $\mu\text{g}/\text{m}^3$, respectively [11]. The profile of indoor air quality (IAQ), using dried yak dung as biofuel at eight residential homes in Tibet with altitudes of 3212 m to 4788 m showed that combustion of solid biomass fuel in a cast-iron stove was the major source of indoor particulate pollution [12]. It was also shown in the same study that, a mean concentration of PM loadings obtained for firewood, kerosene and cooking gas environments was 50.0, 22.2 and 22.7 g/m^3 for $PM_{2.5}$ and 20.1, 24.3 and 9.0 g/m^3 for $PM_{2.5-10}$ respectively. An assessment of a residential indoor and outdoor air in Ibadan indicated that, a mean elemental concentration of potassium (K) values in fine fraction was twice the values in the coarse fractions for kerosene users and four times for firewood users. The high concentrations of Potassium in both fractions indicated that firewood was predominantly present in the study area [13].

The deteriorating effects of various pollutants on human, animal, and plant life and on climate have been well recognized. Increasing degradation of air quality and the environment, in general, is presently the concern for one and all. It is recognized that particulate matter emitted from both solid and liquids from natural and man-made sources is the cause. Particulate matter has complex and varied mixtures of different particle sizes and chemical components. Larger particles of particulate matter come from windblown and industrial dust, volcanic

particles and plant pollen. Finer particles are released from combustion of different fuel sources and conversion of gas particles [14] [15].

It has been shown that particulate matter from biomass fuel (wood, charcoal, and crop residues) combustion has serious effects on women and children and has been implicated as a causal agent of respiratory and eye diseases, including cataract, blindness and conjunctivitis [16] [17]. Epidemiological evidence suggests that short-term exposure leads to changes in respiratory function and excessive exposure leads to mortality [18] [19] [20] [21]. Particulate air pollution has also been found to be associated with day-to-day changes in plasma viscosity [22]. This paper aimed at assessing and describing the concentration of particulate matter (10 μm) generated from different fuels firewood, kerosene, charcoal and gas used by communities in Ibadan and their effects on the health of mothers and their under 5 years old children who were either in the vicinity of the kitchen or lapped by their mothers during cooking.

2. Materials and Methods

2.1. Study Area

The study was located in Ibadan, capital of Oyo State in the tropical rain forest zone. It is one of the largest indigenous cities in Nigeria and with an estimated population of over 3.4 million distributed over an area of 160.45 km² surrounded by seven hills. It is located in the South Western part of Nigeria, on longitude 3°5' of Greenwich meridian and Latitude 7°25' North of the equator at a distance of some 145 km from Lagos, the commercial hub and the former capital of the country. This Metropolitan city has 11 Local Government Administrative areas (LGAs) of which five are within the metropolis and six in peripheral areas. It is divided into 46 geographical and political wards. There are over 1000 recognized communities in the city. The climate is moderate with two distinct seasons, rainy from April through October and dry season from November through March.

2.2. Study Design

The major communities of the five LGAs of Ibadan metropolis were stratified into 3 strata, based on their population density and socio-economic status into high, medium and low-density areas. Stratified random sampling was employed to select 4 communities from the different strata, based on their fuel type used. Thus Ekotedo and Agbeni were selected to represent high-density area, Agbowo to represent the medium density area and Old Bodija to represent the low-density area. Selection of households started from the first street at the entrance of each community to the last street of that community. The number of households selected in each community was in equal proportion to the population of that community. Preferable households were those who were willing to participate and had children between 0 - 5 years of age. The eligible population for the purpose of the study comprised every mother aged 16 years and above and children less than 5 years of age, who were permanent residents in those

areas under study. All together 186 households were monitored for PM₁₀, 130 women and 130 children (who were with them in the cooking area or kitchen) were interviewed and monitored for air pollution effects. A structured questionnaire survey was used to gather information on the fuel types used by the respondents. The study protocols were explained to all the women and their consent obtained. Husbands to mothers that were between 16 to 17 years of age gave their consents. The children (<5 years) were divided into groups depending upon the type of fuel used for cooking in the households where they belong.

2.3. Data Collection

Air monitoring was carried out both in dry (December through January) and rainy (May through July) season, three times during the study periods in all the households selected. The monitoring was in the morning between 4.00 to 9.00 a.m. and in the evening between 6:00 to 9:00 p.m. These periods were chosen considering the cooking practices observed in the households.

2.4. Measurement of Particular Matter

The levels of particulate matter were measured both within the kitchen if present or other areas such as corridor, verandah, outdoor and sleeping places which may be used for cooking by the respondents. The temperature of the cooking area and Peak Expiratory Flow rate of the women were also measured.

In the sampled 186 households, the daily exposure to respirable particulate matter (PM₁₀) was estimated using Haz-dust particulate monitor. The instrument had been calibrated with test-dust, and the particle size from 0.1 - 50 µm represent the US Environmental Protection Agency (EPA) PM₁₀ criteria and thoracic region for airborne particles as defined by the ACGIH (American Conference of Government Industrial Hygienists) and the NIOSH (National Institute for Occupational Health Safety). The Haz-dust monitor was zeroed outside the sampling areas before monitoring was started. The instrument was placed with the display facing upward at a distance of 0.5 m from the centre of the stove or fireplace and at a length of 0.5 m, at a stable position. This was to ensure that heat did not affect the instrument. Precaution was taken as described by the manufacturer, by avoiding high reflective light, which may interfere and give wrong data during PM₁₀ monitoring. PM₁₀ concentration was measured three times in each household for over 5 minutes. Measurements were done when the fire was first ignited and when it was burning. The highest concentration of pollutant was recorded for each household. The instrument provides reading in milligram per cubic meter (mg/m³). Cleaning of the instrument was performed after a day's monitoring and the zero units were checked after cleaning. The batteries were then charged for 10 - 12 hours before the next monitoring.

2.5. Measurement of Peak Expiratory Flow Rate of Women

Lung function of the subjects was determined using a mini-peak flow meter

(Aimed Clement Clarke International London, U.K.). The subjects (women) were asked to make three blows, at a maximum effort. Those wearing tight clothes were asked to remove them before blowing. Of the three blows, the highest was recorded as the value for that respondent. Peak Expiratory Flow rate was taken before and after cooking in monitored respondents.

2.6. Questionnaire Survey

All eligible subjects were interviewed with a structured questionnaire, developed in English and translated into local language, Yoruba and again back to English to ensure uniform questioning and facilitate easy understanding of the questions. The questionnaire addressed the perceived health, infrastructure of the cooking area, socio-economic aspects, and energy use patterns. Most questions were formal with both open and close-ended questions. The questionnaire (English and Yoruba) were pretested and used to assess the exposure rate as well as respiratory and non-respiratory symptoms in women and children.

Respondents were asked to rank the fuel used in order of use frequency and duration of use at a given time. The principal fuel used was the criterion variable when grouping the respondents in the analysis of health and socio-economic variables. For PM_{10} data, the fuel used on site was used as the criterion variable. Along with personal interviews, a community nurse accompanied the researchers and physically examined both the mothers and the children for respiratory and non-respiratory symptoms.

To ensure the reliability of the responses, a number of measures were taken. Questions were framed in such a way that they were simple and with no ambiguity in their meaning so that every respondent could understand them.

2.7. Focus Group Discussion (FGD)

A Focus Group Discussion guide was developed for use in the FGD with selected respondents using a defined fuel source. One FGD was conducted for each of the cooking fuel used. The discussions were held on site and the respondents ranged between 5 and 10 persons per each FGD. The guide contained questions to obtain data on nature, use and general knowledge, attitude and practices of users of the cooking fuel.

2.8. Data Analysis

Descriptive analyses were conducted for the variables of interest and the use of cooking fuels. Subject characteristics are presented as mean (standard deviation) or frequencies (percentages). All statistical analyses were performed using SPSS 20.0 software package and the significance level was set at 0.05.

3. Results

3.1. Fuel Use Pattern

The pattern of fuel used among the women varies. Among the women, 37.7%

used firewood, 33.1% used kerosene, 17.7% used charcoal and 11.5% used gas. The results were statistically significant in the differences in fuel used among the women ($P = 0.000$). Firewood and kerosene were the principal fuels commonly used. The types of wood used in the households included Teak (*Tectona grandis*), used by 50 households, 40 used Cassia (*Cassia siame*), 30 used Akoko (*Neuboldia laevis*) and 20 used *Eucalyptus* spp. for cooking. The users of woods complained of undried or semi-dried wood producing more smoke than dried woods. Though usage of multiple fuels was common among the women, the usage was principally based on its availability and cost. Gas was said to have been extensively used earlier, but an increase in its price and shortage of gas supply had reduced its availability. Blackening or discolouration of walls and roofs were evidence of smoke pollution in the cooking area. This was significant in households using firewood, charcoal, and kerosene for cooking. These women were found in the cooking area mostly sitting, stirring or cleaning food items in the cooking area. Those children who could not walk or crawl were lapped or carried on their mothers back while cooking or they were either sleeping or placed in a corner of the kitchen. **Table 1** gives the concentration of particulate matter from different fuels analyzed in studied areas.

The results in **Table 1** show that users of firewood were exposed to a high concentration of particulate matter within five minutes of cooking than users of other cooking fuels. Users of kerosene and charcoal were almost exposed to the same concentration of particulate matter in the cooking area. Gas users, however, were exposed to the least concentration of particulate matter. The difference in particulate matter concentration was statistically significant between users of firewood and users of other cooking fuels ($P < 0.005$). The highest mean PM_{10} concentrations in the outdoor air were found to be $502.3 \pm 39.9 \mu\text{g}/\text{m}^3$, while the lowest recorded values were $220.6 \pm 69.9 \mu\text{g}/\text{m}^3$ which were higher ($p < 0.05$), than WHO limit of $50 \mu\text{g}/\text{m}^3$ [15] [23]. In another study by Ana *et al.* [24] burning solid wastes rich in paper near schools contributed to release of particulate matter in the air.

3.2. Particulate Matter and Lung Function

Table 2 shows the relationship between the particulate matter concentration in

Table 1. Emission of particulate matter from various cooking fuels.

Fuel source	Particulate matter ($\mu\text{g}/\text{m}^3$)			
	Min	Max	Mean	\pm S.D
Firewood (60)	100	9500	1640.0	1803.7
Charcoal (44)	100	1900	1159.0	601.3
Kerosene (60)	30	1900	909.3	613.5
Gas (22)	20	800	300.9	223.0

The ambient air particulate matter value = $250 \mu\text{g}/\text{m}^3$; outdoor air showed particulate matter in the range of 220 to $502 \mu\text{g}/\text{m}^3$.

Table 2. Mean values of lung function of subjects (l/min).

Cooking fuels	Lung function of subjects			
	Min	Max	Mean	±S.D
Firewood	200	300	233.5	±27.3
Kerosene	200	390	304.3	±45.22
Charcoal	110	300	189.7	±48.87
Gas	400	520	460.4	±43.58
All			273.7	±43.58

the cooking area and the lung function of the subjects. Charcoal users had the lowest lung function values and gas the highest value.

The gas users had the highest lung function values compared to users of other cooking fuels (kerosene, firewood, and charcoal). However, charcoal users had the lowest values.

Duration of cooking among the respondents depend on the type of food cooked, the quantity of food cooked and fuel type used. Firewood users spend more time in cooking and stay longer close to the fire than users of other cooking fuels. Those who cook for more than 6 hours were those women who fry local dishes “puff-puff” or “bean cake” (local name akara) for sale. It was noticed that these women fry from 6.00am to 4.00 pm in the evening. However, 55 (42.3%) women in the study cooked twice a day (**Figure 1** and **Figure 2**).

3.3. Particulate Matter from Cooking Fuels and Perceived Health Effects

Though health effects are subjective, the respondents have perceived some ill effects of fuel usage. The results in **Table 3** show firewood users reported more of the health symptoms than users of other fuels. Firewood users significantly reported more difficulties in breathing ($P = 0.040$), chest pains ($P = 0.036$), chest tightness ($P = 0.026$) and watery eyes ($P = 0.058$), than users of the other cooking fuel. Smoke from the fire, particles from fire, staying in the kitchen when cooking, were possible causes of health symptoms shown by the respondents.

Twenty-five (19.2%) of the respondents had seen a specialist regarding the health symptoms. One hundred and two (78.5%) complained of having cough during and after cooking. Other health problems complained by the women included catarrh 1 (4.5%), hypertension 7 (31.8%), body pain 4 (18.25%), malaria 1 (4.5%) and persistent headache 5 (22.7%). Those who complained of having severe cough and breathing problems were advised to see a specialist.

Table 4 shows the perceived health symptoms of children in households using all the different categories of cooking fuels. Children in households using firewood were exposed to reported concentrations of particulate matter. Children in the studied households had more of cough symptom, running nose and redness of eyes. The perceived health symptoms were common among children of the

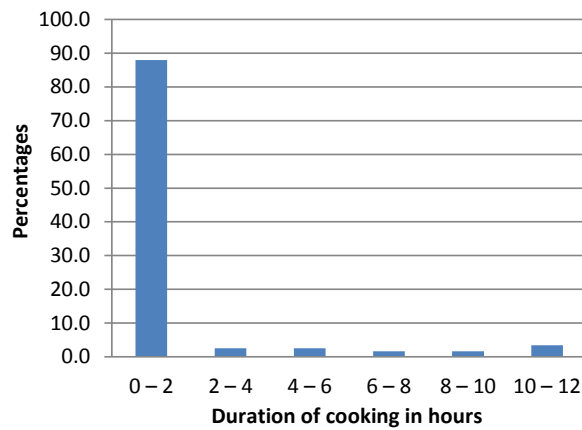


Figure 1. Duration of exposure to smoke pollution.



Figure 2. Sample of Women who stayed in the cooking area for more than 6 hours.

Table 3. Frequency and percentage of perceived health variables reported by the respondents.

Health variables	Firewood n = 49	Kerosene n = 43	Charcoal n = 23	Gas n = 15	P-Value
Difficulty in breathing	10 (20.4)	1 (2.3)	2 (8.7)	1 (6.7)	0.0403
Running nose/sneezing	19 (38.8)	15 (34.9)	9 (39.1)	1 (6.7)	0.12238
Chest pain	14 (28.6)	7 (16.3)	2 (8.7)	0(0)	0.0360
Chest tightness	7 (14.3)	1 (2.3)	0 (0)	0 (0)	0.0265
Wheezing	5 (10.2)	2 (4.7)	0 (0)	0 (0)	0.2175
Watery eyes	27 (55.1)	17 (39.5)	13 (56.5)	3 (20)	0.0585
Redness of eyes	24 (44.9)	17 (39.5)	8 (34.8)	2 (13.3)	0.0951
Irritation of nose	10 (20.4)	7 (16.3)	6 (26.1)	4 (26.7)	0.7427
Irritation of throat	1 (2.0)	6 (14)	3 (13)	1 (6.7)	0.1741
Sweating	30 (61.2)	29 (67.4)	19 (82.6)	10 (66.7)	0.3496
Headache	20 (40.8)	17 (39.5)	11 (47.8)	4 (26.7)	0.6334

Prevalence of symptoms was presented as frequencies and percentage in parenthesis.

Table 4. Frequency and percentage of perceived health variables in children.

Health variables	Frequency (n = 130)	Percentage
Cough	54	41.5
Running nose	28	21.5
Difficulty in breathing	8	6.2
Wheezing noise in chest	1	0.8
Redness of eyes	14	10.8
Watery eyes	10	7.7
Others	2	1.5

firewood users. Apart from the health symptoms above, 9 (6.9%) complained of having other health problem as chest pain, eye problem and malaria.

4. Discussion

As previously been hypothesized, the emission of high concentrated particular matters coming from combustion and non-combustion sources of different cooking fuel, consists of various chemical species that may differentially negatively influence human health and the climate. This has been a great concern in impacting the environmental and on the global health [25] [26]. Particulate matter from cooking fuel combustion has been found associated with health problems like changes in plasma viscosity [18] [19] [22] and respiratory function and mortality. Our study confirms the production of particulate matter from different cooking fuels in Ibadan municipalities. As revealed by our findings, the concentration of particulate matter produced within 5 minutes in the cooking areas especially among users of firewood was consistently high. In this study, the assessed cooking fuels in their combustion state produced particulate matter greater than the Nigeria ambient air quality standard of daily average $250 \mu\text{g}/\text{m}^3$ and environmental health criteria standard of $75 \mu\text{g}/\text{m}^3$ for 24 hours, in the indoor air. These results agree with that of Ellegard [27], where Maputo women in using firewood in Kenya, were exposed to high concentration of particulate matters than users of modern fuels, natural liquefied gas and electricity.

With a concentration of maximum value $9500 \mu\text{g}/\text{m}^3$ in the cooking area exposes the women and their children to health dangers [28] [29]. The lung function test and other health symptoms were found to be common among the respondents, where, the lung function values for charcoal users were the lowest and highest for users of gas. Physical examination as well as complains from the respondents, revealed that firewood users had majority of the health symptoms, followed by users of firewood, kerosene and charcoal, but, less among users of gas. Factual data from in depth studies are scanty in Nigeria. This may be attributed to lack of adequate funding for such researches.

Culturally in Africa, the women are those who do the cooking in majority of the household, and in most cases they are often around the cooking area with

the young ones. They and their children are mostly exposed to the high concentration of particulate matter emitted from the fuel combustion, thereby being the ones that may likely be affected. The duration of cooking, location of cooking area, fuel type, the cooking frequency, the fuel use frequency, the infrastructure (lack of good ventilation), cutting and cleaning of food items around the cooking area and tendering of fire from time to time, are possibly contributing factors for increased exposure to particulate matter arising from cooking fuel combustion. Other factors may be use of multiple fuels for cooking, children playing and resting in the kitchen or cooking area, and the number of years the women have been cooking. Another important factor is lack of knowledge or poor knowledge regarding the health impacts to exposure to the cooking fuels. Women are also traditionally bound to the choice of fuel and their attitude of not protecting themselves from exposure to particulate matter or smoke while cooking.

The main findings that emanated from this study are summarized as follows:

- The choice of fuel type depends on family traditions, availability and the price;
- Maximum exposure time at a single cooking was for up to 2 hours irrespective of the fuel used;
- Users of firewood were exposed to maximum PM₁₀ followed by kerosene or charcoal;
- Charcoal users had the lowest lung function values and users of gas the highest value;
- Firewood users showed higher symptoms of discomfort and perceived negative health effects such as cough and breathing problems, catarrh, hypertension, body pain and headache and about 19% of them sought medical advice.

5. Conclusions

The results of the investigation, revealed that smoke from firewood, kerosene, charcoal and gas contained particulate matter with a maximum concentration of up to 9500 µg/m³. The use of firewood in cooking released more particulate matter. The exposure of women and children to particulate matter has negative perceived health effects which may be short-term or long-term. The common symptoms reported by respondents and their children were difficulty in breathing, running nose, sneezing, wheezing, chest pain or tightness, cough, watery eyes, redness of eyes, irritation of the nose and throat, sweating and headache. It can therefore be concluded that choice of cooking fuel causes indoor pollution through particulate matter in Ibadan.

To overcome the effect of particulate matter from cooking fuel, users of wood fuel should be encouraged to switch to alternative fuels. Another best option is to provide the women with improved cook stoves. Health education is necessary to change the knowledge, attitude and practices of the women who are traditionally bound to the use of cooking fuels. Children as well should be encouraged to stay away from the cooking areas during cooking hours.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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