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Monitoring and Control of Particle Matter Concentration’s Traffic-Related Air Pollution Using Low-Cost Mobile Sensors at Six Intersections in Yaoundé, Cameroon

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors conducted the study and the collection of data relevant for the writing of the article. All authors contributed to conceptualization, structuring and writing of the article. All authors read and approved the final manuscript.

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ABSTRACT

Particle pollution has a major influence on public health in Central African cities. Measuring the levels of pollution to which populations are exposed is difficult because only a few African countries have an air quality monitoring network in place. Yet, given the specific anthropogenic sources

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prevalent in African countries, as well as the predicted increase in their emissions in the next few years if no laws are implemented, solutions must be developed. The methodology utilised in this study allows diverse research teams to estimate the population's exposure levels to urban particle pollution at a lower cost. In this investigation, we collected data concentrations using Air Master. The spatial mapping of pollutants shows that the Mvog-Mbi crossroad and the Education crossroad are the most polluted points among the six measurement points, with $PM_{2.5}$ concentrations around 145–170 $\mu g.m^{-3}$. Regarding PM_{10} and PM_1, the Mvog-Mbi crossroads is the point where concentrations are highest, fluctuating respectively between 150 and 180 $\mu g.m^{-3}$, 41 and 48 $\mu g.m^{-3}$. At some locations, the particle ratio exceeds the WHO recommended range of 0.5–0.8 (Mvog-Mbi Crossroads, Education Crossroads, Poste Centrale, Hilton). These are the high-risk zones for those with respiratory difficulties. At some locations, the particle ratio exceeds the WHO recommended range of 0.5–0.8 (Mvog-Mbi crossroads, education crossroads, Poste Centrale, Hilton). Regardless of particle size, these pollutants in air readings are greater and beyond the World Health Organization's recommended values. Furthermore, this investigation provides critical information on Yaoundé pollution levels, which can be a major source of disease in the city.

Keywords: Urban air quality; low-cost mobile sensors; particulate matter; air pollution; Yaoundé.

1. INTRODUCTION

People's mobility in urban areas today is one of the primary causes of poor air quality in metropolitan regions. The rapid urbanization of cities increases the need for transportation, which lowers air quality. Traffic-Related Air Pollution (TRAP) is the leading cause of air pollution in cities and towns around the world [1]. Intersections in urban settings are places where traffic is dense for much of the day and are positioned as one of the hotspots of pollutants [2]. Gaseous pollutants and particle pollutants are two types of pollutants that harm the environment in metropolitan areas [3,4]. Numerous studies illustrate the impact of high-concentration exposure. Furthermore, exposure to contaminated air causes the development and worsening of respiratory and cardiovascular disorders, lung cancer, and a variety of other ailments [5]. Air quality management entails public awareness efforts about the impacts of exposure, measurement campaigns to determine the levels of gaseous or particle pollutants, and compliance with gaseous emissions requirements (Euro standards) on automobiles (two wheels, three wheels, etc.). Several countries are vulnerable to all of these air quality management requirements. These are mainly Sub-Saharan African (SSA) countries that lack the necessary resources to adequately study and manage air quality deterioration. Conventional air pollution monitors are expensive, and underdeveloped countries such as Cameroon lack the resources to set up the necessary number of monitoring stations to measure air pollution. The advancement of miniaturized sensor technologies provides an intriguing, low-cost alternative approach for monitoring air pollution [6–8]. These sensors have various advantages over traditional monitoring stations, including the fact that they are modular and may be adapted to meet a variety of needs, including mobile air pollution monitoring [7]. Some scientific studies in Africa and elsewhere have already made use of low-cost mobile measurement instruments [6,7,9]. Intersections in metropolitan areas have higher levels of road pollution than in other areas. To that purpose, Houngbégnon et al. [2] found that crossroads are the most polluting spots in cities. In his study, he contrasts the amounts of particle pollution at a crossroads (many lanes) and a single-lane road. In 2014, Antonel and Chaudhry [10] used a fixed measurement station to study the amount of particulate pollution in the city of Yaoundé and discovered that the concentration levels of particulate matter in the air surpassed WHO standards. A few years later, Nducol et al. [4] observed that concentrations in the air in the city of Yaoundé surpassed WHO standards. The evaluation of air pollutants in cities along highways offers the right amounts of emissions generated by automobiles as well as the exposure levels to commuters, walkers, and those who live or work near these routes. To the best of our knowledge, no traffic-related mobile air pollution monitoring study has been published in Yaoundé City.

Due to the high cost of obtaining and maintaining air quality measuring equipment, the paucity of air pollution monitoring networks, even in the most crowded cities, can be compensated for by the installation of low- and medium-priced sensors offering easy and inexpensive alternatives. In contrast to industrialized countries, most developing-country cities lack the infrastructure to monitor urban air concentrations in order to effectively combat air pollution. Due to a lack of permanent monitoring stations for long-term measurements, financial resources for measurement campaigns, and information on air quality monitoring, air quality monitoring in Africa remains a challenge [11]. Routine monitoring of PM does not exist in most African cities, and only a few studies have reported annual average levels of PM_{10} and $PM_{2.5}$. In most of the studies we found, monitoring campaigns were conducted for less than a year and often for various durations of less than 24 hours per day [12]. The deficiency of air pollution monitoring networks, even in the most urbanized cities, due to the high cost of acquisition and maintenance of air quality measurement equipment, can be compensated by the installation of low- and medium-cost sensors offering simple and low-cost alternatives. Given the diversity of anthropogenic sources and their potency, which is expected to increase if no regulations are taken [13], there is a need to expand studies on pollution in African cities. Several studies already exist on air quality in Africa [2,3,6]. Most of this work has been made possible by the use of less expensive measuring devices [6,14].

Although accessible, these sensors cannot be deployed everywhere. To overcome this problem, an existing experimental methodology based on the use of low-cost sensors in intensive measurement campaigns and a geostatistical processing tool is used to assess particulate air pollution in Yaoundé. In this study, the data were collected at six crossroads in the city of Yaoundé during the month of August 2022. The work of Choudhary A et al. [15] shows that the crossroads are considered hotspots in urban areas. The different measurement sites were chosen in the interest of getting an idea of the level of particulate matter concentrations in the city of Yaoundé. Specifically, this study quantifies the level of PM_{10}, $PM_{2.5}$, and PM_1 concentrations and their spatial and temporal distribution and assesses the traffic-related air pollution on road intersections in the city of Yaoundé, Cameroon.

2. MATERIALS AND METHODS

2.1 Study Area

The capital of Cameroon is the city of Yaoundé (3.52° N, 11.31° E). It covers an area of 180 km for a population that has grown from 1.8 million inhabitants in 2006 to 4.3 million inhabitants in 2020 [16]. According to Matcheubou et al. [17], population growth has happened concurrently with vehicle fleet growth, which is predicted to have increased from 152,000 vehicles in 2006 to 216,000 in 2015. Passenger cars, buses, coaches, trucks and vans, trailers, semi-trailers, and motorcycles comprise the vehicle fleet. Motorcycles are typically purchased new, whereas four-wheelers are typically purchased used. According to the Cameroonian Ministry of Transport, 92% of the Cameroonian car fleet in 2015 was made up of used vehicles that were more than 15 years old [3]. Yaoundé's traffic is congested, especially during rush hour, resulting in traffic bottlenecks. The latter increases journey time, resulting in greater energy consumption and considerable exhaust emissions. It should be mentioned that automobiles in Yaoundé run on fossil fuels such as gasoline and diesel. The studies will be conducted within the framework of this study in the city of Yaoundé's major crossroads, which are areas with high traffic and population density. This is the poste centrale (3°51'38''N, 11°31'13''E), carrefour Mvog Mbi (3°51'04''N, 11°31'18''E), palais de justice (3°51'32''N, 11°31'05''E), Carrefour Hylton (3°51'53''N, 11°30'58''E), carrefour éducation (3°53'25''N, 11°30'17''E) and Camair (3°51'54''N, 11°31'18''E).

2.2 Data Collection and Other Material Needed

In this study, a simple, low-cost mobile air quality testing instrument named "Air Master" was utilised to acquire all of the particle concentration data required. The data collection campaign lasted two weeks, with three days of data collection per site. We measured $PM_{2.5}$, PM_{10}, and PM_1 concentrations, as well as relative humidity, temperature, wind speed, and direction. Measurements were taken at hourly intervals from 7 a.m. to 6 p.m. throughout the collection period. The instruments used were mainly GPS for geographical coordinates, AIR MASTER for measuring the various concentrations, and ESTECH for wind direction. At each measurement station, particulate matter was monitored for three days. A GPS was utilised to obtain the geographical coordinates of the various measurement stations (Fig. 2b); the Extech (thermo-anemometer) was used to detect the wind direction (Fig. 2c). The Air Master additionally measures temperature and relative humidity (Fig. 2a). The wind speed was measured using an anemometer (Fig. 2d). The measuring campaign was carried out in the city of Yaoundé during the month of August 2022, where we took measurements on three separate city intersections from 7 a.m. to 6 p.m. (Fig. 1).

Fig. 1. The location of the data collection site

Fig. 2. The different devices needed for this study (a) Air analyser and charger, (b) Garmin type GPS, (c) Extech, (d) Anemometer

The acquired raw data were then organised in Excel software. SPSS was used to evaluate the categorised data, which was then reported as tables and graphs using descriptive statistics (central and dispersion indexes).

2.3 Meteorological Data and Surrounding Pollution

Temperature, relative humidity, and wind velocity are evaluated at local scales to assess the effects of meteorological conditions on PM concentration levels observed at each site throughout the sample period (Table 1). The wind rise allows you to choose your favourite wind direction at each of the six collection stations. The winds blow northwest at Camair and Poste Centrale. The wind is blowing from the east at the Mvog-Mbi interchange, while it is blowing from the south-east at the Education interchange. There are two preferred directions for the two remaining sites (Hilton junction and Palais de Justice), South-East and North-East.

After analysing the field data, it was discovered that the winds at the Education junction have a low percentage of calm wind, i.e. 44.44%, compared to the Mvog-Mbi junction, which has 72%. This is due to the fact that Carrefour Education is placed at a higher height than the other sites.

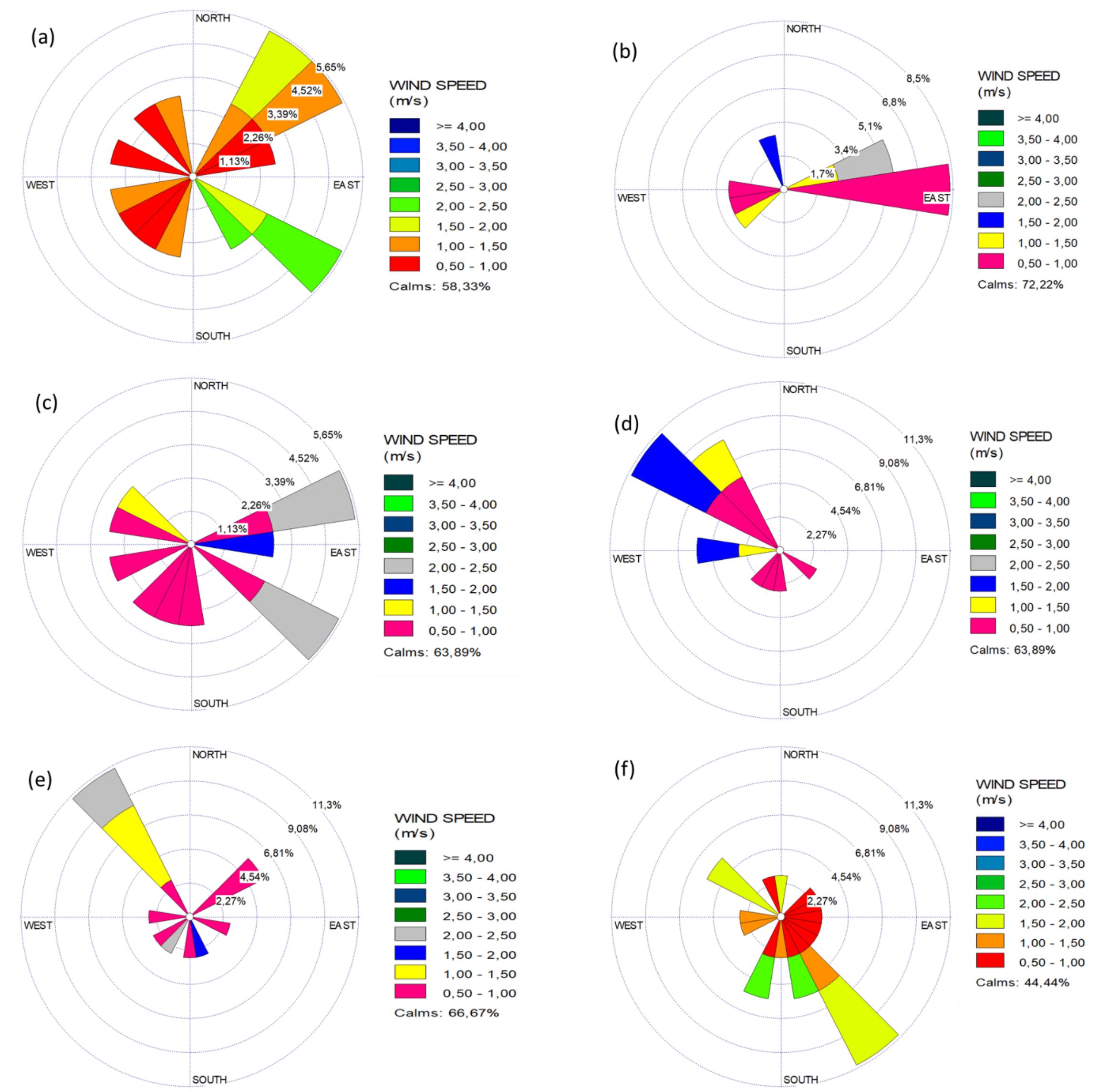


Fig. 3. Wind rose: (a) carrefour Hilton, (b) carrefour Mvog-Mbi, (c) Palais de Justice, (d) Camair, (e) Poste Centrale, (f) carrefour Education

Table 1. Average variation of some meteorological parameters at the different measurement locations (August 2022)

Sites of measurement	Relative humidity (%)	Temperature (°C)	Wind Speed (Km/h)
Carrefour Education	75.33 ± 31	24.92 ± 16	2.61 ± 0.32
Hilton	76.17 ± 19	24.69 ± 31	2.31 ± 0.22
Palais de Justice	76.27 ± 32	24.62 ± 10	1.68 ± 0.72
Camair	76.65 ± 18	25.47 ± 16	1.73 ± 0.2
Poste centrale	77.65 ± 39	25.51 ± 05	1.81 ± 0.39
Carrefour Mvog Mbi	71.63 ± 23	26.78 ± 21	1.51 ± 0.52

2.4 Spatial Mapping

Geospatial Information Systems (GIS) use interpolation to provide a robust method of geographical analysis. In previous publications, the most commonly used methods, kriging (the geostatistical method) and reverse weighting of IDW (the deterministic method) have been compared [8]. The megacity of Delhi revealed that kriging and IDW approaches are linked with errors of approximately 22% and 24%, respectively [18]. Furthermore, as part of the DACCIWA Programme, Bahino et al. [19] investigated the geographical distribution of gaseous pollutants (NO_2, SO_2, NH_3, HNO_3, and O3) in Abidjan (Ivory Coast) and Cotonou (Benin) during the dry season. The later study compared kriging with IDW and discovered that the IDW method is associated with less uncertainty than the kriging method.

Furthermore, our measurement network (number of points and geographic locations) is based on the network of Bahino et al. [19]; thus, in this study, the IDW method is chosen and applied to the acquired data. ArcGIS version 10.3 software (ESRI Inc.) is utilised since it integrates geostatistical data processing and map editing. In brief, IDW interpolation predicts concentrations around a measured point using the technique shown in Eq (1).

$$Z_{p_j} = \sum_{i=1}^{N} \lambda_i \times Z_{0_i} \quad (1)$$

Where Z_{0_i} is the observed value at position from the geometrical mean of measured values at each site during the different measurement campaigns. Z_{p_j} is the expected value for position j; N is the number of measured sample points that will be considered in the prediction around the expected location; λ_i are weighting factors used for each measured value at location. They decrease as the separation distance increases.

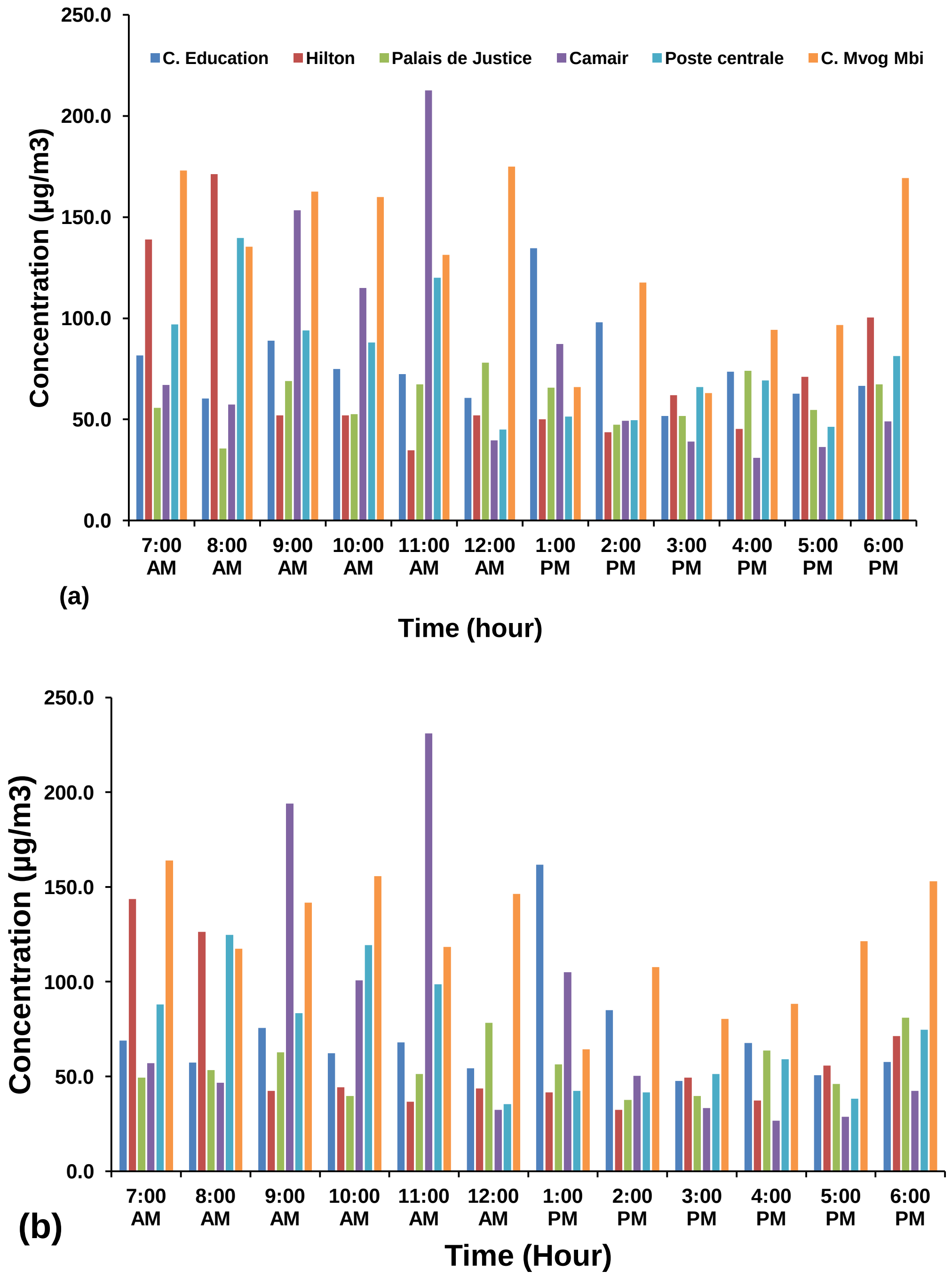
3. RESULTS AND DISCUSSION

3.1 Hourly Variations of Measured Particulate Matter Concentrations

Because of their growing impact on human health, particularly respiratory disease and cardiovascular difficulties, $PM_{2.5}$ pollutants have recently become the focus of intensive research worldwide. The current study considers the importance of monitoring ambient air quality because acute particle pollution can cause poor visibility and a significant increase in respiratory illnesses. The experimental details revealed a similar pattern in $PM_{2.5}$ concentrations as in PM_1. By 11 a.m., the concentrations reached their peak in Camair (230.50 µg/m^3) (Fig. 4a and Fig. 4b). Fig. 4 depicts the various variances based on the hours for the other sites.

Because the particles are similar in nature due to their larger size when compared to the particle size already considered, the results for PM_{10} and TSP have been considered in the same section. While the bulk of these pollutants are smaller particles, the scenario for PM_{10} and TSP is similar. Most research on PM_{10} and TSP has found that $PM_{2.5}$ particles account for about 38-77% of the proportion of these two pollutants [20]. These contaminants are larger than other particles and, as a result, can be deposited due to their increased dispersion rate and deposition capacity. The movement of automobiles causes a steady dispersion of dust from the road surface into the surrounding air. In August, the relative humidity of the air is higher, causing these contaminants to stagnate in the air. Furthermore, fog in the winter provides these toxins with a larger surface area to persist in the air. Camair (220 µg/m^3) had the highest maximum average for PM_{10}, followed by Carrefour Mvog Mbi (175 µg/m^3), Hilton (104.40 µg/m^3), Poste Centrale (140 µg/m^3), Carrefour Education (135 µg/m^3), and Palais de Justice (85 µg/m^3).

Data on particulate matter (PM$_1$) in the research area's ambient air quality was statistically examined. According to the statistics, the highest average PM$_1$ concentration was found at Carrefour Mvog Mbi (39.35 µg/m^3) (Table 2). PM$_1$ particles come from a variety of natural and manmade sources, and they are the consequence of chemical transformations in the gas phase, heterogeneous reactions, and multiphase reactions [21]. Because of their small size, these particles can travel a greater distance and stay in the lower atmosphere for a longer amount of time [22]. Fig. 5 illustrates a box plot of the variance of each particle size at the various measurement locations; it is clear that the roundabout Mvog Mbi has higher particle concentrations than all other areas where monitoring was conducted.



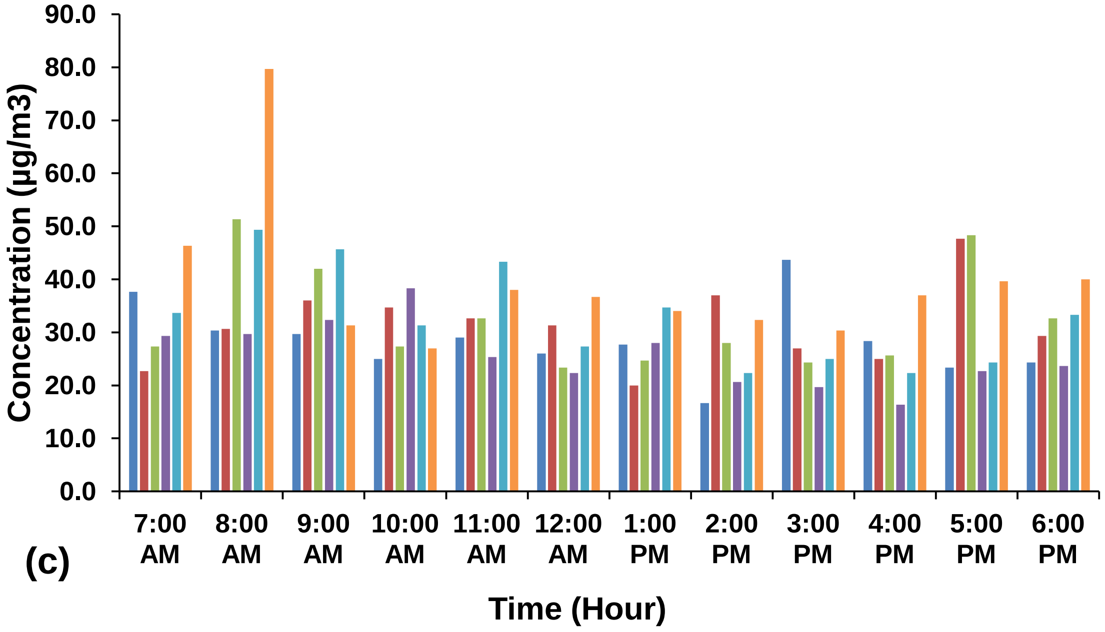


Fig. 4. Hourly average variation of PMs at different measurement sites (a) PM_{10} ;(b) $PM_{2.5}$ and (c) PM_1

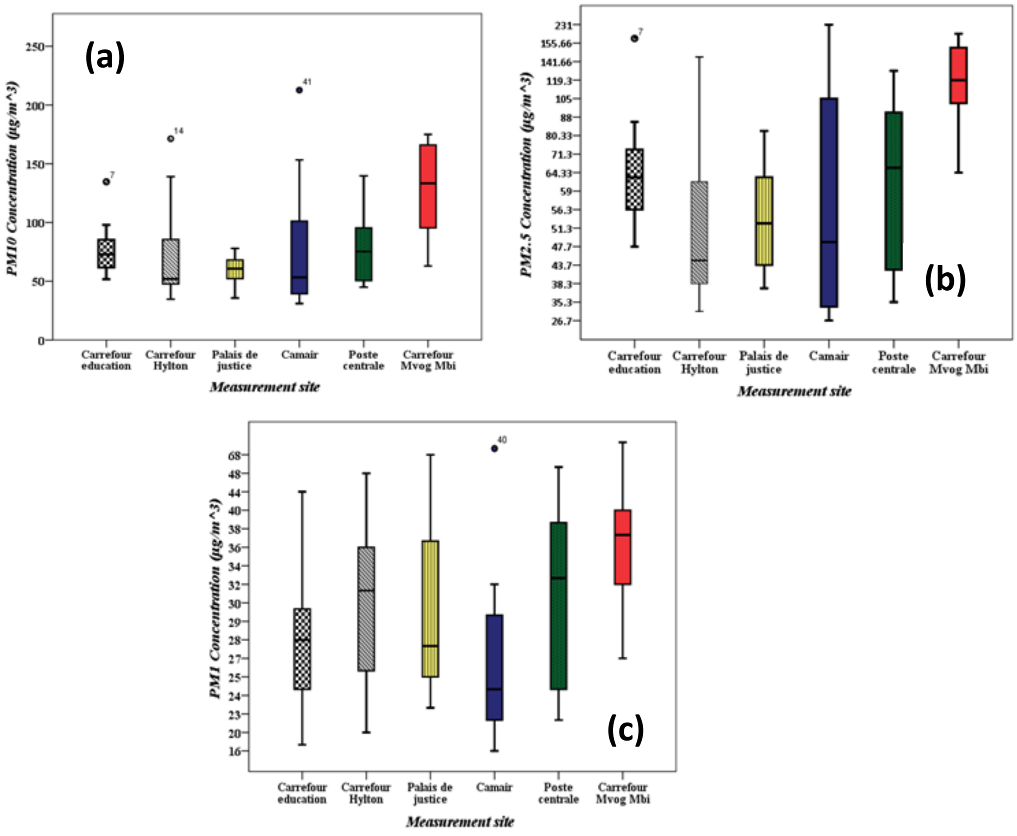


Fig. 5. Box plot of concentrations for different measurement site: PM_{10} (a); $PM_{2.5}$ (b) and PM_1 (c)

Table 2. Average variation of PMs at the respective measurement sites

Sites of measurement	PM_{10} [Min-Max] (µg/m^3)	$PM_{2.5}$ [Min-Max] (µg/m^3)	PM_1 [Min-Max] (µg/m^3)
Carrefour Education	77.20 ± 22.29 [52-135]	71.42 ± 30.36 [48-162]	28.45 ± 6.89 [17-44]
Hilton	72.77 ± 42.46 [35-171]	60.38 ± 36.48 [33-144]	31.17 ± 07.39 [20-48]
Palais de Justice	59.91 ±12.26 [36-78]	54.91 ± 14.31 [38-80]	33.96 ± 13.59 [21-69]
Camair	78.07 ± 55.93 [31-212]	79.00 ± 67.89 [28-231]	29.02 ± 16.19 [17-79]
Poste centrale	78.96 ± 30.32 [45-140]	71.38 ± 31.61 [36-125]	32.70 ± 09.24 [23-50]
Carrefour Mvog Mbi	126.69 ± 41.02 [63-175]	121.51 ± 31.02 [65-164]	39.35± 13.71[27-80]

Referring to the Cameroonian standard NC 2856: 2021 on air quality requirements, which sets $PM_{2.5}$ concentrations at 25 (µg/m^3) and PM_{10} at 50 (µg/m^3), and to the WHO standard, which sets $PM_{2.5}$ concentrations at 15 (µg/m^3) and PM_{10} at 45 (µg/m^3) for daily exposure, we note that daily averages are well above the standard's recommendations. In terms of public health, the 136th session of the World Health Organisation (WHO) Executive Board describes the distressing effects of exposure to such particles: pneumonia, lung cancer, non-communicable diseases, and high mortality rates in developing countries. A significant reduction in pollution levels is therefore an even more topical issue than the present study, given the complementary nature of the two.

3.2 $PM_{2.5}/PM_{10}$, PM_1/PM_{10} and $PM_1/PM_{2.5}$ Ratio Distribution

Table 3 shows the ratio of particulate matter sizes at the various measurement sites. The ratio's high values suggest that the majority of PM pollution is caused by combustion sources, while low values show that air pollution is caused by natural and dust sources [4]. As a result, the larger the ratio, the greater the dangers of PM pollution. The obtained ratio values were interpreted for various site appreciation scenarios. Fig. 6 informs us that the highest ratio values are those of $PM_{2.5}$/ PM_{10} which is about 0.89 ± 0.09. This number is less than one (1). Because this value is less than one (1), we can conclude that road dust is the source of the majority of particle pollution. This resuspension can contribute as much as to 50% of the particle emissions from road traffic [23]. Despite this, the high range of $PM_{2.5}$ and PM_{10} (fine and coarse particles) ratios examined in this study was 0.79 0.09 - 0.89 0.09, which was higher than the WHO guideline standard of 0.5 - 0.80 [24]. This ratio is nevertheless a health risk for pregnant women and their foetus, as well as infants under the age of five, whose respiratory airways have high surface surfaces and absorption capacity for fine particulate matter.

3.3 Pollution Spatial Mapping

Fig. 7 represents the contours of the particulate matter concentration values obtained from extrapolation of the Air Master readings. The scale bar depicts nine distinct colour concentrations, going from less dense (blue) to denser (pink). The geostatistical distribution of PM_{10} is depicted in Fig. 7a. According to the colours on the map in Fig. 7a, the most polluting location is the carrefour Mvog-Mbi, which has concentrations up to 180 vg.m^{-3}, followed by the carrefour education, which has a concentration of around 135 µg.m^{-3}. Concerning Fig. 7a, the least dense areas in comparison to the other two are Poste centrale, Hilton, Palais de Justice, and Camair, with concentrations ranging from 60 to 100 µg.m^{-3}. Fig. 7b shows that the Mvog-Mbi and Carrefour Education crossroads had the highest $PM_{2.5}$ concentration thresholds as compared to

Table 3. $PM_{2.5}/PM_{10}$, PM_1/PM_{10} and $PM_1/PM_{2.5}$ ratio values

Sites of Measurement	$PM_{2.5}/PM_{10}$ [Min-Max]	PM_1/PM_{10} [Min-Max]	$PM_1/PM_{2,5}$ [Min-Max]
Carrefour education	0.86 ± 0.06 [0.70-0.95]	0.40 ± 0.16 [0.17-0.85]	0.44 ± 0.18 [0.17-0.92]
Hilton	0.81 ± 0.66 [0.71-0.96]	0.50 ± 0.24 [0.16-0.94]	0.62 ± 0.25 [0.16-0.93]
Palais de Justice	0.79 ±0.09 [0.58-0.91]	0.53 ±0.18 [0.30-0.99]	0.60 ±0.19 [0.30-0.96]
Camair	0.79 ± 0.11 [0.61-0.95]	0.45 ± 0.16 [0.12-0.68]	0.51 ± 0.22 [0.11-0.79]
Poste centrale	0.83 ± 0.66 [0.67-0.92]	0.43 ± 0.11 [0.32-0.68]	0.50 ± 0.16 [0.26-0.82]
Carrefour Mvog Mbi	0.89 ± 0.09 [0.64-0.97]	0.33 ± 0.13 [0.17-0.59]	0.34 ± 0.14 [0.17-0.68]

other sites, with values ranging from 140 to 170 µg.m^{-3}. Nevertheless, in terms of PM$_1$, the Mvog-Mbi crossroads remains the location with the highest pollutant threshold, around 48 µg.m^{-3}, followed by Carrefour Hilton with a concentration of 37 µg.m^{-3} (Fig. 7c).

In general, the Mvog-Mbi intersection has the highest concentrations of PM$_{10}$, PM$_{2.5}$, and PM$_1$. This is understandable given that the Mvog-Mbi crossroads is in the heart of a market. We know that markets, such as carpentry, painting houses, road traffic, wood burning for catering, and so on, are sources of particulate matter.

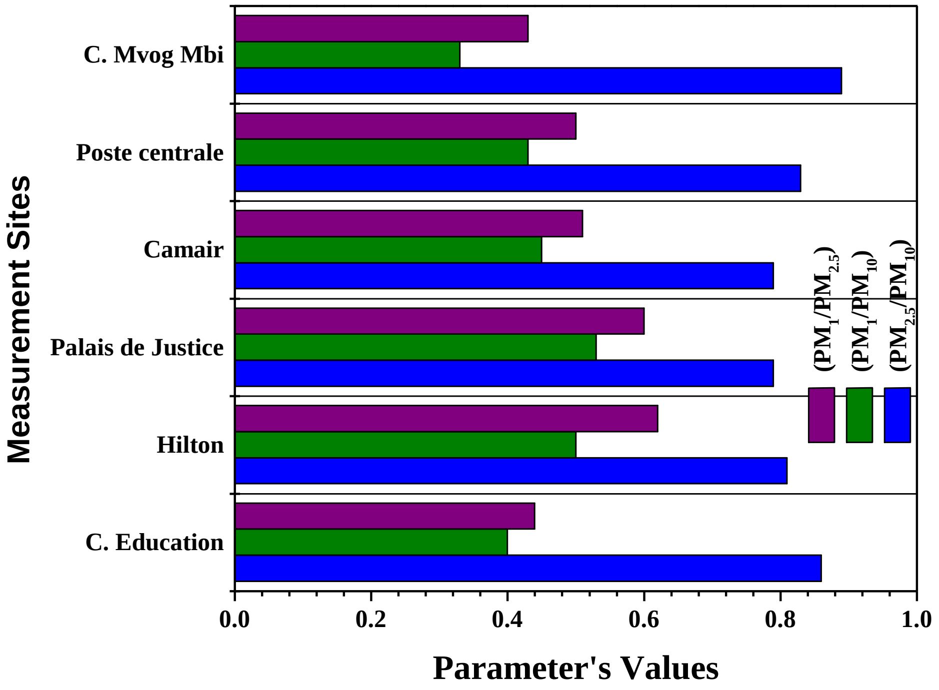
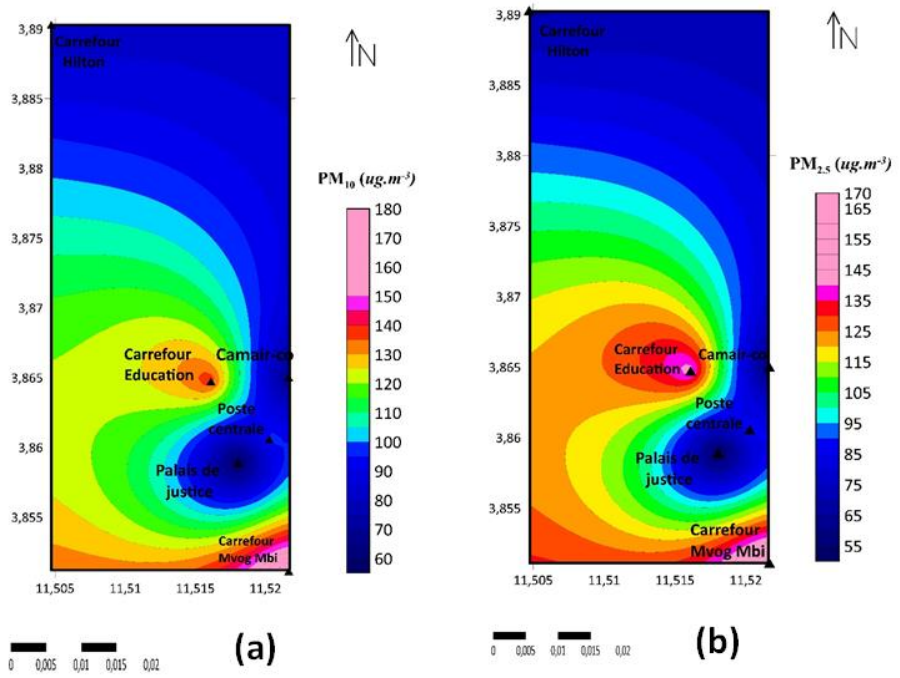


Fig. 6. Ratio of particles in the different measurement locations



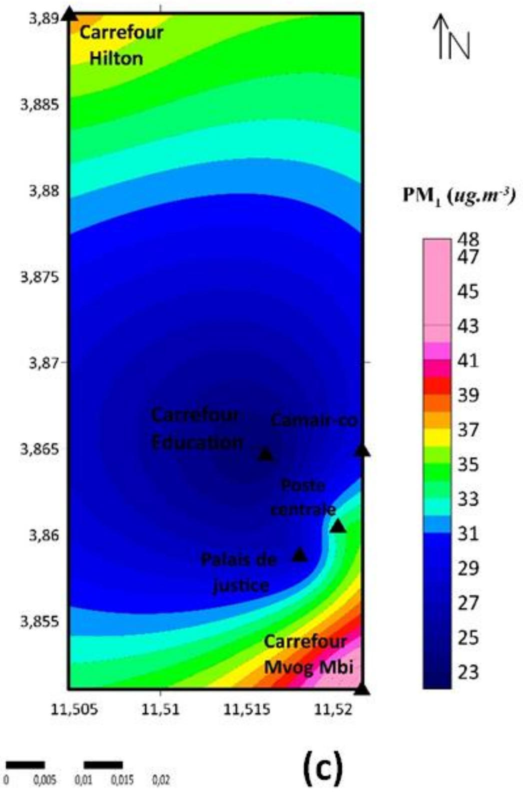


Fig. 7. Spatial variation of the relative difference between (a) PM_{10}, (b) $PM_{2.5}$ and (c) PM_1 in Yaoundé (Cameroon), the black triangle representing each measurement site

In general, particulate matter pollution in the city of Yaoundé exceeds the thresholds set by the National Standards Agency and WHO. The effects on health are all the more important, making it essential to study the means of combating them, or at least to propose concrete solutions. For this reason, municipalities could opt for the implementation of means to clean up roads (this includes asphalting), in fact Yannick et al. [25] shows the contribution of unpaved road in elevated concentration of PMs in Douala city in Cameroun, and please respect the emission standards of vehicles in urban areas since most vehicles in large cities are second-hand or second-generation (Charitos et al. [26]). The development of "green" production processes will also be necessary to meet emission limits. The health sector should also focus on raising awareness and teaching good practises to reduce pollution, as the general public is still largely unaware of the air pollution problem.

All sub-regional countries are developing. Unfortunately, these are the most polluted countries. Therefore, in order to ensure that reference levels are never exceeded, government policies must encourage more research in the field of pollution. It is especially important to contribute to national and international health strategies.

4. CONCLUSION

Particulate matter in the environment is a severe environmental concern for human health, particularly for vulnerable groups such as children. We used a real-time PM detector to quantify ambient particulate matter concentrations such as PM_1, $PM_{2.5}$, and PM_{10} in this investigation (Air Master). Because of the high traffic density at these spots, the results suggest that traffic intersections are the most polluted places in urban regions. In this study, we found very high PM_{10} concentrations at sites such as Carrefour Mvog Mbi, Poste Centrale, and Camair, with average concentrations of around 126.69±41.02 $\mu g.m^{-3}$ 78.96±30.32 $\mu g.m^{-3}$ and 78.07±55.93 $\mu g.m^{-3}$ respectively. Furthermore, the above-mentioned measurement sites have very high $PM_{2.5}$ concentration levels compared with WHO standards for particulate pollutants. With regard to $PM_{2.5}$, we have 121.51±31.02 $\mu g.m^{-3}$ at Carrefour Mvog Mbi, 79.00±67.83 $\mu g.m^{-3}$ at Camair, and 71.38±31.61 $\mu g.m^{-3}$. The Palais de Justice site was the point with the lowest PM_{10} and $PM_{2.5}$ concentration values during this study, at around 59.91±12.26 $\mu g.m^{-3}$ and 54.91±14.31 $\mu g.m^{-3}$ respectively. For PM1, we obtained concentrations of 39.35±13.71 $\mu g.m^{-3}$, 33.96±13.59 $\mu g.m^{-3}$ and 32.70±09.24 $\mu g.m^{-3}$ respectively, at Carrefour Mvog Mbi, Palais de Justice, and Camair. The measuring point with the lowest PM_1 value was Carrefour Education, with a value of 28.45±06.89 $\mu g.m^{-3}$.

Because of the high traffic density, the intersections can be considered hotspots. The varied particle ratios indicate that the majority of the fine particles originate from dust sources. Turbulence caused by vehicle movement revives this dust. According to several studies, resuspension dust caused by road traffic contributes up to 50% of particle emissions in urban areas. According to this study, the Carrefour Mvog Mbi intersection is one of the most polluted in the city of Yaoundé; this high concentration might be justified by the closeness of a market near this crossroads. The closeness of a market near this intersection can explain the high concentration. At the same time, the markets are brimming with alternative particle sources (crushing machines, carpentry, painting, etc.). During the research period, however, mean PM_{10} and $PM_{2.5}$ concentrations surpassed the WHO air quality guideline and national standard. concentrations exceeded the WHO air quality guideline and national standard. We are planning to carry on with this study, focusing on the health impacts of particulate matter in the urban environment, concentrating on fine particles (PM_1, $PM_{2.5}$), because the smaller the particle size, the more it travels through the finest vessels in the body, causing serious health problems.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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