ORIGINAL ARTICLE

# Respiratory symptoms, lung function and particulate matter pollution in residential indoor environment in Ile-Ife, Nigeria

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## ABSTRACT

**Introduction:** Particulate air pollution is associated with increased incidence of respiratory symptoms and decreased pulmonary, function but the relative impact of pollution from different domestic energy sources is not well-known or studied. **Aim:** The study was aimed at assessing the association between particulate concentrations, respiratory symptoms and lung function. **Materials and Methods:** It was a cross-sectional study comprised of randomly selected residents of three communities. These communities were selected according to the predominant type of fuel used for household cooking which were: firewood, kerosene and liquefied petroleum gas (LPG). Assessment of the indoor $PM_{10}$ levels was done by filtration using the Gent stacked filter unit sampler for collection of atmospheric aerosol in two size fractions ($PM_{2.5}$ and $PM_{10}$). The Medical Research Council (MRC) questionnaire was administered followed by spirometry test. **Results:** The mean $PM_{10}$ concentration in participants using LPG, kerosene and firewood was 80.8 ± 9.52 μg/m³, 236.9 ± 26.5 μg/m³ and 269 ±93.7 μg/m³, respectively. The mean age and height-adjusted percent predicted forced expiratory volumes in 1 s (FEV1) for men were 127 ± 7, 109 ± 40 and 91 ± 20 and for women were 129 ± 13, 115 ± 14, 100 ± 14 in users of LPG, kerosene and firewood, respectively. A similar trend was found in the forced vital capacity (FVCs). Users of firewood had significantly lower FEV1 and FVC compared with LPG users ($P < 0.05$). The participants using firewood had the highest prevalence of pulmonary and non-pulmonary symptoms (57.1%), whereas subjects using LPG had the lowest (23.8%). **Conclusion:** There are high levels of particulate matter pollutions with respiratory effects in residential indoor environments in Ile-Ife, Nigeria

**Key words:** Ile-Ife, lung function, particulate matter, particulate, respiratory

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## INTRODUCTION

Indoor air is the air within an indoor environment. Time activity diaries reveal that about 22 h in a day are spent indoors by most people in industrialised countries, out of which 72.7% is spent at home.[1] Exposure to indoor air pollutants like particulate matter, carbon monoxide, sulfur oxides and nitrogen dioxide are major environmental and health challenges in many developing countries.[2] It is estimated that about 3 billion people rely on biomass (wood, charcoal, crop residue and dung) and coal as their primary source of domestic energy.[3,4] Biomass constitutes about 50% of domestic energy in many developing countries and up to 95% in some rural communities in parts of sub-Saharan Africa.[5]

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Elevated levels of particulate pollution have been associated with increased incidence of respiratory symptoms and diseases including acute lower respiratory infections (ALRI) in children,[6] carcinoma of the lungs[7,8] and exacerbations of bronchial asthma and chronic obstructive pulmonary disease.[9] In addition, epidemiological studies have also linked exposure to indoor air pollution to decreased pulmonary function, increased hospitalisation for respiratory diseases and increased mortality.[10-12]

A few studies have investigated the relative impact of different domestic fuel types on respiratory symptoms and lung function in sub-Saharan Africa.[13-16] Firewood and kerosene are used frequently in many sub-Saharan rural homes as major sources of domestic energy; however, their effect on respiratory symptoms or lung function among Nigerians is not well understood.

The present study was aimed at assessing the comparative impact of indoor air pollutants from different domestic cooking fuels on pulmonary symptoms and function in Ile-Ife, Nigeria.

## MATERIALS AND METHODS

This cross-sectional study comprised a sample of residents of three communities in Ile-Ife stratified according to their predominant source of cooking fuel. A snow-ball approach was used in selecting 35 residents of Agbongbo who use firewood for cooking, 34 residents of Olonode who use kerosene as domestic cooking fuel and 21 residents of Obafemi Awolowo University (OAU) staff quarters who used liquefied petroleum gas (LPG) as domestic cooking fuel. The objective of the study was explained to the respondents who subsequently gave their consents to participate. Ethical clearance was obtained from the ethics and research committee of the university and the teaching hospital.

A modified British Medical Research Council (MRC) questionnaire on respiratory symptoms was administered to the 90 subjects. This questionnaire elicited information on anthropometric data, medical history, particularly respiratory symptoms, smoking, occupational history and indoor cooking activities. Additional questions on eye irritation, eye discharge, nasal catarrh and tears while cooking were also included.

A vitalograph bellows spirometer (Vitalograph Ltd., Buckingham) was used to measure the following pulmonary function parameters: forced expiratory volume in one second (FEV1) and forced vital capacity (FVC). Wright peak flow meter was used to measure the peak expiratory flow rate (PEFR). Detailed check and calibration of the spirometer and flow meter were carried out daily. Lung function test was done for all the 90 respondents. However, only spirograms with acceptable manual pattern and reproducibility of within 200 mL of the two highest FEV1 and FVC were included in the analysis.[17] Predicted values were derived using local equation for Nigerians developed by Patrick and Femi-Pearse.[18]

### Respirable particulate matter

Indoor particulate ($PM_{10}$) was collected by filtration using the Gent stacked filter unit sampler used for collection of atmospheric aerosols in two size fractions: coarse 47-mm diameter nuclepore polycarbonate filters of pore size 8 μm and fine 47-mm diameter nuclepore polycarbonate filters of pore size 0.4 μm at an optimum sampling rate of 18 L/s.[19] Sampling was conducted for 8 h between 7 a.m. and 7 p.m. each day. The air filter unit was installed face down in the kitchen some distance away from the walls at a level of about 1.6 m above the ground with the pump placed outside the kitchen to avoid passive dust loading and contamination.

The sampling unit consisted of a double (stacked) filter cassette loaded with two different nuclepore filters, black polyethylene container (which included a pre-impaction stage for $PM_{10}$) for the stacked filter cassette, POLY-Flo tubing (0.375″ outer diameter, 0.25″ inner diameter), a needle valve (WHITEY) that regulates the flow rate, a vacuum gauge, a vacuum pump, a gas flow meter, a precision gas volume meter, a time switch and an hour meter (operating at 220 V, 50 Hz). The nuclepore filters were pre-equilibrated in a desiccator for 24 h before and after sampling using a properly cleaned mettler chemical balance with ±0.1 mg sensitivity. The mass concentration of $PM_{10}$ collected per volume of air sampled is the difference between these two weights calculated as follows:

$$PM_{10} = \frac{W_p}{V_{air}}$$

Where

$PM_{10}$ = particulate matter with aerodynamic diameter < 10 micron

$W_p$ = weight of particulate collected (Weight of exposed filter − weight of unexposed filter)

$V_{air}$ = volume of air sampled

Data was analyzed using the SPSS Statistical Package.[20] Continuous variables were expressed as means and standard deviations (SDs), whereas discrete variables were expressed as proportions (percentages). Comparison of means was done using unpaired *t*-test while comparison of proportions was done with chi square test. Evaluation of the quality of lung function test was based on the American Thoracic Society (ATS) guidelines. Subjects who had ventilatory ratios (FEV1/FVC) less than 70% were categorised as having an obstructive pattern of lung function defect. Those whose vital capacity was reduced as suggested by the predicted FVC but with normal or raised ventilatory ratios (FEV1/FVC > 70%) were categorised as having restrictive ventilatory defect. Statistical significance was considered at $P$ value of less than 0.05.

## RESULTS

Ninety individuals participated in this comparative study, out of which 21 used LPG, 34 used kerosene and 35 used firewood regularly. However, 88 participants gave complete data with acceptable spirometry test.

The mean (SD) age for men and women using LPG was 39.0 (11.6) and 30.1 (12.8) years, for kerosene, 39.5 (10.1) and 34.4 (17.2) years and for firewood, 41.3 (17.3) and 33.8 (21.2) years, respectively [Table 1].

Table 2 shows the $PM_{10}$ levels in the homes with the various types of fuel usage. Participants in homes using firewood had higher concentrations of $PM_{10}$ compared with homes using LPG ($P < 0.05$). However, the comparative levels in homes using LPG versus those using kerosene or in those using kerosene versus those using firewood did not achieve statistical significance.

Table 3 shows the prevalence of pulmonary and non-pulmonary symptoms among the various subjects who cook with any of the common domestic fuels. Those living in homes using firewood reported more symptoms, including eye irritation, ear discharge, nasal catarrh and

**Table 1: General characteristics of participants by type of domestic cooking energy**

| Domestic Fuel Type | Mean ± SD | | | | | |
|---|---|---|---|---|---|---|
| | LPG | | Kerosene | | Firewood | |
| Variables | Men | Women | Men | Women | Men | Women |
| Age (years) | 39.0±11.6 | 30.1±12.8 | 39.5±10.1 | 34.4±17.2 | 41.3±17.3 | 33.8±21.2 |
| Height (m) | 1.71±0.1 | 1.64±0.1 | 1.58±0.2 | 1.59±0.1 | 1.62±0.0 | 1.48±0.1 |
| Weight (kg) | 75.6±8.9 | 68.7±10.7 | 65.9±15.6 | 64.1±14.5 | 64.1±4.6 | 61.7±12.7 |

SD – Standard deviation, LPG – Liquefied petroleum gas

**Table 2: Indoor $PM_{10}$ concentration and lung function**

| Variables | LPG | Kerosene | Firewood | *P* value |
|---|---|---|---|---|
| Particulate matter | | | | |
| Fine (< 2.5μm) | | | | |
| Maximum $PM_{2.5}$ (μg/m³) | 34.1 | 370.4 | 134.7 | $a^{ns}$ $b^{2}$ $c^{ns}$ |
| Mean $PM_{2.5}$ (μg/m³) | 25.8±7.26 | 139.4±20.0 | 118.5±22.7 | |
| Coarse (2.5-10 μm) | | | | |
| Maximum $PM_{10}$ (μg/m³) | 68.2 | 172.8 | 277.8 | $a^{ns}$ $b^{ns}$ $c^{ns}$ |
| Mean $PM_{10}$ (μg/m³) | 55.0±11.8 | 97.5±65.3 | 150.9±11.4 | |
| Total $PM_{10}$ (mean±SD) μg/m³ | 80.8±9.52 | 236.9±26.5 | 269.4±93.7 | $a^{ns}$ $b^{3}$ $c^{ns}$ |
| Exposures | | | | |
| Time spent Indoor (hrs) | 13 | 13 | 15 | — |
| Exposure (μgh/m³/day) | 130.5 | 384.9 | 505.1 | — |
| Exposure (μgh/m³/year) | 47,632.5 | 140,488.5 | 184,361.5 | — |
| Lung function | | | | |
| FEV1 (mean ±SD) (L) | 3.37±0.59 | 2.69±0.6 | 2.12±0.38 | $a^{1}$ $b^{1}$ $c^{1}$ |
| FVC (mean ±SD) (L) | 3.81±0.67 | 3.09±0.63 | 2.66±0.5 | $a^{1}$ $b^{1}$ $c^{2}$ |

FEV1 – Forced expiratory volume in 1 second; FVC – Forced vital capacity; LPG – Liquefied petroleum gas; SD – Standard deviation; a – LPG versus kerosene; b – LPG versus firewood; c – kerosene versus firewood; 1 – $P < 0.001$; 2 – $P < 0.01$; 3 – $P < 0.05$ – ns – not-significant

**Table 3: Prevalence of pulmonary and non-pulmonary symptoms among the various domestic fuel type users**

| Symptoms | LPG | Kerosene | Firewood | *P* value |
|---|---|---|---|---|
| | *N* (%) | | | |
| History of dusty job | 6 (28.6) | 5 (14.7) | 11 (31.4) | $a^{ns}$ $b^{2}$ $c^{1}$ |
| Tears while cooking | 4 (19.0) | 6 (17.6) | 23 (65.7) | $a^{ns}$ $b^{2}$ $c^{1}$ |
| Eye irritation | 2 (9.5) | 9 (26.5) | 17 (48.6) | $a^{ns}$ $b^{2}$ $c^{ns}$ |
| Eye discharge | — | 4 (11.8) | 14 (40.0) | $a^{3}$ $b^{1}$ $c^{2}$ |
| Conjunctivitis | — | 3 (8.8) | 11 (31.4) | $a^{ns}$ $b^{1}$ $c^{3}$ |
| Nasal catarrh | 4 (19.0) | 10 (29.4) | 20 (57.1) | $a^{ns}$ $b^{ns}$ $c^{3}$ |
| Wheeze | — | 3 (8.8) | 5 (14.3) | $a^{ns}$ $b^{ns}$ $c^{ns}$ |
| Shortness of breath | 2 (9.5) | 4 (11.8) | 4 (11.4) | $a^{ns}$ $b^{ns}$ $c^{ns}$ |
| Cough | 4 (19.0) | - | 17 (48.6) | $a^{3}$ $b^{3}$ $c^{1}$ |
| Sputum/phlegm production | 2 (9.5) | 3 (8.8) | 16 (45.7) | $a^{ns}$ $b^{2}$ $c^{1}$ |
| Tightness of chest | 1 (4.8) | 4 (11.8) | 9 (25.7) | $a^{ns}$ $b^{ns}$ $c^{2}$ |
| Chest pain (for 3 months) | 1 (4.8) | 5 (14.7) | 8 (22.9) | $a^{ns}$ $b^{ns}$ $c^{2}$ |
| At least, one respiratory symptom | 5 (23.8) | 11 (32.4) | 20 (57.1) | $a^{ns}$ $b^{1}$ $c^{1}$ |

a – LPG versus kerosene; b – LPG versus firewood; c – kerosene versus firewood; 1 – $P < 0.001$; 2 – $P < 0.01$; 3 – $P < 0.05$; ns – not-significant tearing, compared with those using LPG as domestic fuel for cooking ($P < 0.01$). In addition, those using firewood were more likely to report cough, sputum or a respiratory symptom compared with those using LPG ($P < 0.001$).

Pulmonary function results for women and men who cook with and/or live in houses where these domestic fuels are used for cooking is shown in Table 4. The mean FEV1 and FVC for men in the homes using these various fuels were 3.87 L and 4.39 L, 3.02 and 3.53 L and 2.25 L and 2.98 L, for LPG, kerosene and firewood respectively. The age- and height-adjusted values presented as percent predicted values show that there were significant differences between FEV1 and FVC of those using LPG and firewood ($P < 0.001$) and between those using LPG and kerosene ($P < 0.01$). A similar trend was observed in the lung function values of women.

Lastly, Table 5 shows that normal ventilatory lung function was found in 95% of users of LPG and in 71% of users of firewood. In addition, 17.1% of the subjects who used firewood had obstructive pattern of lung disease compared with 2.94% among kerosene users. None of the subjects who used LPG had an obstructive lung function defect.

## DISCUSSION

Our study showed high levels of particulate matter pollution in households using the various types of domestic fuels, especially those using firewood and kerosene [Figure 1]. We also found a high prevalence of respiratory and non-respiratory symptoms in those who use firewood for cooking and significantly lower lung function values compared with those using LPG.

The present study recruited individuals from households utilizing the various cooking fuels and employed standard methods in lung function testing and interpretation.

The US Environmental Protection Agency recommends a 24-h ambient air quality standard limit of 150 mg/m$^3$ PM$_{10}$, but the World Health Organization (WHO) recommends a maximum level of 50 mg/m$^3$ PM$_{10}$ as global standard.[21,22] Our study reports indoor levels of particulate pollutant that exceed these limits especially in homes using kerosene or firewood. Vast majorities of people in developing countries use kerosene and firewood as their primary fuel for cooking.[5] The WHO estimates that around three quarters of the total global burden of exposure to particulate air pollution is experienced indoors in developing countries; 50% in rural areas and 25% in cities.[23] However, our result also suggest additional sources of pollutants in the various households, as notable levels was also achieved in homes that report regular usage of LPG for cooking. This is unlikely to be due to smoking because smoking rates in the studied community is generally very low. Possible alternate explanations may be periodic use of other fuels or mixed fuel types, housing characteristics or the impact of outdoor pollutants, especially vehicular traffic. Although the role of traffic-related pollution was not specifically investigated in the present study, it is unlikely to change the direction of effect, as the study area was a local non-industrialised university community with low vehicular traffic. However,

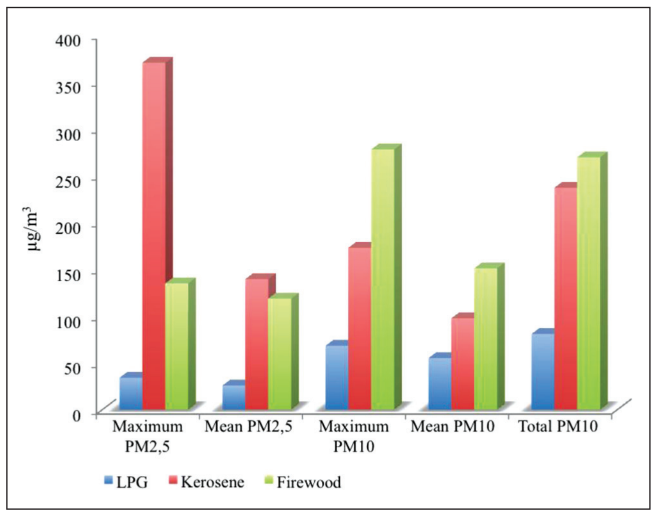


**Figure 1:** Mean and maximum particulate matter levels among the different types of domestic cooking fuels

**Table 4: Pulmonary function according to type of domestic fuel**

| Lung Function Parameters | Men | | | | Women | | | |
|---|---|---|---|---|---|---|---|---|
| | LPG | Kerosene | Firewood | *P* value | LPG | Kerosene | Firewood | *P* value |
| | (Mean ± SD) | | | | (Mean ± SD) | | | |
| PEF (L/min) | 450±38.1 | 409±65.1 | 356±81.9 | $a^{ns}$ $b^2$ $c^{ns}$ | 423±35.8 | 371±63.6 | 328±45.2 | $a^2$ $b^1$ $c^3$ |
| $FEV_1$ (L) | 3.87±0.41 | 3.02±0.72 | 2.25±0.43 | $a^2$ $b^1$ $c^2$ | 2.99±0.39 | 2.48±0.41 | 2.09±0.36 | $a^2$ $b^1$ $c^2$ |
| FVC (L) | 4.39±0.45 | 3.54±0.73 | 2.98±0.55 | $a^2$ $b^1$ $c^3$ | 3.38±0.43 | 2.81±0.36 | 2.58±0.46 | $a^1$ $b^1$ $c^{ns}$ |
| FEV1/FVC (%) | 88.1±3.06 | 84.9±8.13 | 75.4±4.29 | $a^{ns}$ $b^1$ $c^2$ | 88.4±3.15 | 88.1±7.08 | 81±2.67 | $a^{ns}$ $b^1$ $c^1$ |
| Predicted FEV1 (L) | 3.06±0.46 | 2.97±0.78 | 2.54±0.47 | $a^{ns}$ $b^3$ $c^{ns}$ | 2.31±0.24 | 2.15±0.25 | 2.09±0.31 | $a^{ns}$ $b^3$ $c^{ns}$ |
| Predicted FVC (L) | 3.71±0.43 | 3.64±0.74 | 3.09±0.41 | $a^{ns}$ $b^2$ $c^3$ | 2.92±0.42 | 2.63±0.4 | 2.49±0.45 | $a^{ns}$ $b^3$ $c^{ns}$ |
| % $FEV_1$ of predicted | 127±6.97 | 109±40.4 | 91±20.1 | $a^{ns}$ $b^1$ $c^{ns}$ | 129±12.6 | 115±13.8 | 100±14.2 | $a^2$ $b^1$ $c^2$ |
| % FVC of predicted | 119±2.81 | 99±15.1 | 97±16.4 | $a^1$ $b^1$ $c^{ns}$ | 116±12.8 | 108±15.7 | 104±0.52 | $a^{ns}$ $b^3$ $c^{ns}$ |

PEF – Peak expiratory flow; FEV1 – Forced expiratory volume in 1 second; FVC – Forced vital capacity; LPG – Liquefied petroleum gas; SD – Standard Deviation; a – LPG versus kerosene; b – LPG versus firewood; c – Kerosene versus firewood; 1 – $P < 0.001$; 2 – $P < 0.01$; 3 – $P < 0.05$; ns – not-significant

**Table 5: Pattern of lung function among the participants**

| Lung Function Pattern | LPG (%) | Kerosene | Firewood (%) |
|---|---|---|---|
| | | *N* (%) | |
| Obstructive | — | 1 (2.94) | 6 (17.1) |
| Restrictive | 1 (4.76) | 3 (11.4) | 4 (11.4) |
| Normal | 20 (95.2) | 28 (82.4) | 25 (71.4) |

Normal – FEV1/FVC >0.7 and FEV1 predicted ≥ 80%; Restrictive – FEV1/FVC > 0.7 and FEV1 <80% predicted; Obstructive – FEV1/FVC < 0.7

it does suggest that low-income countries are confronted with the dual challenge of indoor and outdoor pollutions. This is largely because of the lack of or low implementation of regulatory policies that are specifically aimed to reduce the level of pollutant emissions from vehicles and motorists in developing societies.

We also found, as expected, that participants who live in homes where firewood is used are more susceptible to pulmonary and non-pulmonary symptoms than those living in homes where LPG is the domestic cooking fuel. Norton and Gunter had reported increased respiratory symptoms among subjects who cook with firewood. A high incidence of cough among firewood was found by Ellegard *et al*., who reported that wood users have significantly more cough, sputum, wheeze and tears while cooking than LPG users.[24] Tears while cooking were found to be a good indicator of high indoor pollution levels in the absence of objective measurements. In the present study, 48% of wood users had a history of cough compared with 0% and 19% of those who used kerosene or LPG, respectively. A similar trend was observed in other symptoms like phlegm production.

Our study also shows significant differences in the lung function values of the study participants according to the domestic fuel type commonly used. Women who cook with firewood or kerosene and men living in such homes had lower age- and height-adjusted FEV1 and FVC compared with women cooking with LPG or men living in such homes. As expected, the FEV1/FVC ratio was significantly lower in those using firewood compared with those using LPG for home cooking. In addition, while 95.2% of the regular LPG users had normal lung function based on FEV1/FVC > 0.7 and FEV1 predicted of at least 80%,[25] only 82.4 and 71.4% of kerosene and firewood users, respectively, had normal lung function. The impact of indoor pollution on lung function is more likely to be a long-term effect. Although the present study examined both the exposure and outcome at the same time, the results suggest that the effects on lung function are the cumulative outcome of continuous exposure to high levels of pollutants over a long time.

In another study which examined the impact of use of biomass fuel on respiratory symptoms using a cross-sectional design, Desalu *et al*., reported that the use of solid fuels like wood constitutes a high risk for respiratory symptoms, especially cough and sputum.[14] They showed that women using wood were five times more likely to report cough and four times more likely to have chronic bronchitis compared with those using gas or kerosene. Behera *et al*., in a descriptive study of 3,318 non-smoking Indian women using four different types of cooking fuels (biomass, LPG, kerosene and mixed) reported that biomass users were more likely to have FVCs, which were lower than 75% of the predicted.[26]

Low FVC has recently been linked to all-cause mortality. Burney and Hooper in an analysis of a limited access dataset of the Atherosclerosis Risk in Communities (ARIC) study found that low lung function among African-Americans was associated with an excess mortality compared with Caucasians of similar age, sex, height and smoking status.[27] Lung function may be determined by early life events, including respiratory infections, birth weight or early life exposures to indoor or outdoor pollutants like biomass smoke.[28-30] Further research with longitudinal designs is needed to quantify the true burden of disease due to air pollution in Nigeria.

This study has some limitations. The sample size is small and this potentially limits the extent the present survey can be generalised. However, it is hoped that this study stimulates further research on this important subject. We were unable to quantify the levels of other pollutants like carbon monoxide, sulfur oxides or nitrogen dioxides, which may have better quantified the levels of pollutants from the different fuel types. Also, we could not estimate the blood lead levels of the participants. Blood lead levels are good estimates of the levels of human exposures to traffic-related air pollution.

Our study highlights the need for policy makers to implement policies that will reduce the use of unclean and dirty fuels like firewood, which are potentially hazardous to lung health. It is imperative to provide support for research into the development of clean, combustible and less polluted energy for domestic use.

In conclusion, our study shows that the use of firewood is associated with high concentrations of particulate matter, increased frequency of respiratory symptoms and lower lung function.

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