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Carbon Monoxide and Respiratory Disorders in Professional Female Fish Smokers at 2 Artisanal Sites in Benin

Mênonli Adjobimey[1,2*], Ibrahim Mama Cissé[3], Fintani Kaki[1], Mariano Steven[4], Sagbohan Perside[4], Fabien Gounongbe[3], Rose Mikponhoue[1], Ayélo Paul[1], Vikkey Hinson[1]

[1]Research and Teaching Unit in Occupational and Environmental Health, FSS Cotonou, Cotonou, Benin
[2]Occupational Health Service of the National University Hospital of Pneumo-Phtisiology of Cotonou, Cotonou, Benin
[3]Faculty of Medicine, Occupational Health Training and Research Unit, Parakou, Benin
[4]Inter-Faculty Centre for Environmental Training and Research for Sustainable Development, University of Abomey-Calavi, Abomey Calavi, Benin
Email: *menoladjobi@yahoo.fr

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Abstract

Introduction: The use of biomass for cooking is a very common practice in Africa and Benin, and is associated with exposure to organic pollutants. The aim of this study was to assess carbon monoxide exposure and respiratory disorders in women at artisanal fish-smoking sites. **Methods:** This was a cross-sectional study of women fish smokers at two artisanal fish-smoking sites in Benin. Recruitment was exhaustive. An interview using a respiratory questionnaire inspired by the Union questionnaire, spirometry and carbon monoxide (CO) measurement were carried out. Descriptive analysis and comparison of means using Student's t-test with a threshold of $p = 0.05$ were performed. **Results:** The median age of the 81 people surveyed was 40, with an interquartile range (IQT) of [25 to 75]. The median duration of daily exposure to smoke was 6 h IQT [4, 7]. Of those surveyed, 64 (79.01%) were illiterate and 39 (48.24%) had been working for 20 years. CO levels at the start of activity varied from 89 to 145 ppm in one case and from 40 to 89 ppm in the other. Respiratory symptoms were present in 19 (23.46%); 18 (22.22%) had mild airway impairment on spirometry. There was a statistically significant decrease between the mean values of peak expiratory flow (PEF), mean expiratory volume in seconds (FEV1) and forced vital capacity (FVC) before and after exposure to smoke. **Conclusion:** CO levels are high on fish smoking sites and respiratory problems are common. Improved working conditions are important for these women.

Keywords

Respiratory Symptoms, Spirometry, Carbon Monoxide, Fish Smoking,

Women

1. Introduction

Fish is a valuable source of protein and nutrients for people in many countries and its contribution to food security is increasing significantly. The annual global consumption of fish is more than 20.5 kilograms per person according to the Food and Agriculture Organization of the United Nations report in 2016 [1]. This attests to the essential role of this fisheries sector for food and nutritional security in the world. Indeed, each year more than 146 million tons of fish are destined for human needs [1]. One of the most widely used fish preservation techniques in the world and particularly in Africa is fish smoking [2]. Smoking is the process of treating fish by exposing it to smoke from the incomplete combustion of wood or vegetable matter. Artisanal fish processing is a lucrative fisheries sector practiced by many communities in most coastal African countries. More than just a temporary survival activity, fish smoking can be considered a permanent job [3]. However, despite its economic and nutritional importance and its undeniable social function, smoking still uses rudimentary techniques that expose smokers to numerous health and safety problems in the workplace, and also affect the quality of the product [2] [4]. Several studies have shown that air quality plays a role in the onset and aggravation of a number of cardiorespiratory diseases [5] [6] [7]. At the respiratory level, exposure to air pollutants contributes to the onset of pneumonia, chronic bronchitis and ventilatory disorders, and can lead to asthma and bronchopneumopathy [8] [9] [10]. The assessment of the respiratory impact of fish smoking on the health of women processors is therefore useful. In Benin, a study conducted by Agodokpessi *et al.* in 2011 among women fish smokers in Cotonou showed that 83.33% of respondents had at least one respiratory symptom and 11.90% had a minute-second expiratory volume (FEV1) of less than 80% of the theoretical value [11]. Similarly, a study of female fish smokers in the town of Porto-Novo in Benin showed a decrease in most ventilatory volumes and flows between measurements taken before and after exposure to smoking activity [12]. None of these studies took into account the measurement of atmospheric pollutants. Several projects to raise awareness and improve smoking ovens have been carried out across the country [13]. Given the lack of data on air pollutants and the fact that the results from Cotonou are older, the present study was initiated at two fish-smoking sites in and around Cotonou. The study was carried out as part of the preparations for a project by the NGO "Jeunes Volontaires pour l'Environnement" (JVE), which aims to improve working conditions for women at artisanal smoking sites by replacing traditional stoves with improved ones. The objectives of the study were to measure exposure to carbon monoxide (CO) and to determine the prevalence of respiratory disorders in women fish smokers.

2. Materials and Methods

2.1. Type and Period of Study

This was a cross-sectional descriptive study that took place from June 24 to September 6, 2019. Description of the workplace.

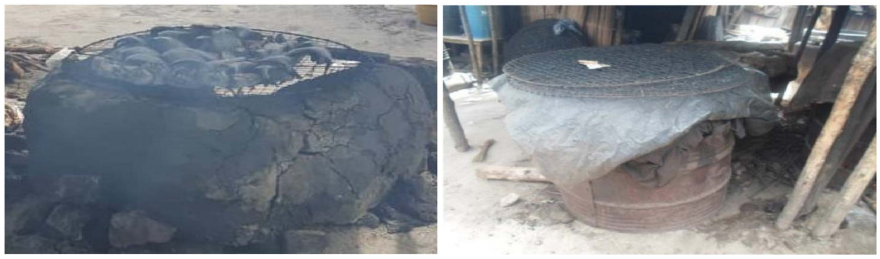
The study was carried out at two artisanal sites (Djeffa in Sème-Podji and Xwlacodji in Cotonou). These two sites were chosen because they are the largest in the towns of Cotonou and Semèkpodji, where fish smoking is a major activity. The stages of work on the sites consist essentially of buying the fish, packaging before cooking, smoking over a wood fire and packaging for marketing. The women work around the clock, with no fixed hours or daily schedules. Most of them have one day off a week. Smoking is done with smoke from wood fires or materials in barrels or clay ovens. Large quantities of smoke are released and inhaled by these women when they handle the fish to cook it, but also when they feed the fire. Some women lived in the workplace with their families. There was no personal protective equipment. In Xwlacodji, the smokehouse was located in an enclosure, covered in sheet metal (**Figure 1**). The women therefore worked in a confined space where the huge quantities of smoke produced had difficulty finding a place to dissipate. The stoves used on this site were made of iron barrels. At Djeffa, the smoking site was in the open air. The smoke produced dissipated immediately in the open air. The fireplaces used at this site are made of clay (**Figure 1**).

2.2. Study Population

All women who smoked fish at the study sites and had been in the business for at least two years were included. Women with a history of active or passive smoking (spouse's smoking), chronic respiratory pathologies (tuberculosis, asthma before entering the profession), or who had not performed the spirometry operations properly were excluded from the study.

2.3. Data Collection

A questionnaire based on the one developed by the International Union Against Tuberculosis and Lung Disease was translated into the local language and completed by a physician in a face-to-face setting to collect socio-demographic data, work history, respiratory symptoms and smoking history. A physical examination focusing on the pulmonary sphere was performed to look for clinical abnormalities. Two sets of pre- and post-exposure pulmonary function tests were performed by a qualified physician using a regularly calibrated portable spirometer (MIR Spirobank II). At least three tests were performed on each woman, taking into account the degree of cooperation and the appearance of the flow/volume curve. A test was defined as acceptable if the woman showed no signs of hesitation at the start of the measurement if she did not cough or hesitate during the operations, if there was no leakage from the mouthpiece, and if the exhalation lasted at least 6 seconds. FEV1, peak expiratory flow (PEF) and



(a) Barrel oven (Xwlacodji) (b) Clay oven (Djeffa)

Figure 1. Photos of the fish smoking system in each site in 2019.

forced means expiratory flow at 25% and 75% of lung volume (FEF 25% - 75%) and forced vital capacity (FVC) were measured. The spirometry results were interpreted by an occupational physician and a pulmonologist. The standard used was that of the African ethnic group incorporated in the spirometer software. For each parameter, the pathological threshold is defined by a result below the threshold of the theoretical value or expected value for the spirometry performed before the start of the job. For the spirometry performed after the shift, the pathological threshold is defined by a result lower than 20% of the value measured before exposure.

An instantaneous measurement of CO was performed using the Carbon Monoxide Meter (FLUS) gas detector calibrated in parts per million (ppm) with 1 ppm = 1.14 mg/m^3. The measurements were carried out on both sites. As the workstations were similar on the same site, the monitoring was carried out at a single randomly selected station per site. The measurements were carried out before the fire was lit, when the oven was lit, and 10 and 20 minutes after the start of smoking. The measurement was made at the respiratory level by placing the device on a stool at the respiratory level with respect to the woman in professional activity. The reading was made directly on the screen of the device.

2.4. Variables under Study

Chronic bronchitis is defined according to the WHO criteria as a chronic cough and sputum occurring 3 months a year for at least 2 years. Asthma is evoked by the notion of paroxysmal attacks of sibilant dyspnea, repeated episodes of chest wheezing or a spasmodic cough with repeated respiratory discomfort. Rhinitis is clinically defined by the presence of one or more of the following symptoms: nasal obstruction, rhinorrhea, pruritus and sneezing. Dyspnea was assessed according to Sadoul's 5-stage classification: stage 0 (no dyspnea), stage I (dyspnea when speeding up or climbing a slight hill), stage II (dyspnea when walking with people of the same age on level ground), stage III (dyspnea when walking at normal pace), stage IV (dyspnea when walking slowly) and stage V (dyspnea at the slightest effort). Women were considered symptomatic if they reported at least one respiratory symptom among the above-mentioned symptoms.

The ventilatory disorders were defined by comparing the spirometry measurements before the start of work with the upper and lower limit values of the theo-

retical value. Thus we distinguish:

Normal spirometry: LIN ≤ FEV1 ≤ ULN and LIN ≤ CVF ≤ ULN and LIN ≤ FEV1/CVF ≤ ULN.

An obstructive ventilatory disorder: FEV1/FVC < LIN and LIN ≤ FVC ≤ ULN.

A probable restrictive ventilatory disorder: FVC < LIN and LIN ≤ FVC ≤ LSN.

A probable mixed ventilatory disorder is a combination of probable obstructive and restrictive ventilatory disorders.

A small pathway syndrome: FEF25/75 < LIN FEF25/75.

2.5. Sample Size

The sample size was not calculated; a census of women smokers was carried out at each site. The number of women directly involved in smoking fish was 105 in both sites. We opted for exhaustive recruitment in order to include as many women as possible.

2.6. Statistical Methods

Data were entered and analyzed using Epi INFO software. A descriptive analysis of the data was performed. Proportions for qualitative variables and medians and interquartile ranges for quantitative variables were calculated because the distribution was not normal. Student's t-test was used for comparison of means at the significance level of $p = 0.05$.

2.7. Ethical Considerations

The smokers' consent was obtained prior to their inclusion in the study. Data were treated anonymously and confidentially. The study was conducted as part of a medical thesis in accordance with the principles of the Declaration of Helsinki. An authorization from the ethics committee was not obtained but the study was nevertheless registered under the number N° 2201/2019 at the Faculty of Health Sciences of the University of Abomey-Calavi.

3. Results

3.1. Socio-Professional Characteristics

A total of 81 women were included out of the 105 identified at the sites. The main reasons for non-inclusion were absence from the workplace, non-consent and less than two years of service. The median age of the women was 40, with an interquartile range of [25 - 75] and 28 (34.57%) were over 45 years. Among the women, 72 (88.89%) were Beninese; 22 (27.16%) did not live with a partner; 17 (21%) were in education; 39 (48.14%) had been working for more than 20 years and the median daily exposure time of the women was 6 hours at the IQT [4 - 7]. Table 1 shows the socio-professional characteristics of women fish smokers.

3.2. Carbon Monoxide Measurements

The level of CO above the fish smoking oven increased progressively over time

Table 1. Socio-professional characteristics of women fish smokers from Xwlakodji and Djeffa sites in Benin in 2019, (n = 81).

	Workforce	Percentage
Ages (years)		
[16 - 30]	21	25.93
[31 - 45]	32	39.51
[46 - 60]	18	22.22
[61 - 75]	10	12.35
Nationality		
Beninese	72	88.89
Other	9	11.11
Ethnicity		
Pedah and Xwla	54	66.67
Fon and related	16	19.75
Mina	06	7.41
Marital status		
Single	05	6.17
In couple	59	72.84
Divorced	06	7.14
Widow	11	13.58
Level of education		
Never attended school	64	79.01
Primary	01	1.23
Secondary	10	12.34
Tertiary	06	7.41
Type of site		
Xwalkodji	56	69.13
Djeffa	25	30.86
Seniority in position (years)		
[2 - 20]	42	51.85
[21 - 50]	27	33.33
Over 50	12	14.81

from 18 to 44 ppm at the ignition of the oven to 90 - 145 ppm 20 min after the operation at Xwlacodji and from 30 to 126 ppm at ignition to 40 - 73 ppm about 20 mm after the smoking operation at the Djeffa site. Table 2 summarizes the CO measurement results.

3.3. Clinical Symptomatology

Respiratory symptoms in women were: chronic bronchitis 12 (14.81%); rhinitis

Table 2. Carbon monoxide measurements at the two fish smoking sites.

	Xwlacodji site		Djeffa site	
	Schedule	**CO (ppm)**	**Schedule**	**CO (ppm)**
Measure 1 Before lighting the fire	07:25	0	07:05	0
Measure 2 When the fire is lit in the oven	07:32	18 - 44	07:12	30 - 126
Measure 3 At the beginning of the smoking of fish	07:45	89 - 145	07:25	40 - 89
Measure 4 After ten (10) minutes of smoking	07:55	88 - 115	07:35	40 - 75
Measure 5 After twenty (20) minutes of smoking	08:25	90 - 145	07:55	40 - 73

10 (12.34%); chest pain 5 (6.17%); dyspnoea 2 (2.5%); asthma 8 (9.88%). The prevalence of chronic respiratory symptoms was 23.45%. Body mass index was as follows: normal weight 35 (43.21%); overweight 25 (30.86%); obese 21 (25.93%). Lung examination revealed 28 (34.57%) cases of auscultatory abnormalities, such as bronchial rales, sibilant rales, or reduced vesicular murmur. These women were referred to the National University Hospital of Pneumo-Phtisiology for better management.

3.4. Ventilation Disorders

The functional disorders observed in the women surveyed were as follows: restriction: 47 (58.02%); small airway syndrome: 18 (22.22%). No cases of obstruction were observed. The mean values of FEV1 and FVC before the start of labour were all lower than the theoretical mean values of the women surveyed ($p < 0.001$), but the mean value of FEF 25/75, although lower than the theoretical mean, was not significant. A comparison of the mean values before starting work with those measured 8 hours after exposure showed a significant decrease in the mean values of FEV1 ($p = 0.0009$) and FEF 25/75 ($p = 0.0001$). Table 3 summarises the spirometry results. In addition, the percentages of women with a fall of at least 20% after taking up the post compared with before taking up the post were respectively: FEV1: 20 (24.69%); FVC: 20 (24.69); PEF: 18 (22.22%) and FEF 25/75: 31 (38.27%).

4. Discussion

The prevention of respiratory disorders in informal workplaces has received very little attention, unlike in the formal sector, particularly in industry. In addition

Table 3. Comparison of mean values of ventilatory flow rates and volumes between theoretical values and pre-exposure measurements and between post- and pre-exposure measurements; Benin, (n = 81).

	Comparison1			Comparison2		
	Theoretical values	Before exposure	p	Before exposure	After exposure	p
FEV1	2.39 ± 0.28	1.93 ± 0.87	<0.0001	1.93 ± 0.87	1.76 ± 0.57	0.0009
FVC	2.83 ± 0. 30	1.99 ± 0.87	<0.0001	1.99 ± 0.87	1.69 ± 0.48	0.0393
FEV1/FVC	84.47 ± 2.88	96.85 ± 8.43	<0.0001	96.85± 8.43	104.31 ± 9.4	0.4004
FEF 25/75	3.06 ± 0.46	2.78 ± 1.21	0.0516	2.78 ± 1.21	2.31 ± 0.85	0.0001

to describe respiratory disorders, this study took into account the environmental aspect by measuring CO monoxide in the workplace. A memory bias should be mentioned in the conduct of the study due to the anteriority of certain declarations, in particular respiratory symptoms. Comparison of the results with those of other authors is sometimes difficult because of the paucity of data in this informal sector.

Wood-burning stoves, heaters and chimneys emit large quantities of toxic compounds, in particular respirable particles with a diameter of <10 μm, CO, nitrogen and sulfur oxides (NOX and SOX), aldehydes, polycyclic hydrocarbons, volatile organic compounds, chlorinated dioxins and free radicals [14]. CO is the main gas resulting from incomplete combustion during smoking operations. Its level at the Xwlacodji site was higher, with a gradual increase, whereas at the Djeffa site there was a peak at the beginning of the activity and a gradual decrease after 20 mm. This difference in progression could be justified by the type of furnace used, the forms of fuel used and the ventilation of the workplaces. At the Djeffa site, the kilns used are made of clay, which concentrates the fumes more easily, the fuels used are firewood and coconut shells, and the work is done in the open air with a distance of at least 5 m between workstations. On the other hand, at the Xwlacodji site, the furnaces are made from makeshift metal barrels, the fuels used are firewood, wood chips and coconut husks, and the site is confined. CO is a dangerous gas that, when inhaled, can cause serious or even fatal poisoning. It is also toxic to the foetus and is therefore classified as toxic for reproduction [15].

The population concerned by this study is female, 25.93% of whom are under 30 and therefore in the reproductive period. The effects of CO depend on its concentration in the air and the duration of occupational exposure, defining the 8-hour time-weighted average and the short-term exposure limit value. The limit value for occupational exposure to CO is 17 ppm for an 8-hour exposure, according to the conclusions of the Committee of Specialised Experts of the French National Agency for Health, Food, Environmental and Occupational Safety [16]. The values currently in force in France (2019) and the European Union (2017) are 20 ppm for 8-hour exposure and 100 ppm for instantaneous exposure [17]. Some of the values in our study are higher than the exposure limit value. The average daily exposure time is 6 hours. The French National Agency for Health,

Food, Environmental and Occupational Safety recommends never exceeding a ceiling value of 200 ppm above the exposure limit value (15 mm), regardless of the duration of exposure, in order to protect workers [16]. The prevalence of respiratory symptoms was lower than that of Agodokpessi *et al.* who found that 83.33% of female fish smokers were symptomatic at the time of the survey in Cotonou [1]. This could be explained by the difference in the number of years of age of these two populations of women. In our study, 48.15% of the women had suffered from asthma for more than 20 years, compared with 73% in the study by Agodokpessi *et al.* In addition, the study by Agodokpessi *et al.* was carried out some ten years ago at the same Xwalcodji site in Cotonou. The proportion of women who knew they had asthma was half that found by Agodokpessi *et al.* (19.05%) [11], but lower than the results of Regalado *et al.* [18] who found a prevalence of 5.1% of asthma-diagnosed by a doctor in a population of women using biomass exclusively for food preparation. Methodological differences may explain this variation, as may differences in time, space and the populations studied. The association between exposure to smoke and respiratory symptoms has been documented by other authors. Dienye *et al.* in Nigeria found a higher risk of respiratory symptoms in female fish smokers than in the control group, with sneezing, rhinorrhoea, coughing and chest pain [19]. Other authors have studied the acute respiratory effects (coughing, rhinorrhoea, sneezing) at the time of smoking, and the prevalences were also high [20]. The effect of smoking on women's respiratory systems is therefore clear.

With regard to ventilatory disorders, no obstruction was found in our study, compared with 3.5% in the work by Agodokpessi *et al.* [11]. This difference could be explained by the diagnostic criteria used in our study and those of Agodokpessi *et al.* In fact, we used the lower limit of the theoretical ratio as a comparator for each woman, whereas in his study the author used the FEV1/FVC < 80% formula.

A Mexican study found FEV1/FVC < 70% in 13% of women using biomass [18], indicating an association between wood smoke and chronic obstructive pulmonary disease (COPD). Indeed, Orozco-Levi *et al.* showed a strong association between exposure to wood or charcoal smoke and COPD in Spain in a case-control study [21]. However, distal airway involvement was 22.2%. This damage usually sets the stage for obstruction if precautions are not taken. The lack of obstruction can also be justified by the withdrawal of sick people from the activity. Indeed, professional fish smoking is often a family activity and is passed on from generation to generation and from mother to daughter.

On the other hand, restriction was found in 58.02% of the women surveyed. This high prevalence of restriction could be explained by the fact that the diagnostic criterion used gives an overestimated value of the prevalence and that a good number of women (57%) were overweight. Indeed, obesity leads to restrictive impairment, changes in ventilatory mechanics and altered ventilatory control [22]. The proportion of distal airway obstruction was similar to that of Agodokpessi *et al.* despite the methodological diversity [11].

The obstruction is the functional disorder classically sought after exposure to smoke in order to demonstrate COPD. Other authors have found a means FEV1/FVC ratio of 68% in female smokers. Sali *et al.* in their editorial showed the involvement of fish smoking in the occurrence of COPD [10]. The comparison of the mean of the spirometry parameters before exposure and the mean of the theoretical parameters shows statistically significant differences in the means of FEV1, FVC and FEV1/FVC before exposure compared to the theoretical means. Also, the comparison between the means of spirometry parameters before and after daily occupational exposure shows a statistically significant drop in the means of FEV1, FVC and FEF 25-75. Similar results were observed by Aikpe *et al.* who compared a study before and after exposure to smoke and found a significant decline in the mean values of the following parameters: PEF, FEV1, FVC and the FEV1/FVC ratio [12]. Dienye *et al.* also found a significant difference between the mean PEF values of fish-smoking women and control women [19].

This drop in respiratory flow rates in the workplace following exposure to gas or dust is classic and even constitutes a diagnostic method for occupational asthma. Indeed, the fall in respiratory flow rates attests to the real inhalation of smoke by women during work and therefore invites the taking of measures to improve working conditions. Following the results of this study, an awareness campaign was conducted among women on the respiratory effects of fumes. As part of its project to replace traditional stoves with improved stoves, the NGO JVE has installed these new stoves, which considerably reduce women's exposure to smoke, while increasing their profitability and reducing the ecological pressure on mangroves caused by the use of wood. However, given the NGO's limited resources, not all the women have yet been able to benefit from the improved stoves.

5. Conclusion

Women who smoke fish are always exposed to pollutants from incomplete wood combustion. Distal respiratory tract damage is not negligible and is a warning sign requiring respiratory monitoring. A spirometry follow-up of these women as well as the improvement of the working conditions remain thus necessary. A cohort study would be welcome to better understand the chronology of respiratory damage in these women.

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Conflicts of Interest

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

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