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Original Research Article

Exposure of children to fine particles ($PM_{2.5}$ and PM_{10}) in schools in the health districts of Yopougon, Abidjan

Harvey Attoh-Toure[1]*, Konan Roland Oussou[1], M'Begnan Coulibaly[2], Noufé Soualihou[2], N'Guessan Konan[2], Loukou Konan Gilbert[1], René Kouao[3], Mohamed Koné[2], Issaka Tiembré[1], Simplice N'Cho Dagnan[1]

[1]Department of Public Health, Felix Houphouët Boigny University, Abidjan, Côte d'Ivoire
[2]National Institute of Public Hygiene, Ministry of Public Health, Côte d'Ivoire
[3]Nangui Abrogoua University, Abidjan, Côte d'Ivoire

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***Correspondence:**
Dr. Harvey Attoh-Toure,
E-mail: harveyattohtoure@gmail.com

ABSTRACT

Background: In Africa, the school environment is becoming a growing concern, as concentrations of fine particles inside classrooms are very high. We decided to estimate the level of exposure to $PM_{2.5}$ and PM_{10} of schoolchildren in the health districts of Yopougon in Abidjan.
Methods: This was an analytical cross-sectional study of pupils aged 8 to 14 years in the health districts of Yopougon. Our study was conducted from 24 November 2020 to 18 January 2021. The pupils were selected by two-stage random sampling. A real-time fine-particle measurement instrument, the DYLOS 1700, and the ISAAC questionnaire were used to collect the parameters studied.
Results: We surveyed 881 pupils from 08 schools. The sex ratio (M/F) of the pupils was 0.9 and the mean age was 12 years. Measurements of $PM_{2.5}$ and PM_{10} levels in the classrooms were 30 times higher than WHO standards and ranged from 200 to 1000 $\mu g/m^3$ and 1000 to 3000 $\mu g/m^3$ respectively. There was a significant link between the presence of pollution sites near schools and the increase in $PM_{2.5}$ and PM_{10} levels in classrooms. Clinical manifestations suggestive of asthma in pupils were significantly associated with high levels of $PM_{2.5}$ and PM_{10}.
Conclusions: Pupils in Yopougon's schools are exposed to high level of fine particle pollution that exceed WHO standards. Respecting and applying pollution reduction measures will help to create a school environment that is favourable to the respiratory health of pupils.

Keywords: Abidjan, Côte d'Ivoire, Fine particles, Pollution, School environment

INTRODUCTION

For several decades now, the atmosphere in the major cities of West Africa has been under threat. This situation is mainly the result of human activities, which generate large quantities of pollutants in the atmosphere.[1] Among these pollutants, particulate matter (PM), particularly the finest ($PM_{2.5}$ and PM_{10}), has direct negative effects on health in the short and long term.[2,3] In Abidjan, industry and households, with 6,974 t/year (50.5%) and 4,759 t/year (34.5%) respectively, are the two main sources of fine particle emissions into the atmosphere.[1] In addition, the outdated and uncontrolled vehicle fleet intensifies this fine-particle pollution. This outdoor air pollution is compounded by indoor air pollution, the poor quality of which is responsible for 7 million deaths worldwide.[4]

Several epidemiological studies carried out in developing countries have revealed high levels of indoor pollution.[5-7] Janssen et al observed that $PM_{2.5}$ concentrations both inside and outside homes increased significantly with road traffic density.[8] In enclosed environments such as schools, where children spend most of their time, pollutants are more likely to reach the lungs.[9] Air pollution can affect the respiratory, cardiovascular and cardiopulmonary systems and lead to cancer.[10] The epidemiological evidence for these health effects is robust, although there are still gaps in knowledge about the exact pathophysiological mechanisms by which air pollutants affect health.[11]

For several authors, the health consequences of this pollution are detrimental to children's health.[12] Children with chronic respiratory diseases such as asthma are particularly vulnerable.[13,14] The weakness of their antioxidant immune defence in the endothelial layer of the lung increases their sensitivity to air pollution.[13] In addition, allergens can associate with fine particles by surface adsorption and can then provoke, "in asthmatics, a response to lower levels of exposure to the allergens to which they are sensitised".[13] Exposure to fine particles can trigger or aggravate asthma and reduce lung function.[12-14] The relationship between particulate matter and asthma has been demonstrated in several epidemiological studies.[15,16] These studies have correlated, for example, the severity of the disease, hospital admissions and deterioration in respiratory function with the level of fine particles.

In this context, it seemed appropriate to examine children's exposure to fine particles $PM_{2.5}$ and PM_{10} in the school environment. The general objective was to analyse exposure to $PM_{2.5}$ and PM_{10} among schoolchildren in the Yopougon health districts of Abidjan. Specifically, the aim was to estimate in real time the level of exposure of schoolchildren to $PM_{2.5}$ and PM_{10}, to identify the associations between clinical signs and variations in $PM_{2.5}$ and PM_{10} levels, and to describe the factors influencing $PM_{2.5}$ and PM_{10} levels in schools.

METHODS

Study type, place and period

This was a descriptive and analytical cross-sectional study. This study conducted in the Yopougon East and West health districts from 24 November 2020 to 18 January 2021. The commune of Yopougon is one of the 10 communes of the city of Abidjan (Côte d'Ivoire). It covers an area of 153.06 km^2 for a population of 1,522,000.[17] The municipality has the country's largest industrial zone, home to a number of industries (agriculture, textiles, plastics, chemicals and cosmetics). It has heavy road traffic linked to public transport. It has 09 public secondary schools with a total of 39,027 pupils and 211 private secondary schools with a total of 83,829 pupils.

Study population

All children, regardless of gender, aged 8 to 14 and attending secondary school in the commune of Yopougon were included in the study. Only children who did not fully complete their questionnaire and did not give their assent were not included in the study.

Sample size and sampling technique

The sample size was estimated using the Schwartz formula $N= (\mathcal{E}^2*p*q)/i^2$ with a prevalence of asthma in schools in Côte d'Ivoire of p=10% and a degree of precision i = 2% and a margin of 10%. Our sample consisted of 881 pupils. Sampling was based on a two-stage random draw. At primary level, 8 health establishments were selected by systematic random draw from a list of 220 public and private secondary establishments obtained from the Regional Directorate of National Education. At the secondary level, in each of the selected schools, we carried out a simple random draw of two classes: one class of 6^{th} grade and one class of 5^{th} grade. Finally, all the pupils present in the classrooms were included in the survey sample.

Data collection techniques and tools

Data collection was carried out by a team consisting of a 7th year medical student and a public health intern, with one visit per school and per class. Data were collected on health and on exposure to particulate matter (PM_{10} and $PM_{2.5}$). Clinical data were collected using an ISAAC questionnaire. The written ISSAC questionnaire was administered "face to face" by the two investigators to all pupils present in the classrooms. It was completed anonymously by the pupils after each question had been clearly explained. Data on PM levels was collected using a latest-generation laser particle counter: the DYLOS/1700. This is an air quality monitor with the technology and engineering to monitor indoor and outdoor air quality. It measures particulate matter smaller than 2.5 µm ($PM_{2.5}$) and 10µm (PM_{10}) in real time. The measurement was carried out over a four-hour period (from 8 am to 12 pm) by two DYLOS inside the classrooms without disrupting lessons.

Data processing and analysis

The analysis was carried out in 2 phases: descriptive and analytical. In the descriptive phase, the quantitative variables were grouped into classes described by their number and percentage. On the analytical level, we used the following statistical tests: (i) chi-square test, (ii) Anova test and (iii) Spearman rank correlation test, with an alpha risk of 5%. For data processing and analysis we used Word 2016 for text entry, Epi info version 7.0 for statistical data analysis and Excel 2016 for histograms and tables.

Participation in the study was voluntary. The survey was conducted in such a way as to guarantee anonymity. The information provided by participants was treated in accordance with the rules of confidentiality. The information gathered was used solely for the purposes of the research.

RESULTS

During our study, we surveyed a total of 881 pupils in 08 schools. Our sample comprised 455 girls (51.6%) and 426 boys (48.4%). The average age of the pupils was 12 years /+- 02 with extremes ranging from 08 to 15 years. Almost all, 99.8%, of the pupils who took part in the survey lived in the commune of Yopougon. Our study found 76 students (8.6%) with asthma and 243 students (27.6%) with a family history of asthma.

At the time of the survey, 161 or 18.3% of pupils had not shown any of the signs we were looking for. The vast majority (720 or 81.7%) showed at least one sign. A total of 231 pupils (26.2%) showed 3 clinical signs (Table 1). Of the 720 pupils with at least one clinical sign, 162 (22.5%) had a hospital consultation and 44 (6.1%) were admitted to hospital.

Table 1: Distribution of pupils according to clinical signs.

Clinical signs	Workforce	Percentage (%)
No clinical signs	161	18.3
One clinical sign	215	24.4
Cough	35	4.0
Rhinitis	136	15.4
Wheezing	44	5.0
Two clinical signs	274	31.1
Rhinitis + Wheezing	72	8.2
Rhinitis + Cough	160	18.1
Coughing + wheezing	42	4.8
Three clinical signs	231	26.2
Total	881	100.0

In 6th and 5th grade classes, all $PM_{2.5}$ levels were above the WHO recommended threshold (25 µg/m3/24h), with a peak of 340 µg/m3 (Figure 1 and Figure 2).

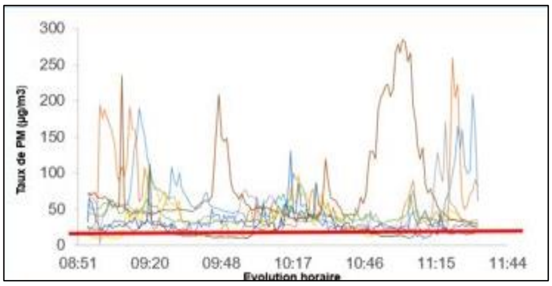

Figure 1: PM2.5 levels in 6th grade classrooms in 8 schools in the Yopougon health districts.

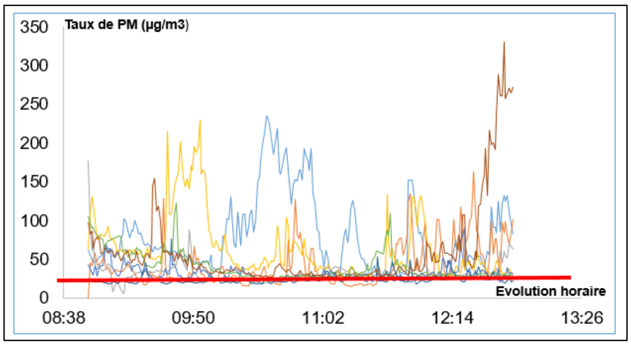

Figure 2: PM2.5 rate in 5th grade classrooms of 8 schools in Yopougon health districts.

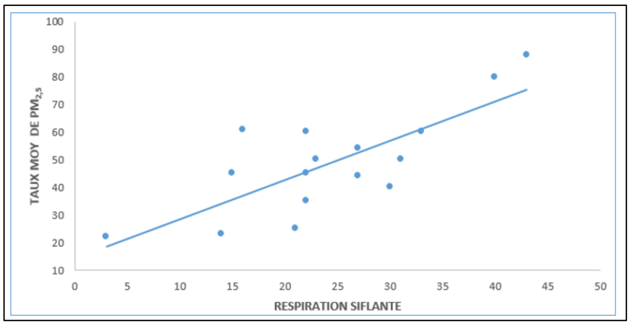

Figure 3: Distribution of wheezing pupils according to $PM_{2.5}$ levels.

The levels of PM_{10} were all above 50 µg/m3/24h (WHO standard) in the classrooms of 6ième and 5ième with a peak of 3000 µg/m3. The increase in $PM_{2.5}$ and PM_{10} levels in the classrooms was significantly linked to the presence of pollution sites near the schools, with p=0.017 for $PM_{2.5}$ and p=0.028 for PM_{10}. The pollution sites were roads with heavy traffic, the proximity of factories or the presence of domestic waste burning sites. Wheezing was significantly associated with high levels of $PM_{2.5}$ (p=0.02) and PM_{10} (p=0.03) in classrooms (Figure 3 and Figure 4). Coughing was significantly associated with high levels of $PM_{2.5}$ (p=0.02) and PM_{10} (p=0.03) in classrooms. Rhinitis was also significantly associated with high levels of $PM_{2.5}$ (p=0.01) and PM_{10} (p=0.02) in classrooms.

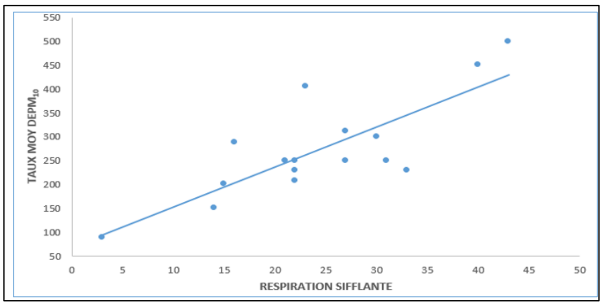

Figure 4: Distribution of wheezing pupils according to PM10 levels.

The occupancy status of pupils in the classrooms was significantly linked to $PM_{2.5}$ and PM_{10} levels with $p<0.05$.

The higher the number of pupils in the classrooms, the higher the level of fine particles. The level of fine particles in our study was not significantly associated with the perimeter of the classrooms, the absence of windows, the temperature of the classrooms or their humidity level.

DISCUSSION

Prevalence of asthma and family history

The prevalence of asthma among schoolchildren in the Yopougon health district was 8.6%. In another study conducted in 2019 in the city of Abidjan by Koffi, this prevalence was 10%.[18] In Lubumbashi in the Democratic Republic of Congo (DRC), the proportion was 11.6%.[19] In France, the cumulative prevalence of asthma in children ranged from 12.3% to 13.4%.[20] According to Weinberg, the prevalence of asthma, which was low in developing countries, is increasing as a result of urbanisation and industrialisation in these countries.[21] Some factors may explain this, in particular industrial pollution and smoke emissions from vehicles and motorbikes. We recorded approximately 27.6% of pupils with a family history of asthma.

Clinical signs suggestive of allergic and asthma diseases

Our results showed 53.1% cough, 44.2% wheeze and 70.1% rhinitis. These results are much higher than those found in the literature, which could be explained by the exposure of pupils in the Yopougon health district to several local pollution sites (busy roads, factories, etc.). The commune of Yopougon is the second most densely populated commune in the district of Abidjan, with dense road traffic and numerous industrial units. A large proportion of pollutant emissions in cities is due to road traffic.[22]

Air pollution is one of the factors that play a role in the increase and aggravation of pathologies but is also the cause of the development of respiratory diseases in healthy subjects. Children are more sensitive to pollution than adults. Their airways are still maturing, making them more sensitive. They are more at risk of developing respiratory diseases such as asthma and allergies.

In France, living since birth in areas with high levels of urban pollution has been linked to an increased risk of exercise-induced asthma, asthma, allergic rhinitis and allergic sensitivity in children in 6 French cities.[23] The weakening of these children's respiratory tracts is also a breeding ground for transmissible infectious diseases. In sub-Saharan Africa, acute respiratory infections are the leading cause of death in children under the age of 5.

These clinical manifestations were more prevalent in children exposed to high levels of fine particles $PM_{2.5}$ and PM_{10} ($p<0.05$).

Fine particle levels in classrooms

The measurements taken showed that average $PM_{2.5}$ levels in schools in the Yopougon health districts varied between 200 and 1000 µg/m3 and average PM_{10} levels between 1000 and 3000 µg/m3. These measurements were well above the standards recommended by the WHO (30 times higher). The standards recommended by the WHO were 25µg/m^3/24h for $PM_{2.5}$ and 50 µg/m^3/24h for PM_{10}. This leads us to say that the majority of pupils in the commune of Yopougon were exposed to very high levels of fine particles in the classrooms where they spend most of their time. Several epidemiological studies carried out in developing countries have highlighted high levels of pollution inside schools.[7] In a study carried out in Accra, Arku found that pupils were heavily exposed to fine particles inside classrooms, with average $PM_{2.5}$ levels ranging from 56 µg/m3 to 150 µg/m3.[6] In Abidjan, industry, with 6,974 t/year, is one of the main sources of fine particle emissions into the atmosphere.[1] Added to this is the inadequacy of urban planning, with neighbourhoods adjacent to industries. The city of Abidjan is undergoing rapid urbanisation, a process fuelled by high population growth. Among the deleterious consequences of rapid urbanisation are waste management problems. Inadequate waste collection systems encourage some people to dispose of waste by open burning, whose emissions of particles into the air are significant and highly toxic. Tens of thousands of second-hand vehicles from Europe and the United States enter Côte d'Ivoire. These vehicles, which no longer meet the standards in force in Western countries, are generally in poor condition and exported to developing countries. These vehicles cause enormous problems for users and owners, but also for the environment, and emit large quantities of fine particles into the atmosphere. Particulate emissions are caused by the incomplete combustion of diesel-powered vehicles, and the Abidjan vehicle fleet is characterised by around 59% diesel-powered vehicles. Our results also showed that the level of fine particles increased with the number of local pollution sites ($p<0.005$). Schools with 2 to 3 pollution sites (open dump, factory or busy road) had higher levels of $PM_{2.5}$ and PM_{10}.

Our study showed that $PM_{2.5}$ and PM_{10} pollution peaks occur mainly at 10 am in schools in the Yopougon health districts. This could be justified by the fact that in schools, 10 am is recess time for pupils. This is a break from lessons lasting between 15 and 30 minutes. During this time, the children play in the school playground and also in the classrooms, producing large quantities of airborne dust from both outside and inside, because the floors in the classrooms are not tiled but made of cement, which is often in very poor condition.

Our study shows that almost all the classrooms had an occupancy status above the standard recommended by UNESCO. Only one school met the standard. The occupancy status of pupils in classrooms was significantly related to $PM_{2.5}$ (p=0.02) and PM_{10} (p=0.01) levels. Overcrowded classrooms quickly become loaded with CO2, which encourages the stagnation of fine particles.

Levels of fine particles and signs suggestive of asthma

Exposure to fine particles can trigger or aggravate asthma and reduce lung function.[12-14] The relationship between particulate matter and asthma has been demonstrated in several epidemiological studies.[15,16] Our results show that the presence of coughing, wheezing and rhinitis in pupils was significantly related to high levels of $PM_{2.5}$ and PM_{10} in classrooms. A 10% increase in PM led to an increase in asthma attacks. Numerous studies conducted in several countries (Taiwan, Thailand, China, Great Britain, Sweden, Switzerland, Netherlands, Finland, Czech Republic, Germany, United States, Chile) show links between respiratory symptoms (coughing, wheezing, sneezing) and the level of particulate pollution.[24-27]

This study has some limitations. First, it only measures levels of fine particle, although students are exposed to other pollutants. Second, the measurements were only carried out in schools while they are also exposed at home. Further studies are necessary to explore this health problem.

CONCLUSION

School children in the health districts of Yopougon are exposed to levels of fine particle pollution PM2.5 and PM10 far in excess of the standards set by the WHO. They spend most of their time in a polluted environment. This exposure could be at the root of their clinical symptoms. However, there are currently no preventive measures in place in Côte d'Ivoire to deal with these high levels. This study is the first one to measure PM on schools in the country and was used to raise awareness among health professionals about pollution and its health consequences. It will be used to implement prevention measures.

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