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Air pollution in urban areas: the case of the commune of Attécoubé in the district of Abidjan (Côte d'Ivoire)

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***Abstract*:**

Air pollution in the district of Abidjan has become an increasingly serious problem. This study was carried out in the Boribana district (Attécoubé lagoon) of the Attécoubé commune using a continuous air quality analyzer located at the naval training center of Attécoubé. Overall, the results showed that particulate matter ($PM_{2.5}$ and PM_{10}) and gas (SO_2 and NO_2) concentrations exceeded the World Health Organization (WHO) thresholds during the study period (April to December 2021), except for CO. Legal air quality limits were frequently breached during the study period. The daily SO_2 limit (125 µg/m^3) was exceeded 200 times, far surpassing the three annual exceedances permitted by the Côte d'Ivoire Air Quality Decree. Similarly, PM_{10} concentrations surpassed the daily limit (50 µg/m^3) 107 times, well over the 35 instances allowed per year. Daily concentrations of $PM_{2.5}$ were generally above the WHO's threshold (15 µg/m^3) throughout the study period. These exceedances may represent a real health concern for the citizens living around of Attécoubé lagoon.

***Keywords* :** Air pollution ; Attécoubé ; Pollutants.

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1 Introduction

Like developed and developing countries, Côte d'Ivoire faces a high level of anthropogenic activities, which are the main cause of air pollution [1]. In the city of Abidjan, three primary sources of air pollution are identified: transportation, industrial processes, and domestic sources (such as solid waste burning and domestic fires) [1]. Due to the negative impacts of air pollution on the environment and human health, Decree No. 2017-125 of February 22nd, 2017, on Air Quality was created and adopted in Côte d'Ivoire to regulate emissions of atmospheric pollutants [2]. This decree establishes standards for ambient air quality and vehicle and motorcycle emissions, aiming to protect human health and the environment from the adverse effects of air pollution.

Despite the adoption of this decree and the implementation of a strategy to improve air quality in Abidjan, air pollution continues to pose a serious health and environmental threat in the city. Recently, as part of the European program Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa (DACCIWA), studies on gaseous and particulate pollution in Abidjan (Côte d'Ivoire) and Cotonou (Benin) were conducted by [3] and [4] at three permanent sites representing the main sources of pollution in West Africa: domestic fires, road traffic, and waste incineration. These studies used passive sensors over a two-week exposure period before being replaced, frozen, and analyzed in the laboratory. Although [3] study covers the district of Abidjan, the data recorded was not continuous throughout the entire study period. Additionally, the data was manipulated by the user during the campaign before analysis, which could lead to discrepancies in the results. In this context, this study aims to address the issues of data continuity and examine air pollution in specific sites such as Attécoubé, one of the most underserved neighborhoods in Abidjan [5]. The study presents the results of a long-term, continuous air quality monitoring program conducted in the Attécoubé commune (Abidjan) from April to December 2021 using a continuous air quality analyzer called 'Cairnet'. The goal is to provide an overview of the air quality around the Attécoubé lagoon (Boribana) by measuring concentrations of $PM_{2.5}$, PM_{10}, CO, SO_2, and NO_2. The paper is organized as follows: Section 2 describes the materials and methods, including the study area (the commune of Attécoubé), the data, the Cairnet instrument, and the methodology. Section 3 presents the results and discussion, followed by the conclusion in Section 4.

2 Material and methods

2.1 Study area

Attécoubé is one of the ten communes of Abidjan, the economic capital of Côte d'Ivoire [1]. It is bordered to the north by the commune of Abobo, to the south by the communes of Plateau and Treichville, to the east by the communes of Adjamé and Plateau, and to the west by the commune of Yopougon (Fig. 1). In general, the average annual precipitation in the Abidjan district is about 2000 mm, with a transitional equatorial climate divided into four seasons in the annual cycle: the great dry season from December to April, the great rainy season from May to July, the little dry season from July to September, and the little rainy season from October to November [6]. The northern center of the Attécoubé commune has an average temperature that is between 22.5 and 25 °C, while the southwestern part is characterized by an average temperature ranges between 21.5 and 22.5 °C [6].

To pilot its air quality monitoring program, the Ivorian Antipollution Centre (CIAPOL) has installed two mobile mini-stations at the naval base school in Attécoubé to measure air pollutants.

This commune is characterized by various human activities (Fig. 2), including the smoking of foodstuffs (fish, meat), an activity that essentially uses firewood as fuel (Fig. 2A), generally from rubber trees. Smoking is a continuous activity performed every day, with peaks observed in the early hours (6 am), after which the smoked products are immediately sold in the market. There is also a heavy traffic of vehicles composed of personal and common transportation (buses, taxis, coaches, lorries, etc.). These vehicles are generally old and use diesel and gasoline as fuel (Fig. 2B).

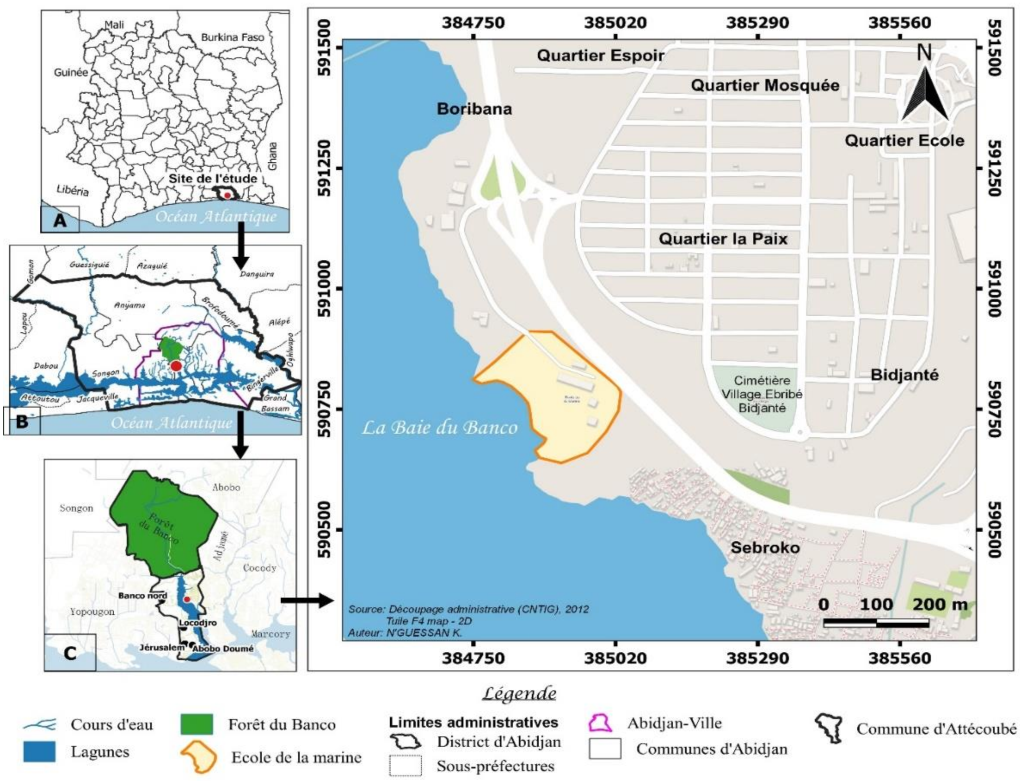

Fig. 1. Map showing the location of the study area (Attécoubé). A- Côte d'Ivoire; B- Abidjan district, C- surrounding area.

Lagoon traffic is operated by traditional boats, commonly known as pinasses. These boats use diesel as fuel. Traffic on the lagoon occurs daily between 6:30 am and 7:30 pm, with peak times from 6 to 10 a.m. and 4 to 7 p.m. (Fig. 2C). The commune of Attécoubé also experiences eutrophication caused by the Bay of Banco, which is mainly made up of sewage and fecal matter (Fig. 2D).

2.2 Description of the Cairnet station

The equipment used in this study to measure concentrations of air pollutants is an air quality monitoring device called Cairnet (Fig. 3). This is a stand-alone network capable of measuring the concentration of several pollutants, such as NO_2, CO, SO_2, PM_{10}, $PM_{2.5}$. The Cairnet consists of one or more Cairsens (or sensors) and a 2G/3G communication system that transmits measurements from each sensor to the Caircloud in real time. The sensors are electrochemical and can store data for 20 days for 1 minute, 303 days for 15 minutes of data, or 1212 days for 60 minutes of data [7]. The measurements are stored in the CairCloud database, from which, among other things, the measurements of each sensor can be viewed and analyzed (Fig. 4).

Fig. 2. Different sources of pollution related to human activities in the commune of Attécoubé; A: fish smoking; B: road traffic; C: inland navi gation; D: pollution of the lagoon.

Fig. 3. Air quality measurement station, Cairnet.

Fig. 4. Data transfer to the Cloud [8].

2.3 Data collection

An air sample enters through the Cairnet ports under the enclosure, where the sensors analyse it before exiting via each sensor's sample outlet. The concentrations of $PM_{2.5}$, PM_{10}, NO_2, CO and SO_2 measured by the sensors are transferred to the File Transfer Protocol (FTP) server (CairCloud) via the mini-USB ports (Fig. 4). CairCloud displays the different pollutant concentrations and is accessed online. The concentrations of the different pollutants are visualized according to the selected period (1 min, 5 min, quarter hour, 1 hour, daily) and can be downloaded in different formats (XLS, PDF, JPEG). The concentration data for the different pollutants are then compared with the thresholds defined by the National Air Quality Decree and the World Health Organization (WHO) thresholds (see Table 1).

3 Results and discussion

Data from the Cairnet station at Attécoubé Naval Training Centre revealed significant variation in the concentrations of key pollutants (NO_2, SO_2, CO, PM_{10}, and $PM_{2.5}$) between April and December 2021. Figs. 5 to 9 show the average daily variation of concentrations of atmospheric pollutants at Attécoubé during this period.

3.1 Daily variability in nitrogen dioxide (NO_2) concentrations

Fig. 5 shows the daily variations in NO_2 concentrations at the Attécoubé lagoon site. They are ranged from 11.28 to 39.50 µg/m^3 throughout the study period, with peaks occurring in June, July, October, November, and December of 2021, exceeding the WHO threshold (25 µg/m^3).

Table 1
The thresholds for the various pollutants set out in the Decree on Air Quality for Côte d'Ivoire and the WHO [2, 9].

Pollutants concentrations (µg/m^3)	Mean time	Côte d'Ivoire Air Quality thresholds	WHO thresholds
$PM_{2.5}$	Annual	25	5
	24 hours	-	15
PM_{10}	Annual	40	15
	24 hours	50	45
NO_2	Annual	40	10
	24 hours	-	25
SO_2	24 hours	125	40
CO (mg/m^3)	24 hours	10000 (µg/m^3) (8 hours)	4

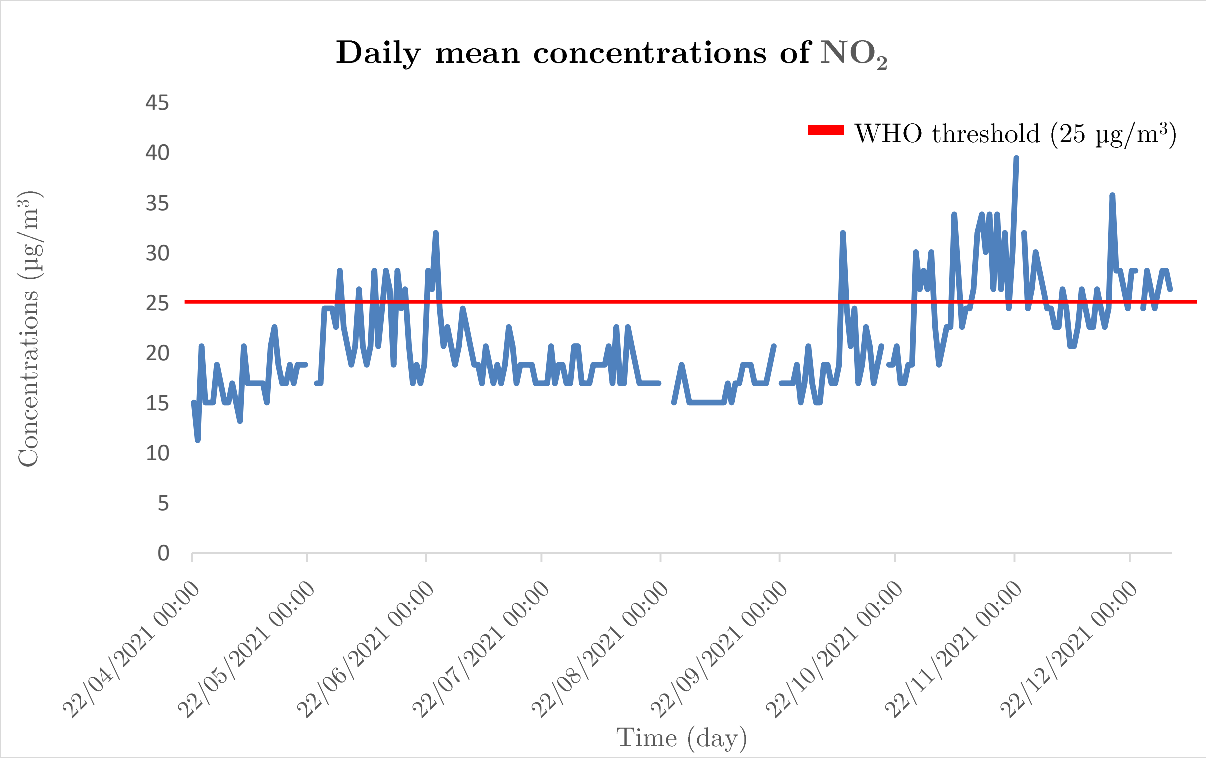

Fig. 5. Daily variations in NO_2 concentrations (µg/m³) in ambient air at the Attécoubé lagoon, from April to December 2021 (the horizontal red line indicates the WHO threshold).

Concentrations of NO_2 are mainly due to road traffic. Our study site is located near the *Boulevard de la Paix*, which is heavily trafficked during the morning and evening rush hours (Fig. 2B). These exceedances of the WHO thresholds expose the population living in the Attécoubé lagoon to serious health risks such as acute respiratory diseases, asthma attacks, and lung diseases. According to [10], people living in areas with heavy road traffic are likely to be more affected by NO_2 pollution than those living near industrial activities.

3.2 Daily variations in carbon monoxide (CO) concentrations

Daily CO concentration levels range from 87 to 1217 µg/m³ from April to December 2021. The CO concentrations show a seasonal variability during the study period. This variability indicates maxima of around 800 µg/m³ from May to June, and approximately 900 µg/m³ from October to mid-December 2021, coinciding with the rainy season in Abidjan. On the other hand, lower CO concentrations occur mainly during the period from August to September 2021. This result indicates that wet conditions favor an increasing trend in CO concentrations. It has been noticed that the average daily CO concentrations are all below the WHO threshold (4 mg/m³), which is around 4000 µg/m³ (Fig. 6). This suggests that people are not being exposed to CO. Most people do not feel anything abnormal at low levels of pollution [11]. However, even at these modest levels of pollution, some people's health can deteriorate, either because their bodies are fragile or because they are exposed to other risk factors that make them vulnerable:

children, asthmatics, the elderly, people suffering from cardiovascular disease [12].

3.3 Daily sulfur dioxide (SO_2) concentration variation

Fig. 7 shows the average daily variations in SO_2 concentrations from April to December 2021. SO_2 concentration values range from 28 to 641 µg/m³ over the study period, with a single peak of about 924 µg/m³ occurring on April 24, 2021. However, significant concentrations (around 400 µg/m³) are observed from May to June, while a decreasing trend is observed from July to October, around 35 µg/m³.

From April to December 2021, SO_2 concentrations consistently exceeded the WHO threshold of 40 µg/m³, with the exception of a single day (August 16, 2021). As a result, the Air Quality Decree threshold (125 µg/m³), which should not to be exceeded for more than three consecutive days, was exceeded more than two hundred times during the study period. This means that people living in the Attécoubé commune are exposed to a high risk of respiratory diseases such as bronchitis, asthma attacks, etc.

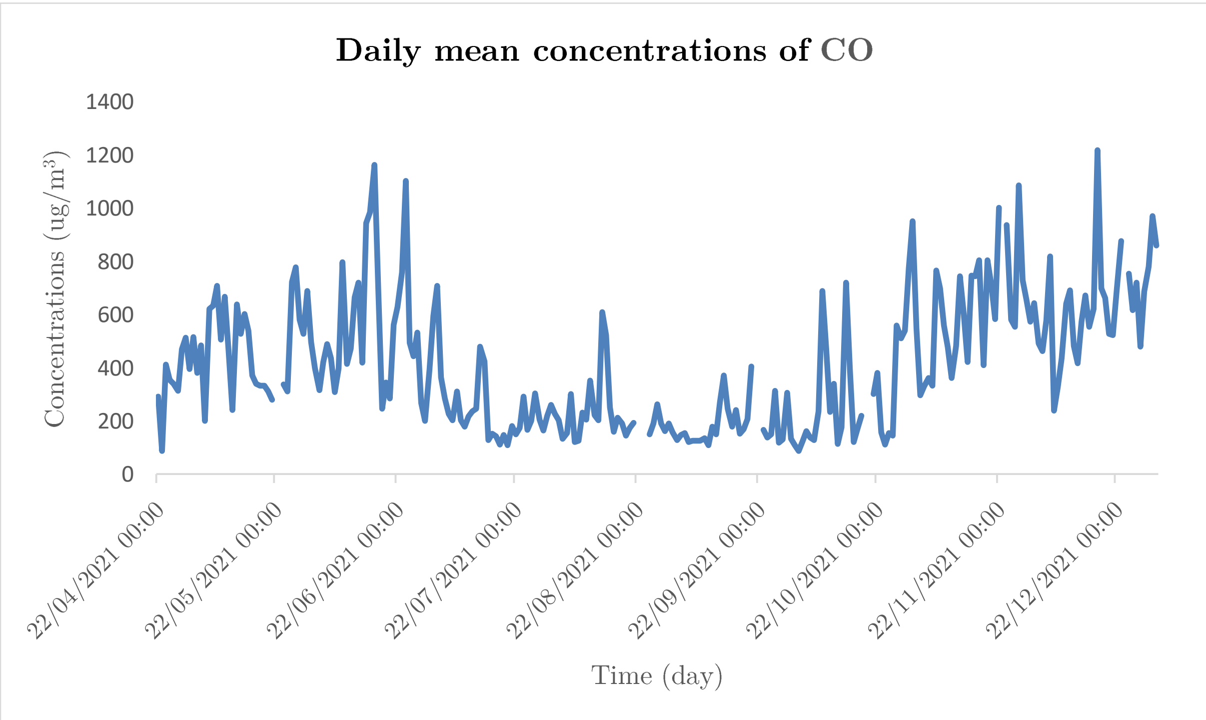

Fig. 6. Daily variations in CO concentrations (µg/m³) in ambient air at the Attécoubé lagoon, from April to December 2021.

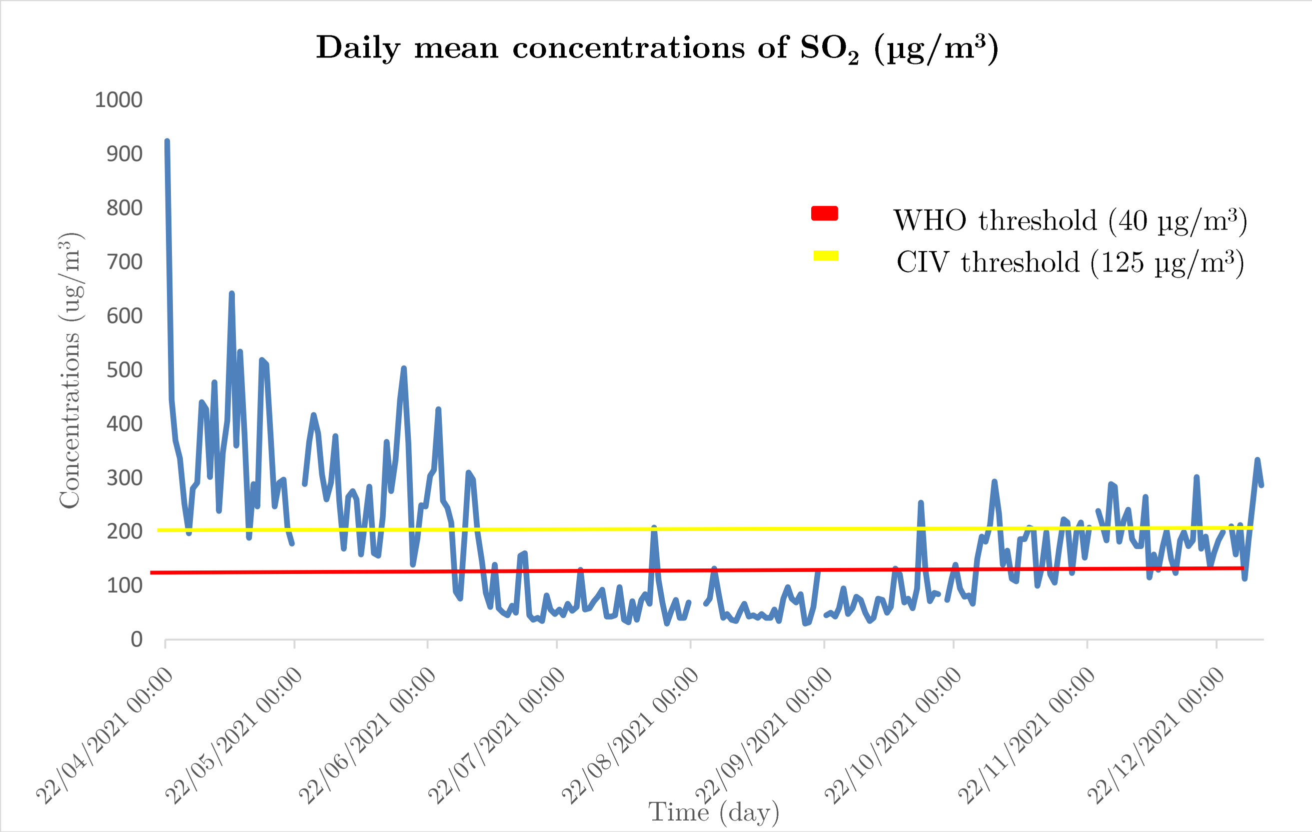

Fig. 7. Daily variations in SO_2 concentrations (µg/m³) in ambient air at the Attécoubé lagoon, from April to December 2021 (the horizontal red and yellow lines indicating WHO and National Air Quality thresholds, respectively).

3.4 Daily variations in particulate matter PM_{10} concentration

Fig. 8 shows the average daily PM_{10} concentrations from April to December 2021. Significant concentrations of PM_{10} are recorded from April to October 2021, with values between 20 and 86 µg/m³. Peaks in PM_{10} concentrations occur in the consecutive months of May, June, August, September, and December, with values around 80 µg/m³. During the study period, PM_{10} concentrations exceeded the WHO's defined threshold (45 µg/m³). In addition, the threshold of the Air Quality Decree (50 µg/m³), which should not be exceeded more than thirty-five times per calendar year, was also exceeded one hundred and seven times during the study period (Fig. 8).

These threshold exceedances can likely be attributed to major emission sources in the study area, such as heavy road traffic, wood-fired cooking, and open waste burning.

3.5 Variation in daily concentrations of particulate matter $PM_{2.5}$

Fig. 9 illustrates the daily variations in PM2.5 concentrations from April to September 2021 at the Attécoubé lagoon. PM2.5 shows a double peak in June, around 39.07 and 50.62 µg/m3 on the 15th and 24th, respectively. A single peak of 46.17 µg /m³ is also recorded on October 9. Notably,

$PM_{2.5}$ levels increase from April to July and again from November to December, while exhibiting a decrease from August to September. These concentrations are strongly linked to seasonal rainfall, consistent with Abidjan's climate pattern: a long rainy season from April to July, a short dry season in August-September, and a brief rainy season from October to November. Throughout the study period, $PM_{2.5}$ levels remain mostly above the WHO threshold of 15 µg/m³ (Fig. 9), exposing Attécoubé's residents to a significant risk of $PM_{2.5}$-related health issues.

Air quality measurements at the Attécoubé lagoon revealed high and variable concentrations of SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$ during the period from April to December 2021. The variations in these concentrations can be explained by the different anthropogenic activities carried out during this period. Road and lagoon traffic was significantly heavier on weekdays, particularly early in the week, in sharp contrast to weekends and public holidays. This low traffic activity on non-working days has reduced the concentrations of some air pollutants, as shown by [13] with car-free days. According to [13], car-free days are events that succeeded in reducing the concentration of some air pollutants but had little or negative effects on the concentration of others.

In general, the concentrations of particulate pollutants (PM_{10} and $PM_{2.5}$) and gaseous pollutants (SO_2 and NO_2) exceeded the WHO's daily threshold during the study period, except for CO. The average NO_2 concentrations in this study (11.28 µg/m³ to 39.50 µg/m³) were relatively lower than those found by [14] in Rio de Janeiro (Brazil), where concentrations ranged from 20 to 80 µg/m³.

In this study, the mean concentrations of PM_{10} and $PM_{2.5}$ were 61.1 µg/m³ and 58.3 µg/m³, respectively. These values are comparable to those reported by [15] at road traffic sites in Abuja, Nigeria, where daily mean concentrations ranged from 5.30 to 70.20 µg/m³.

The Attécoubé lagoon area is located near a lagoon bay, commonly known as "*Baie du Banco*" and the main road (*Boulevard de la Paix*) linking the large commune of Yopougon and the administrative city of Plateau. Due to its geographical location, the Attécoubé lagoon is exposed to all types of pollution, particularly those related to road traffic. Some authors [16-18] have pointed out that vehicle emissions have become the main source of atmospheric pollutants, including carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), volatile organic compounds (VOCs), hydrocarbons, nitrogen oxides (NOx), exhaust gases, and particulate matter (PM).

The high concentrations of SO_2 observed (above WHO and Decree N°2017-125 of February 22nd, 2017 thresholds) during the study period could be caused by the high sulfur content (1500 to 2000 ppm) of the fuel used in Côte d'Ivoire [19].

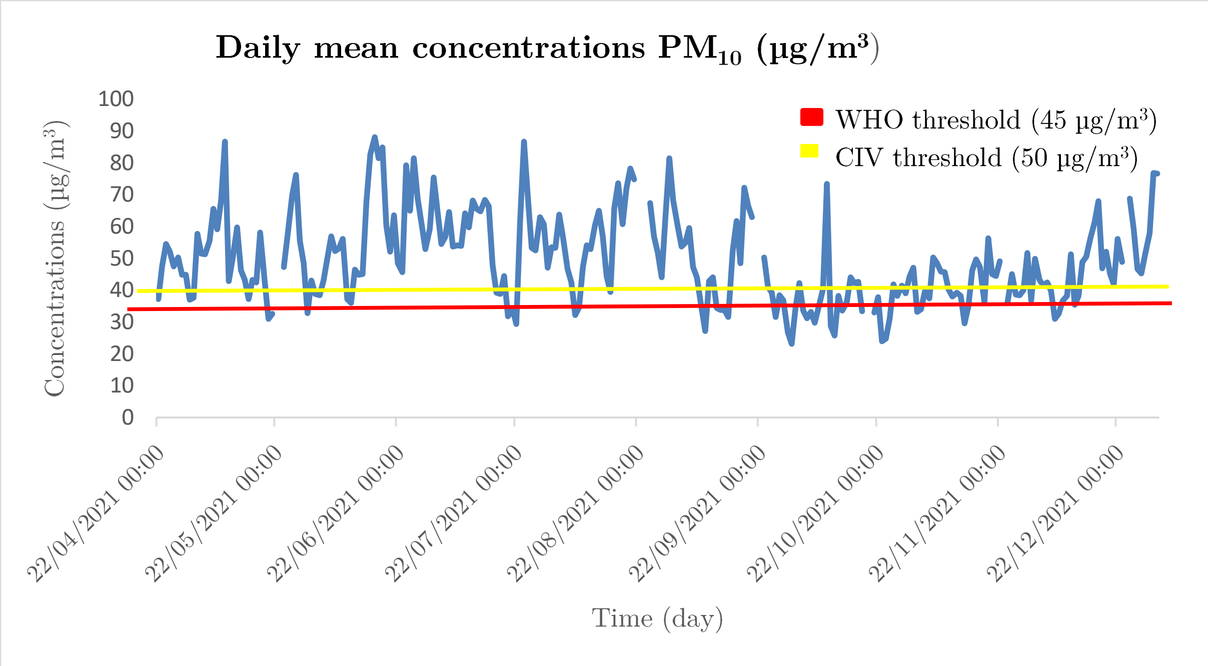

Fig. 8. Daily variations in PM_{10} concentrations (µg/m³) in ambient air at the Attécoubé lagoon, from April to December 2021 (the horizontal red and yellow lines indicate WHO and national air quality thresholds, respectively).

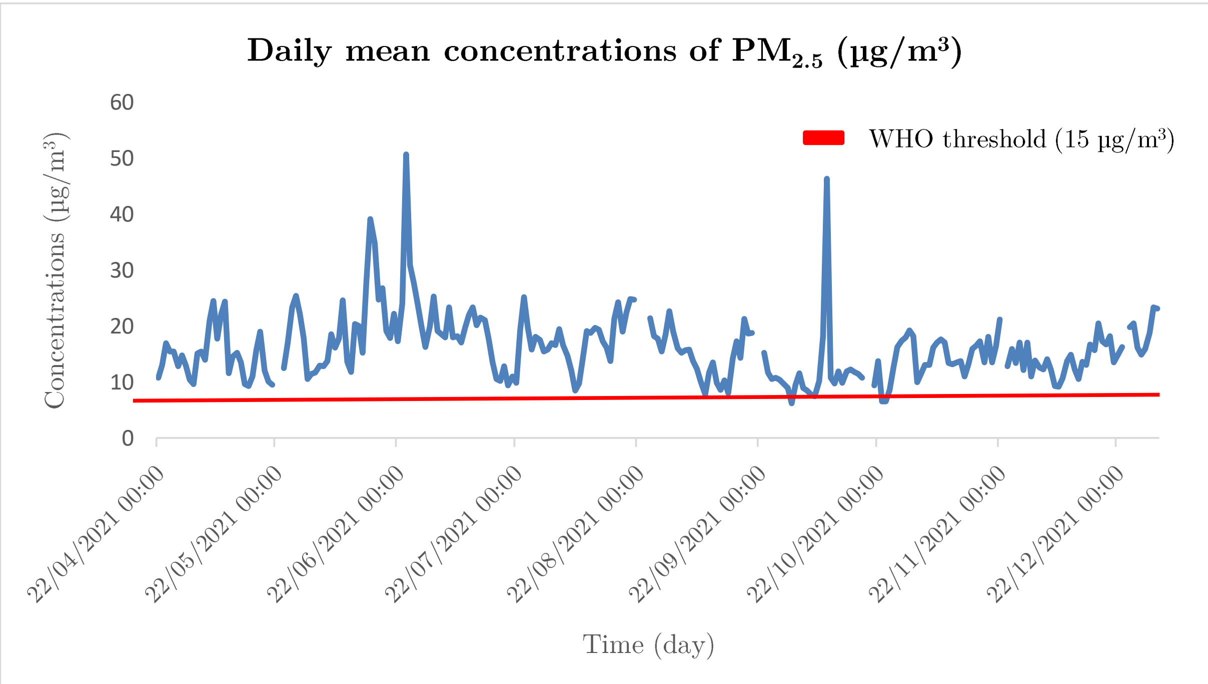

Fig. 9. Daily variations in $PM_{2.5}$ concentrations (µg/m³) in ambient air at the Attécoubé lagoon, from April to December 2021 (the horizontal red line indicates the WHO threshold).

The high levels of particulate matter (PM10 and PM2.5) are caused by domestic fires used for cooking and smoking fish or meat for sale, as well as by industrial activities such as cement factories and sand quarries near the Attécoubé lagoon area. Additionally, the average PM10 concentrations (49.51 µg/m3) recorded during the study are similar in magnitude to those observed by [20] in Sao Paulo (Brazil), where the average PM10 level is 55 µg/m3. It is important to highlight that continuous exposure to pollutants from human activities increases the risk of respiratory diseases, such as asthma attacks, chronic obstructive pulmonary disease (COPD), and others [20].

In Côte d'Ivoire, fish is smoked using highly polluting rubber wood, exposing women involved in this activity (and their babies) to potential respiratory problems, particularly with $PM_{2.5}$.

During the period for which air quality data were measured in Attécoubé, carbon monoxide (CO) concentrations remained below the WHO daily threshold value for the year 2021. Furthermore, the high levels of CO, SO_2, and NO_2 concentrations observed in December could be attributed to preparations for the festive season, which led to heavy traffic and congestion during the day.

4 Conclusion

In this study, an assessment of air quality in the commune of Attécoubé was carried out using an air quality monitoring station called Cairnet. This station was used to measure concentrations of air pollutants, including SO_2, CO, NO_2, PM_{10}, and $PM_{2.5}$. The air quality in the Boribana area of the Attécoubé commune was assessed. This assessment revealed the true extent of the population's exposure to these pollutants. The results showed that the daily concentrations of SO_2, NO_2, PM_{10} and $PM_{2.5}$ exceeded the thresholds set by the National Air Quality Decree and the World Health Organization, except for CO. The daily threshold for SO_2 (125 µg/m^3), set by the National Air Quality Decree not to be exceeded more than three times per calendar year, was exceeded more than two hundred times during the study period (about 8 months). The daily limit value for the protection of human health for PM_{10} (50 µg/m^3) not to be exceeded more than thirty-five times per calendar year was exceeded one hundred and seven times during the study period. Daily concentrations of $PM_{2.5}$ were generally above the WHO threshold (15 µg/m^3) throughout the study period. As a follow-up to this study, we plan to extend the air quality assessment to all major cities in Côte d'Ivoire by setting up a national air quality observation network (RNO-air). The data from this network will serve as an advocacy tool for informed decisions to limit air pollution sources, promoting the well-being of the Côte d'Ivoire population.

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