Impact of main living room's ventilation quality on occurrence of obstructive pulmonary diseases (Asthma and COPD) in Medina (Senegal)

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Abstract

Indoor air pollution is the underlying cause of 4 million deaths worldwide, of which 11% is directly attributable to obstructive pulmonary disease. This study made it possible to characterize indoor air pollution in the Medina (Dakar) and to estimate occurrence risk of obstructive pulmonary diseases associated to lack of ventilation in main living room. This is a cross-sectional study combining a socio-demographic survey, air quality metrology (CO, PM_{10}, NO, CO_2) and a Functional Respiratory Assessment (spirometry). Estimation of the risk was carried out by logistic regression by adjusting for a certain number of factors. Participants are distributed between 27 households using mainly gas (55.56%) and charcoal (29.63%) as cooking fuel and closed kitchens with window (66.67%). Obstructive pulmonary diseases are noted with an estimated prevalence of 33.06%. Regarding pollutants, levels are below WHO guidelines: CO (3.81 ppm), CO_2 (531.5 ppm), PM_{10} (0.27 µg/m^3) and NO (2.88 µg/m^3). In addition, study reveals an occurrence risk (AOR [95%CI]) of obstructive pulmonary diseases multiplied by 2.54 [1.27-5.08] where ventilation of main living room is medium and for exposure to poor ventilation, risk is multiplied by 2.06 [1.02-4.17]. These results therefore suggest indoor air quality, in particular renewal of air in main living room, as a factor determining residents respiratory health.

Introduction

Individuals spend on average 80% of their time inside buildings (housing, public establishments, transport, etc.)[1]. Composition of these environments varies according to weather and activities that take place there. Most of these anthropogenic activities emitting pollutants inside buildings are known. For housing, these include combustion processes (biomass, smoking, etc.), cleaning products, waste incineration, road traffic and/or influence of nearby industries[2]. These sources contaminate indoor air by emitting carbon monoxide, volatile organic compounds (benzene, toluene, ethylbenzene, xylene, formaldehyde, etc.), particulate matter, with harmful consequences for health and environment[3,4]. According to World Health Organization (WHO), indoor air pollution is the underlying cause of 4 million deaths worldwide, most of which occur in low- and middle-income countries[5] (WHO, 2021). In addition, 11% of these deaths are directly attributable to obstructive pulmonary diseases[6]. Countries of Southeast Asia and sub-Saharan Africa are the most affected by these conditions. Among other obstructive respiratory diseases are asthma and Chronic Obstructive Pulmonary disease (COPD) in first line. Prevalence of the latter varies respectively between 4 and 14% and between 4 and 25% in sub-Saharan Africa[7]. These data are supported by a few rare studies carried out in Africa with significantly higher prevalence compared to developed countries[8–10]. In Burkina and Senegal for example, respectively, a prevalence of 18.18% of asthma in women exposed to biomass smoke[9] and 43% of allergic rhinitis in street vendors exposed to road traffic has been documented[11]. These studies are an illustration of the negative impact of air pollution on respiratory health. This study supports existing literature on indoor air pollution and its health impact, particularly in Medina, a cosmopolitan city of Dakar.

Methods

Setting and study design

This is a cross-sectional study combining a socio-demographic survey, air quality metrology and a Functional Respiratory Assessment. Study took place in the Medina, one of the most populous cities in Dakar with a population density of 40,667 inhabitants / km^2 ([12]). Several main and secondary roads pass through the city, hence the heavy traffic on it. In addition, Medina is characterized by the narrowness of housing, most of which accommodates several families. These common housing often have open or closed kitchens with window and very little green space.

Data Sampling and collect

Indoor air quality metrology: Measurement campaign included 27 dwellings, at the rate of two successive days of sampling by 7 hours of time for each of them. Measurements were carried out using air quality monitors: *AQ Pro version 1.05* is used to measure levels of nitrogen oxides (NO and NO_2) while *EVM-7 version 1.05* is used for carbon oxides (CO and CO_2) and Particulates Matter (PM_{10}) levels measurement.

Socio-demographic survey

In each home included in study, a questionnaire was administered to volunteers (over 11 years old). In addition to certain housing characteristics (type of housing, cooking fuel, type of kitchen, burning incense, ventilation, etc.), this questionnaire is used to collect individual information (age, sex, smoking status, health status, etc.).

Functional Respiratory Assessment

It was carried out by spirometry and included participants in socio-demographic survey and others volunteers (over 7 years old) who had lived in Medina for at least five years and who had not had recent thoracic surgery. Moreover, parental consent had been obtained for children. Spirobank II and its accessories (scale, centimeter, recyclable tips, bronchodilator (*salbutamol®*) and inhalation chamber) were used to perform examination. This was done in a seated position and using a nose clip as recommended by American Thoracic Society (ATS). A first phase without bronchodilator was implemented, then a second phase, 15 minutes after inhalation of the bronchodilator. Slow Vital Capacity and Second Maximum Expiratory Volume (FEV1) were obtained during this examination, as well as Forced Vital Capacity (CVF), estimates of Median Maximum Expiratory Flow (MED) at 75%, 50%, and 25% of CVF and Maximum Minute Ventilation (VMM).

Description of variables of interest

- **Obstructive lung disease**: It is defined as a dependent variable and corresponds to being diagnosed with asthma and/or obstructive pulmonary disease. These disorders were diagnosed by spirometry according to the criteria of the Global Initiative for Asthma (GINA), and the Global Initiative for

Chronic Obstructive Lung Disease (GOLD)[13]. Obstructive syndrome is first retained in face of a decrease in FEV1 more than 12%, a FEV1/FVC ratio less than 70% and a reduction of more than 20% in other ventilation flows. Differential diagnosis of asthma and COPD is made through a bronchial obstruction reversibility test using a β2 mimetic (salbutamol)[13,14]. In addition, restrictive syndrome (restrictive ventilatory disorder, bronchospasm) is retained on basis to a decrease in slow vital capacity (CVL) and FEV1/FVC ratio greater than 95% in basal state[13].

- **Main living room's ventilation**: It is a variable with three levels (good, medium and bad). Good ventilation corresponds to presence of at least one door and at least one window permanently open during the day. As for medium ventilation, it corresponds to presence of at least one door permanently open during the day associated to absence of a window. And finally, poor ventilation, corresponds to presence of at least one door not permanently open during the day associated to absence of window.

Statistical analysis

Analysis was carried out with R software after merging different databases (spirometry, survey and air quality), setting a significance threshold for estimates at 5%. Data were described in form of frequencies (for qualitative variables), mean and standard deviation (for quantitative variables). Factors associated with obstructive lung disease were determined using chi-squared test and impact measurement was caried out by logistic regression. The odds ratios (Crude Odds Ratios (COR) and Adjusted Odds Ratios (AOR)) were estimated along with their 95% confidence intervals (95% CI).

Ethical considerations

This study was approved by the ethics committee of Cheikh Anta Diop University under number (0335/2018 / CER / UCAD) issued on 25 / May / 2018. The process was explained to participants, who in turn signed an informed consent letter after reading and understanding study objectives. All participants were coated according to the standards of the Helsinki Declaration, respecting the criteria of anonymity, obtaining consent, confidentiality of results, risks and benefits of the study.

Results

Respondents' individual characteristics: A total of 27 households and 365 volunteers participated (N) in study. The latter concerned all residents aged at least 7 years. Sample was mainly made up of adults (42.47%), with a strong participation of children (29.86%) and adolescents (21.1%) as well as a slight female predominance (52.05%). Less than half of respondents declared having occupational activity (45.7%) and 3.91% of participants are current smokers versus 7.03% former smokers. Pulmonary diseases are noted in 37.16% of participants; these are distributed as follows: asthma (25.74%), COPD (61.03%), bronchospasm (10.29%), mixed ventilatory disorder (2.21%) and other (0.74%). Thus, prevalence of obstructive ventilatory diseases is estimated at 33.06% (Table 1).

Table 1
Respondents individual characteristics (in %)

Respondent characteristics	Frequency
	N = 365
Current age (in year)	
child= [7,15)	29.86
adolescent= [15,25)	21.1
adult= [25,65)	42.47
elderly person= [65,84]	6.58
Sex	
female	52.05
male	47.95
Lung disease	
Yes	37.16
No	62.84
	N = 135
Type of lung disease	
Asthma	25.74
COPD	61.03
Bronchospasm	10.29
Mixed ventilatory disorders	2.21
Other	0.74
	N = 365
Prevalence of obstructive lung disease[1]	33.06
	N = 256
Occupational activities	
yes	45.7
no	54.3

N = Sample size used for tabulation;[1] obstructive lung disease included Asthma, Chronic Obstructive Pulmonary disease (BPCO) or having both;

Respondent characteristics	Frequency
Tobacco-use status	
current smoker	3.91
ex-smoker	7.03
non-smoker	89.6
N = Sample size used for tabulation;[1] obstructive lung disease included Asthma, Chronic Obstructive Pulmonary disease (BPCO) or having both;	

Households selected characteristics: Table 2 records characteristics of surveyed households. Three types of households were identified with the majority having a surface of 150 m2 (74.07%): larger household (44.44%), apartment (37.04%) and wooden house (18.52%). Average number of residents per household is 20.89 (+/- 13.13) and more than half of the households have a good ventilation overall (59.26%). However, concerning main living room, less than half of households (25.95%) have a good level of ventilation. Regarding polluting activities related to cooking, households mainly use closed with window: 66.67% versus 25.93% of open-air kitchen. In addition, 55.56% of households use gas as cooking fuel versus 29.63% of charcoal users. Cooking takes an average 2 hours for the majority of households (55.56%). In addition, exposure to tobacco smoke and deodorant are respectively estimated at 66.67% and 55.56%. However, residents' exposure levels to pollutants such as CO (3.81 ppm), CO_2 (531.5 ppm), PM_{10} (0.27 µg/m^3) and NO (2.88 µg/m^3) are below WHO reference values (Table 2).

Table 2
Housing characteristics (in %) including indoor air parameters (in mean [+/- sd)

Frequency	
Housing characteristics	N = 27
Household type	
larger household	44.44
apartment	37.04
wooden house	18.52
housing size (in m^2)	
150	74.07
300	22.22
200	3.7
Number of residents	
mean [+/- sd]	20.89 [+/- 13.13]
Number of living room	
mean [+/- sd]	12.96 [+/-8.88]
Housing ventilation	
good	59.26
medium	37.04
bad	3.7
Main living room’s ventilation	
good	25.93
medium	33.33
bad	40.74
Kitchen type	
closed with window	66.67
open air	25.93
in bedroom	7.41

Frequency	
Type of cooking fuel	
gas	55.56
charcoal	29.63
both (gas and charcoal)	14.81
Average mean of cooking duration	
1 hour	37.04
2 hours	55.56
3 hours	7.41
Exposed to incense smoke	
yes	66.67
no	33.33
Exposed to deodorants	
yes	55.56
no	44.44
	mean [+/- sd]
Levels of indoor air pollutants	
CO (ppm)	3.81 [+/- 7.53]
CO_2 (ppm)	531.5 [+/- 121.46]
PM_{10} (ug/m^3)	0.27 [+/- 0.26]
NO (ug/m^3)	2.88 [+/- 14.96]

sd = standard deviation

Occurrence of obstructive lung disease by selected characteristics and chi-squared test

Regarding to results of bivariate analysis main living room's ventilation is significantly associated with occurrence of obstructive lung disease ($p = 0.02 < 5\%$). Indeed, 16.16% of participants with an obstructive lung disease lived in households where main living room' ventilation is bad while 12.60% and 3.84% of them respectively lived in households with a medium and good ventilation for this room (Table 3).

Table 3
Distribution of obstructive lung disease (in %) according to selected characteristic

Selected characteristics	Obstructive lung disease	Chi-2 test's p-value
Individual characteristics		
Current age (in year)		0.91
child= [7,15)	9.59	
adolescent= [15,25)	6.58	
adult= [25,65)	14.79	
elderly person= [65,84]	1.92	
Sex		0.22
female	18.63	
male	14.25	
Housing characteristics		
Household type		0.48
larger household	15.62	
apartment	11.51	
wooden house	5.75	
housing size (in m^2)		0.12
150	27.67	
300	3.84	
200	1.37	
Housing ventilation		0.10
good	21.64	
medium	9.59	
bad	1.64	
Main living room's ventilation		**0.02****
good	3.84	
medium	12.88	

*Close to significance; **significant*

Selected characteristics	Obstructive lung disease	Chi-2 test's p-value
bad	16.16	
Kitchen type		0.41
closed with window	18.90	
open air kitchen	12.60	
in bedroom	1.37	
Type of cooking fuel		0.95
gas	12.88	
charcoal	13.15	
both (gas and charcoal)	6.85	
Average mean of cooking duration		0.56
1 hour	13.97	
2 hours	18.08	
3 hours	0.82	
Exposed to incense smoke		0.10
yes	21.92	
no	10.96	
Exposed to deodorants		0.05*
yes	21.37	
no	11.51	

Close to significance;significant*

Impact measurement by logistic regression

Both in univariate and multivariate logistic regression, main living room's ventilation is associated with an excess risk occurrence of obstructive lung disease. Results reveal Crude Odds Ratios of 2.55 [1.08–4.23] and 2.14 [1.31–4.96] for respectively medium and poor levels of ventilation. After adjusting for age, sex, smoking status, occupational activities and exposure to deodorant, Adjusted Odds Ratios (AOR) were estimated at 2.54 [1.27–5.08] (medium ventilation) and 2.06 [1.02–4.17] (bad ventilation) (Table 4).

Table 4
Univariable and adjusted logistic regression models between obstructive lung disease and level of living room ventilation

Variables	Univariable model			Adjusted model		
	COR	95% CI	p-value	AOR	95% CI	p-value
Main living room's ventilation						
good[ref]						
medium	2.55	[1.08–4.23]	< 0.01**	2.54	[1.27–5.08]	< 0.01**
bad	2.14	[1.31–4.96]	0.03**	2.06	[1.02–4.17]	0.04**
Exposed to deodorants						
yes[ref]						
no				1.59	[0.99–2.57]	0.05*
Current age (in year)						
adult= [25,65)[ref]						
child= [7,15)				0.9	[0.46–1.75]	0.75
adolescent= [15,25)				0.85	[0.43–1.70]	0.65
elderly person= [65,84]				0.85	[0.30–2.40]	0.76
Sex						
male[ref]						
female				1.13	[0.69–1.86]	0.63
Occupational activities						
yes[ref]						
no				1.03	[0.55–1.92]	0.92
Tobacco-use status						
non-smoker[ref]						
ex-smoker				0.49	[0.13–1.88]	0.30
current smoker				2.13	[0.52–8.66]	0.29

*ref = Reference category; * close to significance; ** significant;*

Discussion

Average number of residents per household is estimated at 20, therefore higher than national average (6 residents) and those found in Ouagadougou (7 residents) and Durban (14 residents)[15–17]. This situation reflects a promiscuity, partly explained by the history of the city. It happens to be a traditional residential area of which most of the housing is legacies[15] hence the polynuclear structure of families. Moreover, for its proximity to the town, Medina is a locality where civil servants and informal sector's workers converge[18]. 3.91% of respondents (children excluded) declared to be current tobacco smokers, a proportion below the national average estimated at 6% in 2015 ([19]). This low proportion would be linked to the massive presence of women whose consumption is lower compared to men, but also to religion and culture. However, study reveals a high proportion of exposure to passive smoking (66.67%), i.e., twice the 25% recorded in India[20]. The same is observed for exposure to deodorant (estimated at 55.56%). This could be the result of increased promiscuity in urban areas and high demography (about 5% per year)[21]. Indeed, Dakar concentrates about 23% of Senegalese population and nearly 61% of urban population[21]. Participants in study are distributed between 27 households which mainly use liquefied petroleum gas (55.56%) as cooking fuel versus 29.63% of charcoal users. Liquefied petroleum gas is indeed used very widespread in Senegal, particularly in urban areas where it is estimated at 49.5% versus 24.1% of charcoal use[22]. Compared to other West African countries, Liquefied petroleum gas is used much lower: 60% (Burkina Faso), 98% (Mali) and 47% (Ivory Coast)[17,23,24]. Indeed, in most of these countries, access to clean energy is often more difficult for households[9]. In addition, certain ancestral culinary practices are still very widespread in these countries, unlike Dakar where westernization of life and lack of space no longer allow certain cooking methods. Biomass fuel is involved in deterioration of indoor air quality due to the significant emission of several harmful compounds such as carbon monoxide, Volatile Organic Compounds (VOCs) and suspended particles[17,25,26]. It is often used in closed kitchens with window, in open air or inside bedrooms. In urban area of Dakar, 66.67% of households have a closed kitchens window compared to 40.46% in Burkina and 31.3% in Mali[24,27]. Many of these kitchens are often poorly ventilated reflecting a high level of pollution. In these kitchens, also stay daily for hours, women preparing meals. Study reveals an average cooking duration of 1–3 hours. This is similar to that noted in India (2 hours) but relatively low compared to that found in Zimbabwe (1.5-9 hours)[20,28]. Concerning air quality metrology, study reveals concentrations below WHO regulatory values: CO (3.81 ppm), CO_2 (531.5 ppm), PM_{10} (0.27 µg/ m^3) and NO (2.88 µg/m^3). Higher levels of pollution have been documented by other studies. Indeed, much higher concentrations of NO (19 µg/m^3) and PM_{10} (19 µg/m^3) are found in Durban[16], and in Zimbabwe, a level of CO (23.0 mg /m^3) 8 times higher was observed[28]. These levels are the result of biomass combustion inside households, the lack of air renewal, a poor hygienic condition and a set of domestic practices emitting pollutants in air[25,29]. Air quality is a determinant of respiratory health, particularly, obstructive pathologies such as asthma and COPD. 37.16% of participants presented pulmonary involvement, which corresponds to asthma and COPD in 25.74% and 61.03% respectively. A proportion of asthmatics twice as high (45%) as that noted in present study is noted among bus drivers in

Dakar, unlike COPD (40%)[30] which is significantly under[30]. Lower proportions of asthma and COPD are documented by other studies in East Africa. Indeed, asthma and COPD are noted with respective proportions of 9.8% (Uganda) and 4.5% (Rwanda), i.e., 9 and 12 times the values recorded in Medina[31,32]. Moreover, prevalence of obstructive ventilatory disease (asthma and COPD) is estimated at 33.06%. This prevalence multiplied by 3 compared to a Nepalese study (8.1%) among adults exposed to biomass smoke[33]. Other non-obstructive pathologies were also diagnosed in Medina, these are restrictive ventilatory disorders (2.21%) and bronchospasm (10.29%). Main living room's ventilation has been identified as a determining factor in occurrence of obstructive ventilatory disease in the Medina. Indeed, adjusted risk (AOR [95%CI]) on age, sex, smoking status, occupational status and exposure to deodorant, is respectively estimated at 2.54 [1.27–5.08] and 2.06 [1.02–4.17] for medium and poor levels of ventilation for this room.

Conclusion

Study revealed a high prevalence of obstructive respiratory diseases among residents of the Medina. Lack of ventilation in main living room is a determining factor in occurrence of these disorders. This result suggests broadening and deepening studies on indoor air quality in housing and its health impact in order to have enough evidence to support advocacy for regulating indoor air level in Senegal.

Declarations

Data Availability Statement

The data generated and analyzed during the study are not publicly available because they are sensitive personal data. However, they are available to the corresponding author upon reasonable request.

Conflict of Interest

The authors declare that they have no conflicts of interest in relation to this article

Author's Contributions statement

Study conception and design: Salimata THIAM, Mouhamadou Lamine DAFFE, and Mamadou FALL; Data analysis: Salimata THIAM and Mouhamadou Lamine DAFFE; Interpretation and manuscript preparation: Salimata THIAM, Mouhamadou Lamine DAFFE, Khady THIAM and Mamadou FALL. All authors reviewed the results and approved the final version of the manuscript.

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