Research Article

Traditional Smoking and Personal Exposure to Particulate Matter ($PM_{2.5}$) in Urban Area in Abidjan (Côte D'ivoire)

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Abstract

Introduction: Traditional smoking of fish and meat using firewood is practiced at large scales in most West African cities. this activity is harmful to the fish smokers; 83% prevalence of acute respiratory conditions and 49% of spirometry abnormalities.

Methods: We used a cross-sectional approach to compare the level of personal exposure to $PM_{2.5}$ in exposed persons and those who are not exposed to pollutants stemming from the artisanal smoking sites. $PM_{2.5}$ concentrations were registered over 24 hours using a DC1700 Air Quality Monitoring.

Results and discussion: Our study population consisted of 252 persons; 126 exposed and 126 nonexposed. We got a $PM_{2.5}$ daily average concentration of 46.88 ± 10.88 µg/m^3 in exposed persons and 43 ± 7.1 µg/m^3 in the nonexposed ones. This is 2.3 and 2.15 times higher than WHO guideline. The daily concentrations were caracterized by their variability. The lowest concentrations displayed between 00hrs and 05 hrs 59 a.m.; 34.8 ± 6.32 µg/m3 and 37.14 ± 8.33 µg/m^3; and the highest concentrations between 6.00 a.m and 4.00 p.m.; 56.92 ± 5.92 µg/m^3 and 45.35 ± 5.64 µg/m^3 respectively in exposed persons in the nonexposed ones. The $PM_{2.5}$ concentrations high between 6 o'clock and 4:59 p.m; in the nonexposed persons because of the road traffic but in exposed persons by the combined effects of road traffic and mainly of the artisanal smoking activities.

Conclusion: Personal exposure to fine particles helped to have an accurate scope of how pollution affects the populations. It also permitted to see that artisanal smoking adds up to $PM_{2.5}$ concentration in people living in the surroundings of the smoking sites.

Keywords: $PM_{2.5}$; Personal exposure; Traditional smoking

1. Introduction

Air pollution is a major environment risk factor for human health. Exposure to air pollution is estimated to be responsible for 8 million deaths in 2016 and most of these deaths occur in low- and middle-income countries [1]. A number of facts such as the number of exposed persons, the intensity and length of exposure, insufficiency in monitoring its morbid effects account for the severeness of its effects on the populations [2]. In Africa, as in the majority of middle and low-income countries, people depend on biomass fuel for cooking and heating [3]. People used wood, charcoal, crop residues and other raw plant material for making traditional dishes, smoke fish or meat [4]. Biomass combustion emit pollutants (Particulate matter with a size less than 2.5 micrometers (µm) (($PM_{2.5}$), carbon monoxide, nitrogen dioxide, etc.) and plays an important role in air pollution [1, 4] . Indeed, the average indoor and outdoor concentrations of $PM_{2.5}$ recorded in 76 % of households were 4 or 5 times higher than the World Health Organization (WHO) guideline value (25 µg/m^3) for air quality [4]. Fine particles can penetrate deeply into the respiratory system and reach up to the alveolus. Worst of all, they can even circulate to the cardiovascular system. Therefore, So, chronic exposure to $PM_{2.5}$ resulting from biomass combustion, increase the risk of cardiovascular and respiratory diseases and lung cancer [4, 5].

In Cote d'Ivoire, traditional method including smoking, drying, frying, etc. are used to preserve the perishable food. Traditional fish or meat smoking using firewood is a common practice in rural and urban cities. It also, artisanal smoking of foodstuffs such as frozen fish and meat is a very large sale business [6]. This business is exclusively in the hands of women essentially uses firewood as combustible [7]. Two studies conducted in Aplahoué and Cotonou - in Benin – have revealed 83% prevalence rates for acute respiratory conditions with a 49% of spirometry abnormalities and 100% of varied conditions in the women involved in the fish smoking business [6, 7]. In Abidjan – Cote d'Ivoire, we find these artisanal fish and meat smoking sites in most of the marketplaces and nearby stores. Hence, people in the neighborhoods – namely children of less than five years of age find themselves exposed to the pollutants emitted by the smoking sites [8, 9]. We actually carried out this study in order to assess the level of fine particles and carbon monoxide pollution caused by the artisanal smoking business. We specifically intended to see the exact extent to which artisanal fish and or meat smoking pollute neighbouring populations with $PM_{2.5}$ particles and carbon monoxide (CO). After presenting the socio-demographic characteristics of our study populations, we set to determining the hourly average $PM_{2.5}$ and CO concentrations per individuals from around the smoking site in the Niagon-sud and also from places far away. After that, we compared the concentrations registered from the two groups we set up.

2. Methodology

Our study aimed at assessing the level of $PM_{2.5}$ and CO pollution caused to people living in the vicinities of the foodstuffs artisanal smoking sites. To collect the $PM_{2.5}$ and CO data, we resorted to portable captors to measure personal exposure. The study is an analytic cross-sectional one based on the ‘‘here and elsewhere’’ principle. It was conducted from 29th November 2018 to 5th June 2019. Actually, it was intended to compare the personal exposure to fine particles sizing less than 2.5 µm including CO in two groups of people: those who reside in the surroundings of the artisanal smoking site on the one hand and on the other hand, those living in the same square but far away from the site.

2.1 Study population and setting

Our study populations were all residents from the Niangon-sud area in Yopougon; the largest commune of Cote d'Ivoire (Figure 1). We chose this area because there already existed consistent data on indoors and outdoors level, of road traffic and artisanal fish smoking pollution about it. The available data were produced by three (3) studies carried out in the framework of two projects [8-10]. The study population was divided in two groups; the group of people said to be ‘‘exposed’’ and the group of ‘‘non-exposed’’ people. The group of ‘‘exposed’’ was composed of people who live in the vicinities of an artisanal smoking site located in the ‘‘Lubafrique’’ sub-area in Niangon-nord. The site operates everyday round the week from 6 o'clock to 4 p.m except Sundays and the days of important popular feasts. The site uses firewood as its source of energy to smoke frozen meat and fish [8]. Empirically, we chose a *sample* size of n =120 and N=2n=240 people. Included in the study are residents of the ‘‘Lièvre Rouge’’ sub-area in Niangon-sud who have been doing a full-time occupation in a closed place for at least 2 years and aged more than 7 years. Were excluded from the study tobacco smokers and people in close contact with a tobacco smoker.

The study populations were selected using the three-degree random survey scale:

- Selection of the study areas: The group of exposed people consisted of persons spending the longest part of their typical day; approximately ten hours (08 hours to 18 hours) in the study area which was of 400 meters of radius from the artisanal smoking site. The non-exposed were from the ‘‘Lièvre Rouge’’ sub-area. They either resided or worked beyond 1 kilometer off the smoking site [11]. Out of the five targeted sub-areas, four got chosen by way of simple random drawing (Figure 1).
- Selection of households: In each of the study zones, the first household got chosen by convenience. The others got selected by relation.
- Selection of the individuals: In every targeted household, we selected two persons

who fulfilled our study criteria. But, when there were more than two falling into our selection category, we used the simple two-step random method to do the selection.

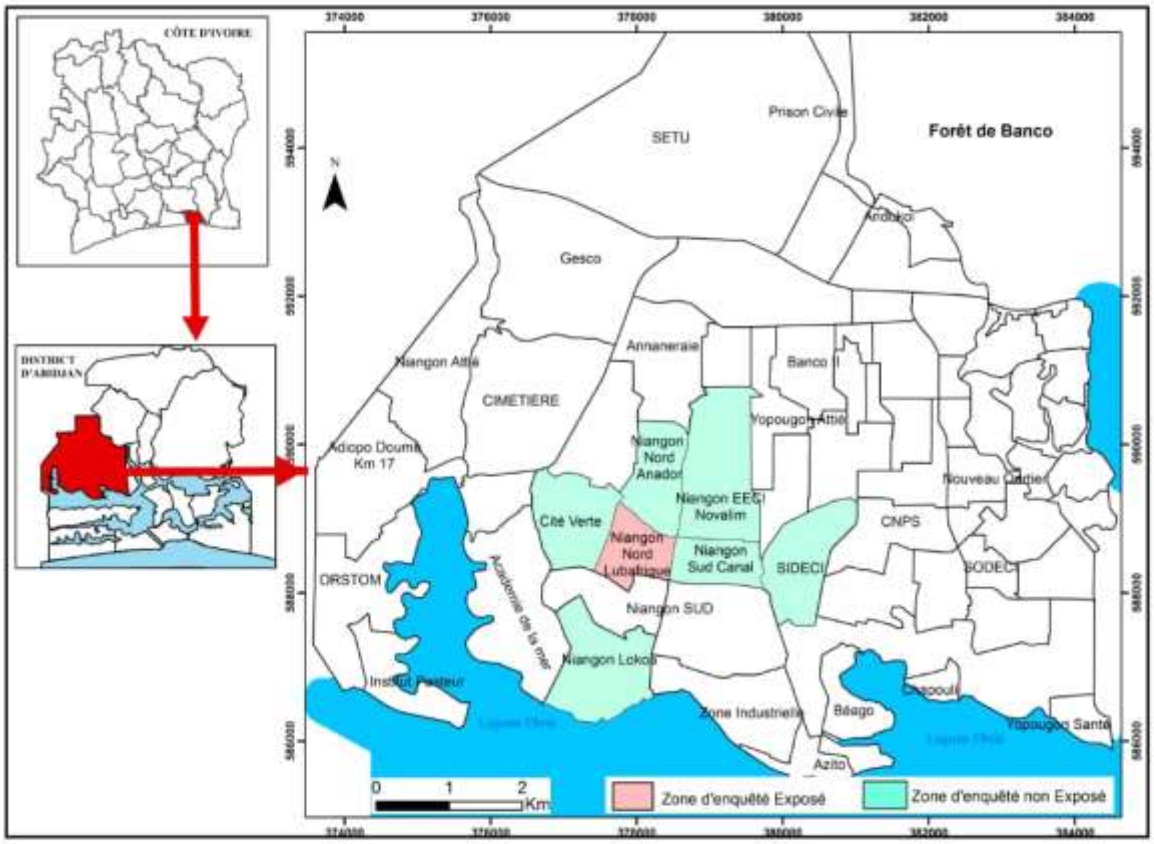

Figure 1: Study zone.

2.2 Data collection method

To collect the data, we used the questionary form the French Institut National de Prévention et d'Education pour la Santé (INPES) [12]. But we adapted the socio-demographic points to the Ivorian context. The DC 1700 by the Dylos Air Quality Monitoring Corporation is the device taken to measure fine particles, particularly those sizing less than 2.5 microns of diameter. Personal exposure measuring takes into account the different variations permanently taking place within a single micro environment and which static air quality surveillance networks cannot capture. For us, that is the best way to know the level of exposure to fine particles [13, 14]. The DC 1700 is a fine particle counting device. It is small (~ 10 × 3 × 2 cm), light (~ 82 g), easy to use and has only an ON/OFF button. It emits nearly-not-audible sound; making it not uncomfortable to use while conducting one's daily activities [13].

It records particles in two class size; particles of 0.5 to 2.5 µm and particles whose aerodynamic diameter is more than 2.5 µm. The DC 1700 registers data every 10 seconds and displays them - depending on calibration, in two different measurement units; either in cubic foot or in μg/m^3. It is capable of registering ≤0.5 μm diameter particles. It has a sealed battery which can last 6 hours in continuous operation [13]. CO is an invisible and odorless gas which, when in the blood, anchors to the hemoglobin at the exact place of oxygen; resulting hence in carboxyhemoglobin (HbCO). In so doing, it reduces the quantity of oxygen necessary for the different organs [15]. The ToxCO is a carboxyhemoglobin noninvasive monitor. It permits to detect the level of CO in the air. To measure air quality with it, you take a deep breath, hold the air for 15 seconds, then you start exhaling slowly through the tip of the device. To complete, you finish exhalation with a strong push-out of the air.

2.2.1 Data collection: The pace of collecting the data was dependent on the artisanal smoking activity's timetable. In fact, smoking sites used to open six days per week, Monday to Saturday except important popular feast days. Every day, we used to interview two investigated subjects from a pre-established list; one from the exposed group and the other from the nonexposed group. To capture the $PM_{2.5}$ concentration, we used to hand to each of them a bag containing a DC 1700 which they had to carry along on the field. Then, the investigator had to call the investigated subject from time to time to ascertain the collection device operates well. The subjet had the possibility to charge the DC 1700 by connecting it to a wall socket at times of rest. The process of measuring the CO and HbCO used to take place between 8:00 a.m and 8:30 a.m for exposed persons and nonexposed ones.

2.2.2 Data analysis: Socio-demographic and pollution data were entered and processed using the SPPSS DATA software. Quantitative variables were expressed by the means and standard deviations, and the qualitative variables, by the numbers and percentages. For each respondent, we downloaded the data captured by the DC 1700 them and processed all on a computer. On Excel, the data were converted into hourly average concentrations; starting 00 hours to 23 o'clock. Thanks to bi-variate and multi-variate analyses, we noticed that statistically, socio-demographic settings have their influence on $PM_{2.5}$ concentrations. We used the Student's t-test to compare the averages from two independent samples with a significancy threshold of 5%.

2.2.3 Administrative and ethical provisions

- Authorization of sanitary and administrative authorities
- Informed consent of subjects with signature of the consent form.
- Ethical approval

3. Results

In our study, we investigated 252 people; 126 exposed and 126 nonexposed from the Yopougon commune in Abidjan. Individual exposure to $PM_{2.5}$ was identified to be above 25 μg/m^3 which represents the WHO standard.

3.1 Socio-demographic characteristics

Exposed persons' average age was 32.42 ± 9.67 with limits at 16 and 67. This group consisted at 59% of men with a ratio of M/W =1.42. The nonexposed average age was 29.26 ± 8.6 with limits at 14 and 58. The majority of this group were men (58.7%) with a sex ratio of M/W =1.42 too. The average size of households from the exposed group was 4.07 ± 2.81 members; the largest being made up of 15 members. The average size of households from the nonexposed group was 5.98 ± 2.57. The largest family from this group was made up of 12 members. A bivariate analysis of socio-demographic data such as sex (OR = 1.47; IC0.05 [0.89-2.42]) and age (OR = 1.73; IC0.05 [0.61-5.24] for subjects aged 20-40 and an OR = 3.54; IC0.05 [0.95-13.62]) for subjects over 40 years old compared to subjects under 20 years old, revealed no real difference between exposed and nonexposed persons. Nevertheless, it displayed a big difference between exposed and nonexposed people in terms of number family members per household. Exposed households had comparatively less members than nonexposed households. Statistically it gave this: OR=0.23; $IC_{0.05}$ [0.08-0.57] for households composed of 3 to 5 members while OR=0.07; $IC_{0.05}$ [0.03-0.19] for households containing more than 6 members in comparison to households of only one member (Table 1).

3.2 Pollution data

More than half of the exposed persons (55.3%) resided in low standing houses. 24.3%, 27% and 22.1% dwelt in a one, two or three roomed houses. In more than half (56.9%) of the cases, the kitchen was separated from the main house. Most of the investigated nonexposed populations (66.6%) resided in middle to high standing houses. 17.6%, 34.4% et 24.8% of them lived in a two, three to four roomed houses respectively. In the majority of them, the kitchen was included in the main building (71.7%). The analyses have priory revealed significant differences between the two groups. Initially, the type of residence for the exposed people was relatively low in comparison to that of nonexposed persons (OR=6.26; $IC_{0.05}$ [3.25-12.07]). The same analyses also showed that the number of rooms per household was smaller for exposed persons compared to that of nonexposed ones (OR=0.24; $IC_{0.05}$ [0.09-0.61]) (Table 1).

3.3 Individual exposure to $PM_{2.5}$

3.3.1 $PM_{2.5}$ variations by individual: Daily average $PM_{2.5}$ concentrations used to vary every hour from one individual to another (Figure 2). This upward and downward variation was characterized:

- In exposed individuals by 50.45 ± 30.29 µg/m^3 average concentrations per day with extremes of 15.13 µg/m^3 (on 18th May 2019) and 188.44 µg/m^3 (on 28th December 2018).
- In nonexposed individuals by 42.67 ± 29.34 µg/m^3 average concentrations per day with extremes of 12.92 µg/m^3 (on 15th May 2019) and 181.48 µg/m^3 (on 24th December 2018).

Between mid-December and early January, we registered the highest $PM_{2.5}$ average concentrations. They swayed between 32.22 µg/m^3 and 188.44 µg/m^3 and between 33.80 µg/m^3 and 181.48 µg/m^3 with average concentrations of 81.01 µg/m^3 and 78.71µg/m^3 respectively for the exposed people and the nonexposed individuals.

3.3.2 Variations depending on time-slots: For all our study population, $PM_{2.5}$ hourly concentration varied; not only within a single group but also from the group of exposed persons to that of the nonexposed (Figure 3).

The different variations we observed took place within the three times intervals below:

- From 00:00 to 5:59 a.m, the difference in $PM_{2.5}$ average concentration between exposed people and the nonexposed wasn't that relevant (p=0.66).

- From 6:00 a.m to 4:59 p.m: the difference in $PM_{2.5}$ average concentration was big from one group to the other (p=0.002).
- From 5:00 p.m to 11:59 p.m: the difference in $PM_{2.5}$ average concentration between exposed people and the nonexposed wasn't that relevant (p=0.89).

From 00:00 to 23:59, the difference in $PM_{2.5}$ average concentration between exposed people and the nonexposed wasn't that relevant (p=0.07) (Table 2). Depending on the period of the day, $PM_{2.5}$ hourly concentrations used to be different within each group, and also between the two groups. From 00hrs to 6hrs and 7hrs to 23hrs, $PM_{2.5}$ concentrations were identical in the two groups with an expo $PM_{2.5}$ / non-expo $PM_{2.5}$ ratio respectively of 0.98 and 1.09.

3.4 Carbon monoxide pollution

In exposed people, the air average concentration with CO was 4.25 ± 1.6 ppm with extremes of 2 and 16 ppm. In that same group, the average HbCO was 1.49 ± 0.37% with extremes of 0.95 and 3.39%. In nonexposed people, the air average concentration with CO was 3.47 ± 0.92 ppm with extremes of 2 and 08 ppm meanwhile the average HbCO was 1.19 ± 0.17% with extremes of 0.75 and 1.91%.

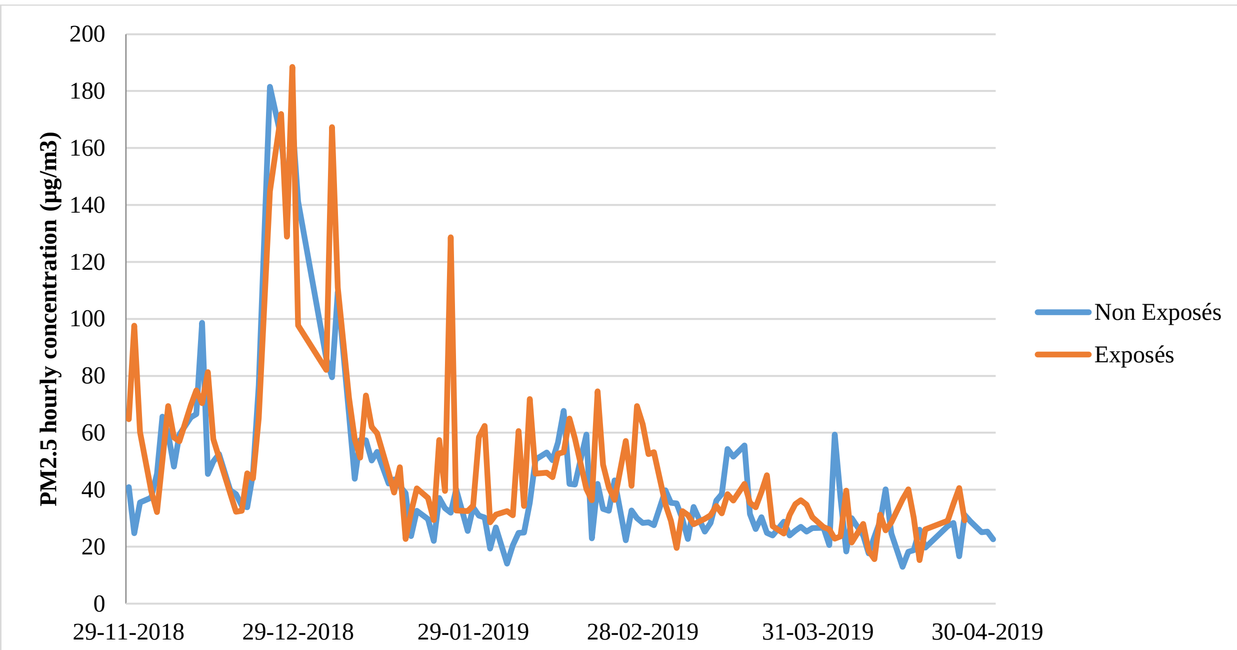

Figure 2: PM2.5 hourly average concentration for Exposed & Nonexposed people.

Parameters	**Exposed**	**Nonexpo**	***Odds ratio***	***Khi 2***	***I C95***	***P***
Sociodemographic characteristics						
Sex						
Male	62	74	Ref			
Female	64	52	1.47	2.30	0.89-2.42	0.13
Age range						
≤ 20	7	13	Ref			
20 - 40	95	102	1.73	1.27	0.61-5.34	0.26
40 <	21	11	3.54	4.64	0.95-13.62	0.03
Number of members per household						
≤ 2	44	10	Ref			
3-5	54	45	0.23	12.44	0.08-0.57	0.0004
≥6	28	71	0.07	41.79	0.03-0.19	0.0000
Pollution data						
Type of residence						
High to middle standing	27	77	Ref			
Low standing	68	31	6.256	37.19	3.25-12.07	0.0000
Number of Rooms						
1 room	26	18	Ref			
2 rooms	33	22	1.04	0.008	0.43-2.51	0.93
3 rooms	27	43	0.43	4.57	0.19-1.00	0.03
≥ 4	13	38	0.24	11.02	0.09-0.61	0.001
Kitchen location						
Inside	38	86	Ref			
Outside	54	30	4.07	22.997	2.17-7.65	0.0000
Main energy source						
Gas	96	100	Réf			
Charcoal	24	20	1.25	0.44	0.62-2.55	0.5

Table 1: Comparative analysis of sociodemographic pollution data for the two study groups.

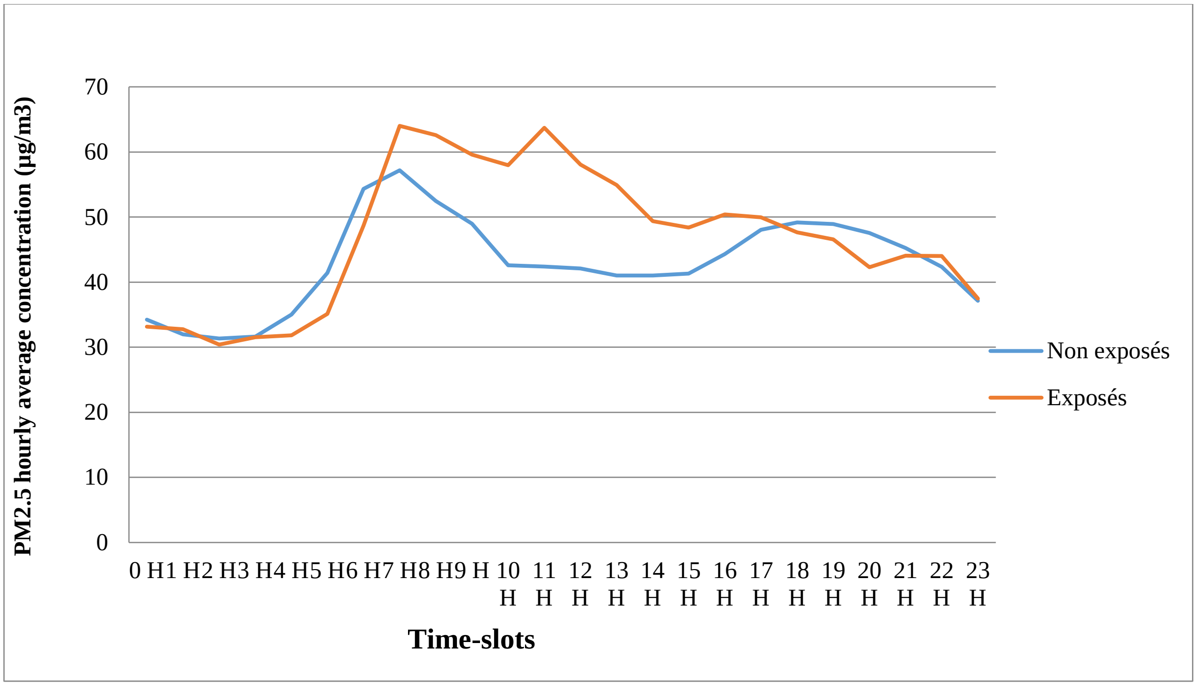

Figure 3: Average hourly evolution of $PM_{2.5}$ concentration in exposed / non-exposed.

Time-slots	n	Average (µg/m³)	Standard deviation	p-value
0hrs00 to 6 :59 a.m				
Exposed	94	34.85	29.27	0.66
Nonexposed	116	36.64	30.16	
7 :00 a.m to 16hrs59				
Exposed	122	57.44	31.76	0.002
Nonexposed	126	44.87	30.35	
17hrs00 to 23hrs59				
Exposed	113	45.46	32.54	0.89
Nonexposed	121	44.85	32.48	
00h00 to 23hrs59				
Exposed	122	49.62	30.29	0.07
Nonexposed	126	42.60	29.34	

Table 2: Comparative analysis of $PM_{2.5}$ concentrations per time-slot for the two study groups.

4. Discussion

4.1 Socio-demographic characteristics

Larger households seemed to be the bigger polluters as compared to smaller ones with some specificities related to the age factor in each family [16]. Besides, it should be noted that the household's groups of our study were of smaller size in comparison to the average households we have in Abidjan as a whole - and more specifically in the commune of Yopougon; just as it is in most middle and low-income countries [17- 20].

4.2 Pollution data

With regard to parameters such as construction materials, type of house, access to water, toilets, type of kitchen, we were able to state that 77.6% of houses in middle and low-income countries are at high level of pollution risks [21]. Though different from those described in a research by Kouao in the same commune of Yopougon, what characterized houses in our study, are quite similar to those described in many studies conducted in West Africa [3, 18, 20, 22]. All the analyses had shown that for most households from the group of exposed people, the kitchen was situated away from the main house. But, for the nonexposed, the kitchen was most of the times located within the main building (OR=4.07; $IC_{0.05}$ [2.17-7.65]). The type and place of the kitchen impacts air pollution, especially indoors pollution. In our study, the difference due to the place of the kitchen was really significant. The type of house may have accounted for this difference. In many West African countries, families generally have their kitchens apart from the main house; though they differ in many respects [3, 4, 22].

The first source of energy used for cooking food in the two groups of our study population was, to a proportion of 78.7%, gas for the exposed against 81.3% for nonexposed households. The same proportions were showed up in a previous study about the same zone [3, 4]. The secondary source of energy which is charcoal, was used to the proportions of 19.7% by exposed people against 16.3% by nonexposed households. But, both referred to charcoal at equal proportion for cooking and heating; as the study observed. However, compared to charcoal, gas appeared to be the main source of energy for both exposed and nonexposed categories (OR=1.25; $IC_{0.05}$ [0.62-2.55]) (Table 1). Nearly 90% households refer sporadically to charcoal for cooking and heating. But, gas remains the main source of energy. Resorting to butane gas is progressively becoming the norm in most Ivorian cities, more specifically in the economic capital Abidjan. This trend was made possible thanks to promotion campaigns for butane gas, its availability and somehow low cost which makes it accessible to the majority of households. Opting for gas also has to do with an increasing scarcity of firewood and charcoal subsequent to the diminishing of the country's forest cover and the continuous extension of Abidjan city [18]. Charcoal and firewood are the major sources of energy for households from three of the poorest sub-squares of Yopougon [19].

4.3 Individual exposure to $PM_{2.5}$

4.3.1 $PM_{2.5}$ variations by individual: Daily average $PM_{2.5}$ concentrations level in the exposed and nonexposed people were respectively 2 and 1.7 times above the WHO standard [1] (OMS, 2018). The daily $PM_{2.5}$ average concentrations for the whole study populations were also above indoors $PM_{2.5}$ (30.0 ± 3.4

µg/m^3) and outdoors $PM_{2.5}$ (35.2 ± 3.8 µg/m^3) in the households of the study zone who use gas (Kouao et al., 2019). Nevertheless, they are higher than the indoors $PM_{2.5}$ (40.7 ± 7.6 µg/m^3) and inferior to outdoors $PM_{2.5}$ (67.6 ± 10.9 µg/m^3) registered in households from the same area who use firewood [9] (Kouao et al., 2019). Still, the registered data were nearly three (3) times inferior in exposed persons and 3.5 times in nonexposed persons as compared to the $PM_{2.5}$ that displayed at the artisanal smoking site (145 µg/m^3*)* [8]. The personal exposure to the $PM_{2.5}$ was obviously the best way to estimate people's level of exposure to fine particles [20, 23, 24]. Apparently, the level of pollution in the commune of Yopougon is lower than the one we have in Asian big cities, but higher than in Western large cities [24-28], Du W., 2018]. Meanwhile, it is important to mention that the latters have put in place since decades, policies and strategic plans for reducing air pollution [9]. Between mid-December and early January, we registered the highest $PM_{2.5}$ average concentrations. These concentrations were the result of the desert dusty dry winds blowing from the Sahara down to the Guinea Gulf. The phenomenon is known as ''Harmattan'' and stands as one of the major sources air pollution [29]. It impacts the populations' health by rising not only the number of meningococcal cerebrospinal meningitis cases, but also the risks of respiratory conditions *including* severe lung diseases.

4.3.2 Variations depending on time-slots: These results indicate there is, not only a relation of sameness between the two groups but also a common level of pollution for both. The lowest level of $PM_{2.5}$ concentrations in both exposed and nonexposed people were registered between 00hrs00 and 4:00; which is the time-slot when nearly everybody is in bed [24]. Though $PM_{2.5}$ concentration revealed to be at the highest between 6:00 and 17hrs in the day for all the groups, it was at the worst for the group of the exposed population. The fact that the $PM_{2.5}$ concentration started to rise fast in the 6:00 – 8:00 time-slot was due to the effects of road traffic emissions – for the nonexposed people. For the exposed ones, the rising process was the result of road traffic and the emissions from the traditional fish smoking sites [8, 10]. Just after the peak of this time period, we noticed a sudden decrease in $PM_{2.5}$ concentration at the level of the nonexposed as road traffic intensity reduces. In the meantime, it kept rising at the level of exposed populations till the moment when the traditional fish smoking site closes down.

4.4 Carbon monoxide pollution

Most of the times, people incriminate carbon monoxide for cases of acute intoxication. But it is important to note that long exposures to this substance is also harmful for human health [30]. The highest carbon monoxide concentrations in urban areas occur alongside the roads, namely on the busiest roads. They started to drop considerably as we distance away from busy roads [31]. Practically, all CO concentrations registered in the air in the two study groups was below 10 ppm and 6.5% of exposed persons had an HbCO which was above 2% - the WHO guidline'. Longthy exposure to low level of carbon monoxide or any unknown source of intoxication with carbon monoxide can cause clinic conditions such as headache, dizziness or a feeling of muscle weakness. These conditions can easily be mistakenly taken for certain common diseases. They aslo negatively impact the daily ativities of the exposed persons [32]. Some of our study population presented certain conditions with a 2.6% HbCO rate. Some others with underlying cardiovascular diseases are vulnerable to CO intoxication [30].

5. Conclusion

The present study aimed at assessing the level of $PM_{2.5}$ fine particles and carbon monoxide pollution caused by artisanal fish and or meat smoking business upon the neighbourhood populations. The results revealed that most commonly, the level of $PM_{2.5}$ pollution is above the standards of the WHO which is 25 µg/m^3. In addition, artisanal smoking of fish and/or meat exposes the populations living near of the smoking site to additional $PM_{2.5}$ pollution 2 to 3 times higher than WHO guideline; particularly during daytime when this activity usually takes place. According to this organisation, no threshold of $PM_{2.5}$ concentration, has been identified below which no damage to health is observed. Notwithstanding, any increase - even the slightest in $PM_{2.5}$ concentration is likely to result into unpredictable morbid effects; namely upon children of less than 5 years of age, pregnant women, chronic pathology-bearers and the elderly. Therefore, attenuation measures should be envisaged and more studies must be undertaken to assess the artisanal fish and meat smoking business' impacts on the neighbour of the smoking site populations health.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

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