



## Indoor Air Pollution Related Respiratory Ill Health, a Sequel of Biomass Use

David Mulenga<sup>a\*</sup>, Seter Siziya<sup>a</sup>

<sup>a</sup> Copperbelt University, Michael Chilufya Sata School of Medicine, Ndola, Zambia.

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### Abstract

**Introduction:** Climate change may worsen existing indoor air problems and create new problems by altering outdoor conditions that affect indoor conditions. Since climate change is due to both natural variability and human-induced contributions, public health professionals through their expertise in health promotion and behavior change can play a vital role in promoting lifestyle choices that will decrease greenhouse gas emissions. This study, therefore, aims at presenting the health effects of indoor air pollutants from biomass use. **Methods:** A cross sectional study involving 1,170 consenting women was conducted in Masaiti and Ndola districts of Zambia. Data collection tools included a structured questionnaire; foobot (indoor air quality monitoring device) and spirometer (lung function test device). Data was analyzed using SPSS version 16 and analyses were done at Univariate, bivariate and multivariate level at 5% statistical significant level. **Results:** Population using biomass as cooking fuel was 69.2%. Indoor particulate (PM<sub>2.5</sub>) overall median (Q1, Q2) distribution during cooking period was 501(411, 686)  $\mu\text{g}/\text{m}^3$  and daily average was 393(303,578)  $\mu\text{g}/\text{m}^3$  while VOC daily average was 343(320, 363) ppb. The proportion of women with respiratory symptoms and impaired lung functions was higher in households with high levels of indoor pollutants. There was a statistically significant association between mean indoor particulate concentration levels and the number of maternal respiratory symptoms. There was a significant association between indoor VOC and forced vital capacity ( $p=0.011$ ). **Conclusion:** The results contribute to the growing evidence regarding the effect of biomass use on indoor air quality and consequent adverse respiratory health outcomes.

**Keywords:** Particulate Matter; Volatile Organic Compounds; Biomass.

### 1. Introduction

Natural variability and human activities have been implicated for climate change. The scale of environmental health problems as a result of climate change has expanded from household irritants, to global level. According to research, climate change may worsen existing indoor air problems and create new problems by altering outdoor conditions that affect indoor conditions. Climate change can also lead to changes in the mixing of outdoor and indoor air. Reduced mixing of outdoor and indoor air limits penetration of outdoor pollutants into the indoors, but also leads to higher concentrations of pollutants generated indoors since their dilution by outdoor air is decreased [1].

Climate change may alter the indoor concentrations of pollutants generated outdoors such as ground-level ozone, particulate matter, and aeroallergens such as pollen. Changes in the climate may also increase pollutants generated indoors, such as mold and volatile organic compounds. Whether outdoors or indoors, poor air quality, can affect negatively the human respiratory and cardiovascular systems. Most of the air people breathe over their lifetimes will be indoors, since people spend the vast majority of their time in indoor environments. Thus, alterations in indoor air pollutant concentrations from climate change have important health implications. That is why Brazil and India have

\* Corresponding author: [davykdn@gmail.com](mailto:davykdn@gmail.com)

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substantially expanded the use of liquefied petroleum gas (LPG) in their household energy mix. The net climate impact of this approach compared to current biomass stoves is minimal or non-existent, and the social and health benefits are, in contrast, potentially great [2].

Current research indicates that the health impact resulting from direct exposure to biomass cook smoke leads to about 2.2–3.6 million excess deaths per year, accounting for about 3.9%–6.4% of global mortality (GBD 2015), making air pollution (household and ambient) the largest Environmental source of ill-health globally.

This study is designed to monitor indoor air quality (PM<sub>2.5</sub> and VOC) and assess the association between the concentration levels and respiratory ill health. Research has demonstrated that decrease in pollution can improve lung function in both children and adults [3]. Children during periods of increasing PM regulation and therefore decreasing average PM concentrations. Investigators found higher FEV<sub>1</sub> and FVC in the children exposed to the lowest concentrations of PM and, as air quality improved, the proportion of children with clinically low FEV<sub>1</sub> subsequently declined [4]. Similarly, reductions in PM in an urban area of the Netherlands were associated with a 3% and 6% improvement in FEV<sub>1</sub> and FVC, respectively, in both children and adults<sup>69</sup>. In the SAPALDIA study, a 10 µg/m<sup>3</sup> decrease in PM<sub>10</sub> concentration was associated with a 9% decrease in the rate of yearly decline of FEV<sub>1</sub> in over 9000 randomly selected Swiss adults [5]. These studies highlight that even modest reductions in PM can translate to meaningful improvements in lung function. As the EPA does not regulate the indoor environment, interventions to mitigate exposure to indoor PM are less well studied. A small number of research studies have shown improvements in indoor PM concentrations following behavioral modifications and use of indoor air cleaners [6-8].

Therefore, public health professionals through their expertise in health promotion and behavior change can play a vital role in promoting lifestyle choices that will decrease greenhouse gas emissions [9, 10]. This study, therefore, aims at presenting the health effects of biomass use one of the sequels of climate change impacts.

The precise mechanism as to how air pollutants such as particulate matter (PM<sub>2.5</sub>) may influence health and lung function is unknown. However, research suggests that PM may mediate adverse health effects via the generation of reactive oxygen species [11-13], activation of cell signaling pathways, and alterations of respiratory tract barrier function and antioxidant defenses, all of which may lead to airway inflammation and changes in pulmonary function [14]. Additionally, cellular changes resulting from PM exposure may cause epigenetic modifications, leading to alterations in gene expression [15].

## 2. Methods

A cross section study was conducted in rural (Masaiti) and urban (Ndola) areas of study population. This was a cross section study using quantitative methods and descriptive in nature.

### 2.1. Study population

Women were recruited from 9 health centres of the indigenous communities in rural (Masaiti) and urban (Ndola) compounds. A two stage sampling method was used to recruit respondents. In the first stage, health facilities were sampled using simple random sampling method based on ministry of Health (MoH) Facility Listing as sampling frame. The second stage involved use of antenatal (ANC) registers and women were selected using systematic random sampling. Every third woman was considered for enrolment after a random start for each clinic.

### 2.2. Assessment of Respiratory Symptoms and Lung Function

Questionnaires recorded frequency and duration of respiratory symptoms including cough, phlegm, wheeze, and chest tightness experienced in the previous 6 months. The respiratory questionnaire was adapted from the standard respiratory questionnaire of the Centre for Environment and Respiratory Health, University of Oulu, Finland. Lung function test were conducted using the spiobank G SN A23-048.00000 (Italy) and the parameters of interest were FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratio.

### 2.3. Exposure Assessment

The primary measure of indoor air pollution was particulate matter of aerodynamic diameter >2.5 and volatile organic compounds (VOC). The measurement was conducted using a foobot FBT0002100 (China) and 24h average readings were obtained in households.

### 2.4. Data Analysis

Data was analyzed using SPSS version 20 and Mean concentrations, median distributions and standard deviations for PM<sub>2.5</sub> and VOCs in µg/m<sup>3</sup> and ppb respectively were calculated. Comparisons of distributions of PM<sub>2.5</sub> & VOCs between health endpoints or rural and urban areas using Mann Whitney U test and Kruskal Wallis test were

performed. Multinomial logistic regression for associations and the relative risk ratios to determine the risk of having respiratory symptoms among women from households with varying levels of indoor air pollutants were conducted.

### 3. Results

#### 3.1. General Characteristics

The study considered a sample size of 1,170 pregnant women of which the majority (91.2%) were married with more than half (54.6%) having attained secondary and only close to a third (30.0%) primary education. More than two thirds (69.6%) of the participants were unemployed and were mainly housewives. Hypertension and diabetes were not common and only 3.7 and 1.8% respectively were reported. Percentages of 19.7 and 3.1% constituted reports of alcohol use and cigarette smoking respectively.

#### 3.2. Exposure Variables

Only less than 5% of the women reported not being involved in cooking duties during pregnancy. Charcoal was the main biomass fuel used in cooking followed by wood in the population (Table 1). Table 2 shows a summary of the various types of cooking environments reported in the rural and urban study population.

**Table 1. Cooking fuel types of rural, urban and whole population**

Fuel type	Rural		Urban		Total	
	%	95% CI	%	95% CI	%	95% CI
Wood	36	32.2-40.4	8	6.2-10.2	15	13.1-17.0
Crop residue	4.3	2.4-6.0	2	1.0-3.0	2	1.4-3.1
Charcoal	56	52.1-61.0	51	47.3-55.0	52	49.3-55.2
Electricity	3.7	2.0-4.2	16	13.1-18.4	12	11.0-15.0

**Table 2. Showing types of cooking environments in the rural and urban population of the study**

Kitchen type	Rural		Urban		Total	
	%	95% CI	%	95% CI	%	95% CI
Under a shed	13	6.0-10.0	8	6.1-9.2	8.0	6.1-9.2
Semi-enclosed	17	14.4-20.0	17	15.0-19.2	17.0	15.0-19.2
Enclosed	43	34.3-41.4	40.1	37.3-43.1	40.1	37.3-43.1
Open space	14.3	19.3-25.4	20.3	18.0-23.0	20.3	18.0-23.0
Living room	1.2	1.0-3.0	1.4	1.0-2.3	1.4	1.0-2.3
Unclassified	13.2	12.3 -16.0	14	11.0-16.3	14.0	11.0-16.3

#### 3.3. PM2.5 and VOCs Monitoring

Indoor PM2.5 varied between 79 µg/m<sup>3</sup> and 921µg/m<sup>3</sup>, with an overall mean (SD) for daily average of 444.5 µg/m<sup>3</sup> (170.2) while VOCs the range was from 245 ppb to 393 ppb with an overall mean (SD) for daily average of 342 ppb (25.3). The maximum readings were obtained during cooking time while the minimum before cooking period. Table 3 presents the overall median PM2.5 and VOC in the entire population while Table 4 is an indoor air pollution concentration index for PM2.5 and VOCs.

**Table 3. Showing overall mean PM2.5 and VOCs in the whole population**

Pollutants	Median (Q1, Q3)
<b>PM2.5</b>	
During cooking	501 (411, 686)
Daily average	393 (303, 578)
<b>VOC</b>	
Daily average	343 (320, 363)

The median (Q1, Q2) recorded for the study population for PM2.5 during cooking activities and daily average were 501(411, 686) and 393 (303,578) while for VOCs daily average was 343(320, 363).

**Table 4. PM2.5 and VOC concentration index**

Period	PM2.5 ( $\mu\text{g}/\text{m}^3$ )	From	To	VOC (ppb)	From	To
Before cooking	Low	79	179	Low	245	320
	Moderate	180	344	Moderate	321	350
	High	345	664	High	351	383
During cooking	Low	335	432	Low	297	322
	Moderate	433	601	Moderate	323	353
	High	602	921	High	354	393
After cooking	Low	262	369	Low	272	333
	Moderate	370	535	Moderate	334	363
	High	536	855	High	364	393
Daily average	Low	226	328	Low	300	325
	Moderate	329	493	Moderate	326	355
	High	494	813	High	356	385

**3.4. Maternal Respiratory Symptoms**

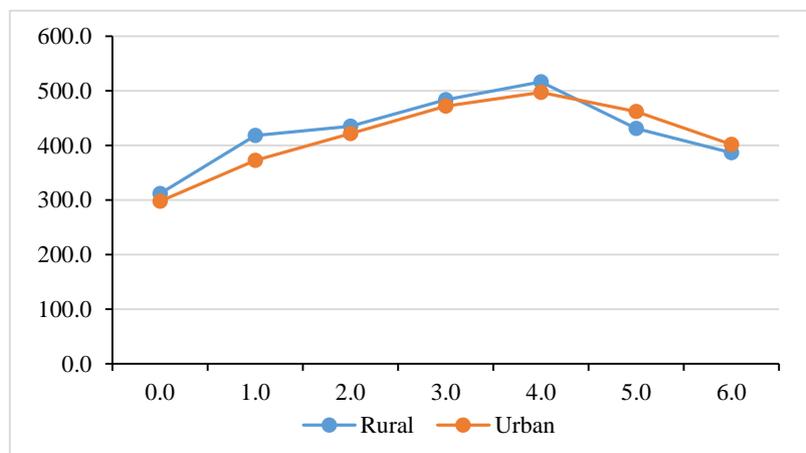
Cough was the main respiratory symptom among the participants followed by sputum then nasal symptoms. The rural area had more records of cough and sputum compared to the urban area.

Maternal respiratory symptoms and mean household air pollution (PM2.5 and VOC) concentration levels in rural and urban area.

**Table 5. Presents the proportion of pregnant women with respiratory symptoms**

	Rural	Urban	Total
Symptom	%	%	%
Cough	79.4	69.0	72.0
Sputum	48.0	45.3	46.0
Wheezing	34.0	29.3	30.4
Breathlessness	17.3	16.0	16.3
Nasal symptoms	41.0	47.2	46.0
Throat symptoms	37.0	32.0	33.0

Figure 1 shows that on average a PM2.5 of  $311.3\mu\text{g}/\text{m}^3$  in rural and  $297.6\mu\text{g}/\text{m}^3$  in urban areas has no effect on maternal respiratory symptoms. Impliedly an additional PM2.5 of  $106.7\mu\text{g}/\text{m}^3$  in rural areas and  $74.7\mu\text{g}/\text{m}^3$  in urban areas marks the onset of respiratory symptoms among exposed pregnant women. Therefore, exposing a pregnant woman to an indoor mean concentration of  $418\mu\text{g}/\text{m}^3$  in rural areas and  $372.3\mu\text{g}/\text{m}^3$  in urban areas increases the risk of having at least one respiratory symptom.



**Figure 1. Number of maternal respiratory symptoms versus mean indoor concentration levels of particulate matter (micrograms) in rural and urban areas**

On average a PM2.5 of 311.3µg/m<sup>3</sup> in rural and 297.6µg/m<sup>3</sup> in urban areas has no effect on maternal respiratory symptoms. Impliedly an additional PM2.5 of 106.7µg/m<sup>3</sup> in rural areas and 74.7µg/m<sup>3</sup> in urban areas marks the onset of respiratory symptoms among exposed pregnant women. Therefore, exposing a pregnant woman to an indoor mean concentration of 418µg/m<sup>3</sup> in rural areas and 372.3µg/m<sup>3</sup> in urban areas increases the risk of having at least one respiratory symptom.

**Table 6. Showing mean differences of indoor PM2.5 between participants with and those without respiratory symptoms in rural area**

Group	Mean (SD)	95% C.I
Without MRS	53.7 (11.0)	(45.2, 62.1)
With MRS	83.9 (35.5)	(80.7, 87.2)
Combined	83.4 (35.4)	(80.2, 86.6)
diff	-30.3(11.8)	(-53.5, -7.1)
<b>p value =</b>	0.011	

After running an independent test to ascertain mean differences of PM2.5 and maternal respiratory symptoms, the findings indicate that there was a statistical significant mean difference in PM2.5 of those with respiratory symptoms and those without respiratory symptoms in both rural (p-value= 0.0109) and urban (p-value <0.0001) area.

### 3.5. Multinomial Logistic Regression

Impact of HAP (PM2.5 and VOC) on the number of maternal respiratory symptoms.

There was a statistically significant association between mean indoor PM2.5 concentration levels and the number of maternal respiratory symptoms. However, mean indoor volatile organic compounds concentration levels did not show any significant association with the number of maternal respiratory health.

**Table 7. Showing the association between maternal respiratory symptoms (MRS) and household air pollution (PM2.5 and VOC)**

		Number of respiratory symptoms						
		0	1	2	3	4	5	6
	PM25	1	1.04*	1.04**	1.05**	1.05***	1.04*	1.03
<b>Rural</b>			(1.00 - 1.08)	(1.00 - 1.08)	(1.01 - 1.09)	(1.01 - 1.10)	(1.00 - 1.08)	(0.98 - 1.08)
	VOC	1	1	1.02	1.03	1.01	1.01	1.07
			(0.93 - 1.08)	(0.95 - 1.09)	(0.97 - 1.11)	(0.94 - 1.08)	(0.94 - 1.09)	(0.97 - 1.19)
	PM25	1	1.05***	1.06***	1.07***	1.07***	1.07***	1.05***
<b>Urban</b>			(1.01 - 1.08)	(1.03 - 1.09)	(1.04 - 1.10)	(1.04 - 1.11)	(1.03 - 1.10)	(1.02 - 1.09)
	VOC	1	0.99	0.98	0.99	0.98	0.96*	1
			(0.95 - 1.03)	(0.95 - 1.02)	(0.95 - 1.03)	(0.94 - 1.03)	(0.92 - 1.01)	(0.93 - 1.08)

ciEform in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## 4. Discussion

This study is one of the first to evaluate household air pollution using PM2.5 and VOCs as indicators in Zambian houses. To the best of our knowledge it is the first study, to derive an optimal mean indoor PM2.5 threshold for detecting onset of respiratory symptoms in Zambia among pregnant women that cook predominantly with solid fuel. The current study found high indoor mean PM2.5 and VOCs concentration levels in both rural and urban areas of the study population. However, there seemed to be higher mean indoor concentration levels of PM2.5 and VOCs in households that used biomass only compared to those that used electricity. This result is in accord with what is pertaining in sub-Saharan Africa and similar findings elsewhere indicate that particulate matter levels may be 10–50 times higher than the recommended standards in houses where solid fuels are used [16]. Our study also observed more respiratory symptoms among women from households where biomass only was used as cooking fuel compared to women from households that used electricity. This finding is consistent with research results in randomized control trials in rural Mexico that indicated that cleaner fuels were significantly associated with a reduction of respiratory symptoms among women [17].

We found that there was a significant association between mean indoor PM<sub>2.5</sub> concentration levels and onset of maternal respiratory symptoms. These findings are consistent with results elsewhere [18], indicating that even short-term exposure to PM<sub>2.5</sub> results increased risk for cardiovascular and respiratory hospital admissions and this is further confirmed by studies which indicate that even at relatively low levels respirable particulate exposure can increase respiratory symptoms and mortality [19, 20]. Results in an Indian study also showed that increased respiratory symptoms are related to an increased indoor concentration levels of PM<sub>2.5</sub> [21, 22]. The gases and particles are said to be responsible for weak host defenses against respiratory infections which would further lead to an increased predisposition to respiratory infections. Inflammation of the airways and alveoli, resulting from the exposure to these pollutants, may be another mechanism increasing the severity of respiratory infections [23].

A review of information relating to air pollution in Zambia indicate that there is paucity of such information because like in many countries in the sub-Saharan Africa, air monitoring is limited and there is a lack of air quality standards at national level. In our study, an indoor mean concentration of 418 $\mu\text{g}/\text{m}^3$  in rural areas and 372.3 $\mu\text{g}/\text{m}^3$  in urban areas was responsible for increasing the risk of having at least one respiratory symptom among pregnant women. This is comparable with previous studies conducted in Asia [24] stating that PM<sub>2.5</sub> concentrations in houses get as high as over 2000  $\text{mg}/\text{m}^3$  and in some African countries like Zimbabwe and Kenya where indoor air pollution monitoring has been conducted [23, 25]. The findings of our study show that indoor air pollution in our study population excessively exceed the WHO recommendations [26, 27].

This finding is an indication that Zambian urban and rural women will continue to carry the burden of air pollution-related morbidity and mortality if no public health interventions are implemented to control the poor environmental conditions which are fueled by limited air monitoring and lack of air quality standards at national level. Our current study creates an important baseline for the implementation of systematic PM<sub>2.5</sub> data collection to enable air pollution-related respiratory health impact assessment among women predominantly using biomass for cooking. This will in turn help in the development of strategies and policies relating to air quality and respiratory health.

The promotion of gas and electricity as household fuels has not, until quite recently, been linked to the health agenda surrounding continued use of biomass. Primarily in India starting in 2015, but also beginning in a few other countries, however, there have recently been major government-led programs launched to enhance the use of LPG driven in large part by health concerns.

## 5. Conclusion

Household air pollution levels in Zambian homes are high. Further research work is required because the concentration levels that have been observed in this study are hazardous and are likely to be have adverse health outcomes. Public health interventions should therefore be identified to reduce indoor concentration levels to less harmful standards. The process of reducing concentration levels of PM<sub>2.5</sub> is beyond the control of individuals and requires action by public authorities and health sector can play a pivotal role in leading a multi-sectoral approach to the prevention of exposure to air pollution by engaging and supporting other relevant sectors such as housing, industry and energy sectors in reducing the risk of indoor air pollution to respiratory health among women.

Therefore, since our intended goal to lower disease rates and health care costs, the practical way of responding to these challenges is to abide by the new WHO Indoor Air Quality Guidelines which among other issues recommend phasing out household kerosene and coal use, scaling-up production and use of the cleanest household fuels, including LPG, ethanol and biogas. The guidelines also recommend transitioning from inefficient biomass cookstoves to improved models with adequate venting. Small solar systems to power lights can be substitutes for kerosene lamps – in homes

## 6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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