# What is the impact of the concentration of particulate matter on the respiratory health of households in urban Cameroon?

*Quel est l’impact de la concentration des particules matières sur la santé des ménages en milieu urbain camerounais ?*

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# Abstract

The galloping increase in the world's population is promoting growth in the number of cars in major cities, with an impact on air quality in urban areas caused by road traffic. In this study, data on particulate pollutants are obtained through an in situ data campaign from January to March 2023 at major intersections in the city of Douala using the OC 300 Dust Particle Laser, a low-cost portable sensor. In order to estimate the impact of particulate pollutants on the respiratory health of the surrounding population, we surveyed 1,721 individuals in 344 households in the vicinity of the particulate pollutant measurement campaigns. The qualitative econometric analysis model was applied to measure the impact of particulate pollutants on the health of individuals. The analyses show that fine particles (PMs) have a very marked impact on respiratory diseases, with specific effects of 0.231 (PM10), 0.122 (PM5) and 0.018 (PM2.5). In addition, the results show that unsealed roads and traffic density have a strong influence on PM levels. Finally, our results also show that socio-demographic characteristics, in particular the level of education and the distance of households from intersections, moderately influence the impacts of pollution.

**Keywords:** Particulate matter; air pollution; respiratory health; urbanisation; Probit model; Cameroon

JEL : O13 ; Q53 ; I10

# Introduction

Since 1950, the world's urban population has quadrupled, and according to a report by the United Nations Habitat Organisation (UN-Habitat, 2015), Africa is the region of the world that is urbanising faster than any other. Cameroon has not remained on the sidelines of the strong urbanisation recorded by Africa, as its urbanisation rate has risen from 28.5% in 1976 to 52% in 2010. This urban dynamic is creating ever-increasing challenges for the public authorities responsible for urban development. While economic progress has been made in Cameroon in terms of defining the reference frameworks for effective urban policies, several aspects of their implementation still pose problems in terms of heavy air pollution, which threatens the health of inhabitants. The effects of air pollution on household health remain a major concern today. Air pollution is now one of the leading causes of death in the world, surpassing even smoking, AIDS, parasitic or other infectious diseases and violence of all kinds, and has serious consequences for people's health (Li and Jia, 2021). Indeed, more than one million premature deaths each year are attributable to air pollution (Smith et al., 2014; Stanaway et al., 2018). Air pollution leads to health problems, which in turn can lead to difficulties in accumulating human capital. This, in turn, generates economic losses, including lack of income and increased medical expenses. Health problems caused by air pollution can also increase the overall burden of disease within the household and thus affect the performance of health systems by requiring an increase in the human, financial and material resources of the health system (Stabridis and van Gameren, 2018).

A large body of research has identified air pollution as a major risk to individual health, particularly in developing countries (Bakehe, 2021). Research indicates that pollutants can be associated with acute respiratory infections such as cough and flu in children and obstructive lung disease in adults (Duflo and Greenstone, 2008). For example, authors such as McCracken and Smith (1998) show that households exposed to carbon monoxide have more health problems than less-exposed households. In India, Duflo and Greenstone (2008) found a significant correlation between symptoms of respiratory illness and air pollution from household cooking. The main limitation of all these studies is that they consider pollutants such as tropospheric ozone (O3), nitrogen oxides (NOx), carbon oxides (COx), sulphur oxides (SOx), etc., which are gaseous pollutants. Atmospheric pollutants can be divided into two main categories, comprising both small particulate pollutants such as dust, smoke and fog, and gaseous pollutants such as carbon dioxide and carbon monoxide. This article focuses on particulate pollutants such as PM1, PM2.5, PM5 and PM10 (the numbers 1, 2.5, 5 and 10 represent the aerodynamic radius measured in micro metres) which are recognised as having the worst negative effects on human health (Nducol et al., 2021). The work of Mezoue et al (2023) and Ngangmo et al (2024) shows that the dangerousness of a particle is linked to its size.

According to the 2024 report by Green peace[[1]](#footnote-1), fine particle (PM) pollution is now the second leading risk factor for death in sub-Saharan Africa after malnutrition, and the leading environmental risk factor for death in North Africa (Murray et al. 2020). In Central Africa in particular, the sector contributing most to PM emissions is residential combustion, followed by the industrial sector. Poor air quality in this region is therefore attributed to waste combustion, mining and industrial practices such as mineral processing and cement manufacture. In Cameroon specifically, and during the first study of air pollution by particulate matter (PM) in this country in 2014 in the cities of Bafoussam, Bamenda and Yaoundé, Antonel and Chowdhury were already showing that PM2.5 and PM10 concentrations were high and that the burning of refuse and cooking gases increased PM concentrations in the outskirts of the cities. The same authors showed that carbonaceous and non-carbonaceous particles contribute to increasing PM2.5 concentrations in Cameroon. However, Cameroon is making efforts in the fight against pollution, being among the very small group of countries with air quality standards.[[2]](#footnote-2)

The work of Wang et al (2021) and Martins and da Graça (2023) shows that particulate pollutants cause numerous diseases such as asthma, lung infections, coughing, coronary instability, atherosclerosis and arteriosclerotic cardiovascular disease (ischaemic heart disease (IHD) and stroke). Similarly, particulate pollutants that penetrate the central nervous system cause neurodegenerative diseases, alter fasting plasma glucose (FPG) levels and the incidence of type 2 diabetes mellitus (Wang et al., 2021; Martins and da Graça, 2023). These particulate pollutants, which directly affect the ventilation function of the lungs, leaving the body in a hypoxic state, are likely to lead to a reduction in life expectancy (Wang et al., 2021).

The aim of this paper is to assess the impact of particulate pollutants on the health of households in urban Cameroon. The aim of this study is to arouse the interest of the scientific community in the effects of particulate matter pollution on household health in SSA. This paper is of threefold interest. Firstly, it highlights the negative effects of particulate pollutants on the health of households in urban areas. Secondly, it shows the effects of human activities on the concentration of particulate pollutants. Finally, this paper shows the cyclical relationship between the concentration of particulate pollutants, the health of individuals and human activities.

The remainder of this article is as follows: section 2 provides a brief overview of the literature, section 3 develops the methodology adopted, section 4 presents and discusses the results obtained and section 5 concludes.

# 2. Littérature review

Particles are an atmospheric mixture of fine solids and liquid droplets of different sizes (Omokungbe et al., 2020; Oyediran et al., 2021). In most African cities, annual average levels of PM10 and PM2.5 have not been well studied, and systematic monitoring of PMs is lacking. Most of the studies we found conducted their monitoring campaigns for less than a year, often less than twenty-four hours a day (Elisaveta et al., 2013). The lifespan of people who already have health problems is shortened by polluted air, which also increases the risk of respiratory and cardiovascular disorders and has immediate adverse consequences for those exposed (Dockery and Pope 1994; Pope 2000). Particulate matter can be released directly into the atmosphere (primary particles) or formed in the atmosphere (secondary particles) by the physical and chemical conversion of primary particles released by various anthropogenic and natural sources (Sumesh et al., 2017). Wind-blown dust, volcanic eruptions, regional dust, soil resuspension and biological particles are the main natural sources of particles, while anthropogenic sources include fossil fuels, power stations, biomass combustion, quarries and mines (Seinfeld and Pandis, 1998).

Long-term exposure to air pollutants has also been associated with premature mortality and reduced life expectancy (Shaddick et al., 2020). One of the risks of air pollution is the aggravation of diseases such as cardiovascular disease, asthma and respiratory problems (Mezoue et al., 2017). US legislation prescribes limit values for PM10 and PM2.5 in ambient air. The current daily limit values for PM10 and PM2.5 are 150 µg.m-3 and 35 µg.m-3 respectively. The US EPA repealed the annual limit standard in 2006 (US EPA, 2006). Taking into account several studies carried out mainly in the United States, the WHO has established air quality guidelines and provisional objectives for PM10 and PM2.5. The WHO annual average guidelines are 15 µg.m-3 and 5 µg.m-3 for PM10 and PM2.5 respectively (WHO, 2021). However, there are also short-term exposure guidelines of 45 and 15 µg.m-3 averaged over 24 hours for PM10 and PM2.5 respectively (WHO, 2021).

There are many studies showing the effects of particulate pollution on health, but very few in Africa. Guo and Liu (2024) set up a spatial econometric model to study the impact of air pollution on the healthcare expenditure of residents in nine Chinese prefectures. They show that PM2.5 emissions are positively and significantly related to the real cost of healthcare per person and that air pollution is the main source of the increase in healthcare expenditure. Fang et al (2024) highlight the fact that increased particulate pollution could affect eye and ear health by estimating the causal effect of particulate pollution on eye and ear health using data from the China Health and Nutrition Survey. The double least squares (2SLS) method shows that the possibility of eye or ear disease increases by 1.48% for a 10 μg/m3 increase in the average concentration of PM2.5 over four weeks, with impacts lasting around 28 weeks before becoming insignificant thereafter, while being amplified by smoking more and sleeping less. Also in China, Ding et al (2024) establish an integrated assessment framework that combines an emission concentration response surface model and a health impact assessment model to analyse the transport-related health impacts of PM2.5 and O3 pollution in 31 provinces. They found that PM2.5 and O3 contributed to 747,000 and 110,000 deaths respectively in 2017, representing 38% and 48% of deaths caused by total anthropogenic emissions.

In Portugal, Cardinali et al (2024) used data from 1,365 participants and a mediation analysis to show the negative effects of pollution. The contribution of their study is to suggest that the amount of connected green space measured in an intermediate environment seems to be a main characteristic of green space that could lead to the mitigation of air pollution on health. Focusing on children's health, Liu et al (2024) reviewed 33 studies and concluded that pollution caused numerous respiratory diseases, hypertension, leukaemia, autism, otitis media, obesity, pneumonia, asthma, eczema and allergic rhinitis in children. In summary, the study by Liu et al (2024) shows that particulate pollution affects health in several ways: (i) the blood system, (ii) the nervous system, (iii) the circulatory system, (iv) infectious diseases, (v) the metabolic system, (vi) the respiratory system and (vii) allergies. Furthermore, these authors note that there is little research on low- and middle-income countries, despite the fact that developing and developed countries alike suffer from air pollution.

There is a general call for rapid action to combat air pollution, but few studies of air quality have been carried out in Africa because most of the continent's countries do not have monitoring stations or operational data (Agbo et al., 2020). However, the literature identifies several sources of air pollution, particularly in urban areas. The main source of air pollution is road traffic (Ngangmo et al., 2024; Mezoue et al., 2023). When roads are not properly managed and dusty roads are not systematically built, the problem of resuspension of dust is more frequent since previously deposited particles can be resuspended under the effect of tyre pressure, vehicle turbulence and other activities such as wind and pedestrian activity (Singh et al., 2020). Air pollution from an urban perspective is of particular concern in regions undergoing rapid urbanisation, such as sub-Saharan Africa (SSA), where urbanisation rates are among the highest in the world (Schwela, 2006).

Traffic is one of the main reasons why particle levels are too high and is the main source of particles in urban areas (Pant et al., 2013). Vehicles emit particulate matter through their exhaust gases and from sources other than exhaust gases, such as tyre wear, brake wear, road surface wear and the resuspension of road dust (Antonel and Chowdhury, 2014, Fussell et al., 2022). Road transport emissions can be divided into two types of sources: exhaust and other (Jandacka et al., 2023). Exhaust sources are heavily regulated, manufacturers must comply with strict emission standards and the majority of diesel vehicles on the road are now fitted with a particulate trap (Xu et al., 2023; Harrison et al., 2021). As a result, attention is now turning to unregulated emission sources, such as non-exhaust emissions, which have been found to contribute significantly to particulate concentrations (Keuken et al., 2010). Non-exhaust emissions arise from the re-suspension of road dust or road surface wear as the vehicle travels on the road, corrosion of vehicle components or mechanical processes associated with driving, such as brake, clutch or tyre wear (Ngangmo et al.,2024).

Poor air quality in SSA is certainly due to a problem of poverty, as people do not have the means to purchase either air quality monitoring stations or measuring equipment, which makes it difficult to carry out air quality studies in some SSA countries (Amegah and Agyei-Mensah, 2017). Faced with these financial difficulties in carrying out measurement campaigns with state-of-the-art equipment, several studies in SSA have used low-cost equipment to carry out a measurement campaign (Houngbégnon et al., 2019; Ngo et al., 2018, Mezoue et al., 2023). The PM10 measurements taken by Ana et al. (2014) from January to March 2008 in Ibadan (Nigeria) are of the same order of magnitude as the concentrations measured in Korhogo in January 2019. These PM10 concentration levels are typical of the dry season in West Africa. For the same period of the year, Antonel and Chowdhury (2014) found lower PM10 concentrations (105 µg.m-3) in Bafoussam (Cameroon), which is further south, in a forested area, and therefore less exposed to dust. In addition, the results obtained by Dionisio et al (2010) showed that concentrations in low-income areas are higher than in high-income areas in Accra. In this study, PMx concentration data (in µg.m-3) were obtained using the low-cost OC 300 Dust Particles Laser. The instrument is capable of simultaneously measuring four particle sizes: PM10, PM5, PM2.5 and PM1. The measuring device is manufactured by the OCEANUS group, based in China. In addition, the OC 300 Dust Particles Laser was used for the measurement campaign in the city of Douala, Cameroon (Mezoue et al., 2023).

The African Development Bank Group (2012) shows that by 2030, half of Africa's population is expected to live in urban areas, making it all the more urgent to study air pollution in sub-Saharan Africa, a problem strongly associated with urban growth. This high level of urbanisation consequently leads to high levels of mobility (Gnamien et al., 2020). Urbanisation, combined with increased industrialisation and an increase in the number of motor vehicles (Ngo et al., 2018; Mezoue et al., 2017), can lead to a substantial deterioration in air quality on the continent.

# 3. Methodology

We first present the data and variables used and then the estimation method.

## 3.1. Data and variables

The data used in the study were obtained from the Laboratory of Fundamental Physics of the University of Douala during the months of January and March 2023. The study was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent prior to inclusion in the study. Ethical approval was obtained from the ethics committee of Faculty of Health Sciences Institutional Review Board of the University of Buea in Cameroon. The field studies were conducted at eight (08) of the busiest intersections in Douala (1-Rond-point Déido, 2-Douche Akwa, 3-Tradex Ndokoti, 4-Marché central, 5-PK 14, 6-Tradex Yassa, 7-Carrefour Agip and 8-Carrefour Bonamousssadi), the capital of Cameroon, as traffic was expected to be the main source of particulate matter at the various measurement sites (Appendix 1). Measurements of particulate matter were carried out using an OC 300 laser dust particle detector (Oceanus, 2016). This detector is a computerised instrument that monitors the concentrations (μg.m-3) of four fine particle sizes at the same time (PM10, PM5, PM2.5, and PM1) before converting the count data into mass measurements (µg/m3) using a custom algorithm. The instrument, which is classified as a low-cost sensor that simultaneously measures air quality in real time (Savio et al., 2022; Zafra-Pérez et al, 2023), has been calibrated to a full-scale accuracy of less than 3%. The effective range of detectable particle concentrations is between 0 and 999 µg/m3 and was placed approximately 5 m from the road and at a height of approximately 1.50 m at the various measurement sites. At each site, measurements were taken three times a day from 7 a.m. to 8 p.m. during the study period, i.e. in January and March 2023. Appendix 1 shows the different sites and the changes in PMs concentration.

The variables of interest and control variables were taken from the questionnaire submitted to a random sample of individuals located no more than 500 metres from the centre of each site at the end of March 2023. Studies show that PM is generally transported by the wind no further than 500 metres. To ensure that individuals were at the right distance, we surveyed individuals belonging to households or businesses located no more than 500 metres from the centre of each site. This approach enabled us to take account of two situations: (i) the distinction between individuals who carry out their activities close to the sites and those who live there, and (ii) passers-by who are only briefly and inconsistently exposed to the PM of the sites. In fact, those who carry out their activities are exposed to PM from the sites only for the duration of their activities, and it is possible that they live elsewhere. In all, we surveyed 1,721 individuals in 344 households. In addition, the fact that the questionnaire was submitted at the end of March 2023, i.e. in the middle of the academic year, limits the risk of household migration. The choice of these last variables was guided by the literature and the context. Health is assessed by the occurrence of respiratory illnesses such as asthma, lung infections, coughs and respiratory problems, which are the most common among households (Bley et al., 2013). The control variables group together a set of social-economic and demographic characteristics such as: age, sex, level of education, distance between the dwelling and the nearest site, household size, occupation and mobility.

## 3.2. Estimation method

Given the binary nature of each of our health variables, a qualitative econometric analysis model is appropriate for measuring the impact of PM on the health of urban individuals in Cameroon. The binary logit model is one of the most widely used models in this field. Indeed, the logit model is considered both as an alternative method to linear discriminant analysis, a regression model where the dependent variable is binary or even as a discrete choice economic model (Afsa, 2016). To model the health status of the individuals in our sample, we assume that the individuals are divided into 2 categories C1 and C0 corresponding respectively to the fact of having or not having a given respiratory disease. We want to analyse and quantify the link between the individual characteristics Xik and the occurrence of the disease.

We assume that the probability P that individual i, given his characteristics, belongs to category C1 is given by:

represents all the variables retained, including PM concentrations and the other social and economic variables presented above. After simplification, we obtain the following equation:

represents the effect of the variable on Y while , which represents the error term, contains in particular all the information, all the variables that can influence health status but that remain unknown to us because we do not observe them (Brooks, 2019). We use the robust maximum true likelihood method to estimate the parameters of equation 2 (Brooks, 2019). Moreover, there is certainly an endogeneity of PM concentration on health. This endogeneity stems from at least two sources: the high probability of errors in the reporting of health variables and the omission of relevant explanatory variables explaining the occurrence of the diseases selected above, such as medical history, blood group and others. In this context, a binary logit model is no longer appropriate and we must resort to an instrumental variable logit model in order to correct for endogeneity bias (Wooldridge, 2016).

The challenge of an instrumental variable model is to identify the instruments that are correlated with PM concentration but not with the health status of individuals (Wooldridge, 2016). Furthermore, the literature recommends mobilising at least two instrumental variables per endogenous variable to increase the robustness of the model, even if only one relevant instrument ensures the robustness of the model (Wooldridge, 2016). This paper uses two instruments. The first instrument is the proportion of unpaved roads in each site, which is a quantitative variable. Indeed, we believe that an unpaved road is likely to produce more PM than a paved road while it is weakly correlated with the health status of individuals. The second instrument is the rate of road traffic at each site. It is logical to assume that the heavier the road traffic at a site, the higher the PM concentration. Moreover, this variable is uncorrelated with the state of health of individuals. The rate of road traffic is estimated by the simple and practical method of manual counting, although there are other methods such as video surveillance and the use of artificial intelligence (Ngangmo et al., 2024). In this study, manual counting was used to obtain road traffic data using count sheets by category (Trucks, Light Buses (LB), Taxi (T), and Light Vehicles (LV) and motorbikes). The traffic data for this study are obtained by manual counting over four days at the beginning of March 2023, between 7 and 8 am and between 7 and 8 pm. The four counting days are divided into two days during working days (Tuesday and Thursday) and two days during the weekend (Saturday and Sunday). The road traffic rate is calculated as the category-weighted average of the number of vehicles per hour.

# 4. Results

We present the results in two parts: firstly, the results of descriptive analyses and secondly, the results of econometric analyses.

## 4.1. Descriptive analysis

Table 1 below presents the descriptive analysis calculations for our variables, with descriptive statistics in panel (A) and the correlation matrix between the health variables, the MP and the instruments used to correct endogeneity problems in panel (B).

**Table 1: Presentation of descriptive analysis**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **(A)** | | | | **(B)** | | | | | |
|  | | **Mean** | **SD** | **Min** | **Max** | **a** | **b** | **c** | **d** | **e** | **f** |
| 1. **Respiratory disease (yes)** | | **0.73** | **0.09** | **0** | **1** | **1** |  |  |  |  |  |
| 1. **PM1** | | **49.74** | **9.53** | **29.57** | **77.06** | **0.24\*** |  |  |  |  |  |
| 1. **PM2.5** | | **72.81** | **14.20** | **58.29** | **104.21** | **0.36\*** | **1** |  |  |  |  |
| 1. **PM5** | | **80.60** | **16.50** | **73.51** | **95.24** | **0.41\*\*** | **0.58\*** | **1** |  |  |  |
| 1. **PM10** | | **86.91** | **17.74** | **62.33** | **112.05** | **0.54\*\*** | **0.36\*** | **0.39\*\*** | **1** |  |  |
| 1. **Unsealed roads** | | **0.24** | **0.01** | **0** | **0.34** | **0.18** | **0.62\*** | **0.34\*** | **0.31\*** | **1** |  |
| 1. **Traffic density** | | **844** | **218** | **523** | **1354** | **0.09** | **0.32\*\*** | **0.28\*\*** | **0.48\*** | **0.15** | **1** |
| **Age** | | **35.9** | **14.7** | **2** | **69** |  |  |  |  |  |  |
| **Gender (male)** | | **0.53** | **0.38** | **0** | **1** |  |  |  |  |  |  |
| **Education (no education)** | | **0.11** | **0.03** | **0** | **1** |  |  |  |  |  |  |
| **Primary** | | **0.25** | **0.11** | **0** | **1** |  |  |  |  |  |  |
| **Secondary** | | **0.33** | **0.14** | **0** | **1** |  |  |  |  |  |  |
| **Higher** | | **0.31** | **0.18** | **0** | **1** |  |  |  |  |  |  |
| **Profession (merchant)** | | **0.35** | **0.21** | **0** | **1** |  |  |  |  |  |  |
| **Industry** | | **0.23** | **0.19** | **0** | **1** |  |  |  |  |  |  |
| **Student** | | **0.18** | **0.09** | **0** | **1** |  |  |  |  |  |  |
| **Service** | | **0.24** | **0.11** | **0** | **1** |  |  |  |  |  |  |
| **Size (Household/Company)** | | **4.88** | **2.17** | **1** | **9** |  |  |  |  |  |  |
| **Distance to crossroads** | | **315.39** | **89.46** | **10** | **500** |  |  |  |  |  |  |
| **Mobility (yes)** | | **0.78** | **0.12** | **0** | **1** |  |  |  |  |  |  |
| **Sources : Authors** | **SD: Standard deviation** | | | | | **\*\* p<0.01, \* p<0.05** | | | | | |

Panel A of the table presents the descriptive statistics for the variables, including data on respiratory health problems, air pollution and other environmental factors. We find that 73% of people report suffering from respiratory health problems, with a low standard deviation of 0.09, implying that most participants are affected by this problem. With regard to pollution, the average levels of PM concentrations were 49.74, 72.81, 80.60 and 86.91 µg/m³ for PM1, PM2.5, PM5 and PM10 respectively. These results reveal considerable exposure to different particle sizes in the air. However, PM5 and PM10 show even higher concentrations, with respective standard deviations of 16.50 and 17.74. In addition, the table shows that on average 24% of roads are unpaved, with little variability (standard deviation of 0.01). Unsealed road infrastructure could influence fine particle pollution. Similarly, an average density of 844 vehicles per hour was observed, with a standard deviation of 218, revealing significant differences between the zones in terms of traffic.

With regard to the control variables, the average age of the participants was 35.9, and 53% were men. This shows that the majority of our respondents are young, and it is possible that this attenuates the effects of PM on the declarations of the diseases in question. Indeed, it is very likely that older people are more likely to report these illnesses. In addition, the level of education shows that 11% of participants have no education, 25% have primary education, 33% have secondary education and 31% have tertiary education. This means that around 89% of people have at least a primary level of education and may be aware of some basic pollution protection measures. In terms of sector of activity, the most common occupations are shopkeepers (35%), followed by those working in industry (23%) and services (24%). It should be remembered that shopkeepers are likely to be more exposed to pollution than other occupations, since commercial establishments are generally open, whereas service establishments are generally hermetically sealed and air-conditioned. The average size of households or businesses is 4.88 individuals and the average distance to the point of intersection is 315.39 metres, with a wide spread (standard deviation of 89.46). Finally, around 78% of participants are mobile, reflecting a relatively active population and therefore individuals who may leave the intersection points from time to time.

With regard to correlations between variables, we find that fine particles or matter (PM1, PM2.5, PM5 and PM10) show significant associations with the prevalence of respiratory diseases, with increasing coefficients according to particle size: PM10 shows the strongest correlation (0.54), suggesting that prolonged exposure to larger particles is particularly harmful. Furthermore, the presence of unpaved roads and traffic density do not show significant direct correlations with respiratory illnesses, but these factors indirectly influence air quality via significant correlations with fine particles. Panel (B) also highlights the interrelationships between potential sources of pollution. For example, fine particles (PM1, PM2.5, PM5, and PM10) are strongly correlated with each other, suggesting common sources or cumulative effects. Unsealed roads show a significant correlation with PM2.5 (0.62) and PM10 (0.34), confirming their role as a potential contributor to particulate pollution. In addition, traffic density is positively correlated with PM5 (0.48) and PM10 (0.39), underlining that vehicles represent a major source of air pollution.

## 4.2. Impact of PM concentration on household health

Table 2 below shows the marginal effects of the results of the estimates of the effects of PMs on the respiratory health of households in Douala using a Probit model with instrumental variables.

**Table 2: Marginal effects of PM on household respiratory healths**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variables** | **(1)** | **(2)** | | **(3)** | **(4)** |
| **Health equation** | | | | | |
| **PM1** | 0,056\* |  | |  |  |
|  | (0,078) |  | |  |  |
| **PM2.5** |  | 0,018\*\*\* | |  |  |
|  |  | (0,000) | |  |  |
| **PM5** |  |  | | 0,122\*\* |  |
|  |  |  | | (0,039) |  |
| **PM10** |  |  | |  | 0,231\*\*\* |
|  |  |  | |  | (0,000) |
| **Age** | -0,042 | 0,001 | | -0,028\* | -0,009\* |
|  | (0,376) | (0,622) | | (0,093) | (0,057) |
| **Gender (male)** | 0,019 | 0,000 | | 0,003 | 0,007 |
|  | (0,552) | (0,413) | | (0,291) | (0,158) |
| **Educational level (no education)** |  |  | |  |  |
| **Primary** | -0,087\* | -0,031\*\* | | 0,094 | -0,019\*\* |
|  | (0,069) | (0,046) | | (0,129) | (0,024) |
| **Secondary** | -0,013 | 0,000 | | -0,027\* | -0,102 |
|  | (0,712) | (0,369) | | (0,068) | (0,249) |
| **Higher** | -0,027\* | -0,008 | | 0,017\*\* | 0,069\* |
|  | (0,088) | (0,133) | | (0,025) | (0,058) |
| **Profession (merchant)** |  |  | |  |  |
| **Industry** | 0,014\* | -0,012 | | 0,049\*\* | -0,072\*\* |
|  | (0,085) | (0,391) | | (0,031) | (0,044) |
| **Student** | -0,124 | -0,097\* | | -0,131\*\*\* | -0,093 |
|  | (0,186) | (0,068) | | (0,000) | (0,259) |
| **Service** | -0,043\* | -0,068\*\* | | -0,085\*\* | -0,217\*\*\* |
|  | (0,079) | (0,039) | | (0,018) | (0,000) |
| **Size (Household/Company)** | 0,118\* | 0,063\* | | 0,103\* | 0,095\*\* |
|  | (0,054) | (0,092) | | (0,078) | (0,034) |
| **Distance to crossroads** | -0,089 | -0,113\* | | -0,207\*\* | -0,397\* |
|  | (0,453) | (0,067) | | (0,046) | (0,088) |
| **Mobility (yes)** | -0,002 | -0,047\* | | -0,093\*\* | -0,147\*\* |
|  | (0,158) | (0,085) | | (0,016) | (0,022) |
| **Instrumental equation** | | | | | |
| **Unsealed roads** | 0,561\*\*\* | 0,294\*\* | | 0,079\*\* | 0,038\*\*\* |
|  | (0,000) | (0,021) | | (0,015) | (0,000) |
| **Traffic density** | 0,288\*\*\* | 0,197\*\*\* | | 0,113\*\*\* | 0,327\*\*\* |
|  | (0,000) | (0,000) | | (0,000) | (0,000) |
| Constante | 0,101\* | 0,155 | | 1,109 | 2,058\* |
|  | (0,086) | (0,113) | | (0,172) | (0,076) |
| ***N*** | **1 721** | **1 721** | | **1 721** | **1 721** |
| **LR test of rho=0** | **0,000** | **0,001** | | **0,000** | **0,000** |
| **Wald test** | **0,000** | **0,000** | | **0,000** | **0,000** |
| **Sources: Authors. Values in brackets () are probabilities.** | | | **\* p<0,1 ; \*\* p<0,05 ; \*\*\* p<0,01** | | | |

The two instrumental variables used (unpaved roads and road traffic density) have statistically significant and positive effects on the concentration of fine particles. Unsealed roads significantly increased PM levels by 0.038 to 0.561, and traffic density had a strong influence on PM10 concentration by 0.327. These results support the idea of a strong correlation between these factors and air pollution, confirming the work of Mezoue et al (2023), who demonstrated that traffic intensity and road condition contribute to particulate pollution. These results support the relevance of these instruments in our model and underline the need to improve road infrastructures to reduce pollution.

With regard to our variables of interest, the results show that fine particles or particulate matter (PM) have a positive and significant impact on the probability of respiratory disease. PM10, for example, significantly increases the probability of respiratory disease by 0.231, followed by PM5 and PM2.5, which increase this probability by 0.122 and 0.018 respectively. These results corroborate the conclusions of Ngangmo et al (2024), who found that larger particles are associated with serious health effects due to their ability to penetrate deep into the respiratory tract. The effects observed confirm the work of Wang et al (2021), who showed that PM2.5 is particularly dangerous, causing cardiovascular and respiratory diseases. In Central Africa, the results also align with research by Antonel and Chowdhury (2014), who reported high levels of PM in urban areas of Cameroon due to rubbish burning and traffic. However, the low significance of PM1 could be attributed to less pronounced effects of these ultrafine particles. This raises an interesting question, suggesting that the chemical composition or source of PM1 could differ, as observed by Gulia et al. (2015).

Among individual characteristics, age has significant but variable effects. Younger people appear to be less affected by PM than older people. For example, one additional year reduces the risk of respiratory disease by 0.028 in the presence of PM5. This reflects the findings of Liu et al (2024), who found that children and the elderly are more vulnerable to the effects of air pollution. On the other hand, the level of education plays a protective role, since individuals with a higher level of education have a lower probability of developing respiratory problems, with marginal effects of -0.027 in the presence of PM1 and -0.008 in the presence of PM2.5. These results confirm the observations of Cardinali et al (2024), who pointed out that awareness and access to cleaner environments increase with the level of education. However, gender did not show a significant effect. This could be explained by similar exposure to pollutants in the dense areas studied, consistent with studies by Mezoue et al. (2017), where gender-based differences were negligible in urban areas.

In terms of household and firm characteristics, size was found to be positively and significantly associated with the probability of respiratory disease occurrence, with a positive marginal effect of 0.118 in the presence of PM1. This may reflect the fact that higher population density leads to greater exposure, as suggested by the work of Dionisio et al. (2010). In fact, high population density can increase the contagion of respiratory diseases between people and facilitate respiratory exchanges of the finest PM. It is therefore possible that overcrowded housing increases the risk of exposure to PM. On the other hand, distance from intersections has a negative and significant effect on the probability of respiratory disease, indicating that households located further from intersections are less exposed to fine particles. We also find that the effects of distance are proportional to the size of the PM. This result is in line with the observations of Houngbégnon et al. (2019), who showed that proximity to main roads significantly increases exposure to PM. Finally, individual mobility reduces the impact of PM on respiratory health in urban Cameroon. In the presence of PM5, for example, individual mobility reduces the probability of respiratory disease by 0.093. This could be due to intermittent exposure rather than constant exposure, supporting the conclusions of Smith et al. (2014), who noted that prolonged exposure is more harmful than sporadic exposure.

# Conclusion

The aim of this paper is to assess the impact of particulate pollutants (PM) on the respiratory health of households in urban Cameroon. This is a crucial issue in a context of rapid urbanisation where air quality is compromised by road traffic, inadequate infrastructure and human activities. Rooted in environmental pollution theories, such as those on the direct effects of pollutants on respiratory health, this study employed a rigorous methodology based on a Probit model with instrumental variables. Using data collected at eight major intersections in Douala and from 344 households, the analysis revealed three key findings. Firstly, fine particles, in particular PM10 and PM2.5, were significantly associated with an increase in respiratory problems, confirming their dangerous nature. Secondly, infrastructure characteristics, such as the proportion of unpaved roads and road traffic density, increase PM concentrations, validating their critical role in worsening urban pollution. Thirdly, socio-demographic characteristics, notably the level of education and the distance of households from intersections, have a moderate influence on the impact of pollution, suggesting disparities in the vulnerability of populations. Based on these findings, three practical recommendations adapted to the Cameroonian context emerge. Firstly, it is crucial to improve road infrastructure, in particular by increasing the percentage of tarmac roads, to reduce the resuspension of particles. Secondly, campaigns to raise awareness of air pollution and its effects on health should be stepped up, targeting the less-educated population in particular, to encourage protective behaviour. Finally, decision-makers should set up air quality monitoring stations to collect real-time data, which is essential for developing effective environmental policies and monitoring progress.

# 5. Author contributions statement

|  |  |
| --- | --- |
| **Taks** | **Authors** |
| Conception and design | Ngangmo ; Nzepang ; Adiang Mezoue |
| Analysis and interpretation of the data | Ngangmo ; Adamou |
| Drafting of the paper | Ngangmo ; Nzepang |
| Revising it critically for intellectual content | Ngangmo ; Nzepang ; Adamou ; Adiang Mezoue |
| Final approval of the version to be published | Ngangmo ; Nzepang ; Adamou ; Adiang Mezoue |

All authors agree to be accountable for all aspects of the work.

# 6. Declaration of funding

There is no sponsorship or funding.

# 7. Human participants a statement

Ethical approval for participation in the study has been obtained from *Faculty of Health Sciences Institutional Review Board of the University of Buea* in Cameroon.

# 8. Disclosure of interest

There are no interests to declare.

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# Appendices

**Appendix 1:** Description of measurement sites in the town of Douala

|  |  |  |
| --- | --- | --- |
| **Code** | **Measurements Sites** | **Geographic position** |
| P1 | Rond Point Deido | 4°3’50.472"N ; 9°42’23.649"E |
| P2 | Douche Akwa | 4°2’34.374"N ; 9°42’10.778"E |
| P3 | Carrefour Ndokotti | 4°2’37.811"N ; 9°44’35.364"E |
| P4 | Marche Central | 4°2’12.138"N ; 9°42’21.236"E |
| P5 | Carrefour PK14 | 4°4’44.216"N ; 9°47’35.297"E |
| P6 | Tradex Yassa | 4°0’1.588"N ; 9°48’19.294"E |
| P7 | Carrefour Agip | 4°5’3.012"N ; 9°43’11.445"E |
| P8 | Marche Bonamoussadi | 4°5’32.846"N ; 9°44’15.414"E |
| **Time evolution of daily PM concentrations at different measurement sites** | | |
|  | | |
| C:\Users\YAN\Desktop\Dr.Mezoue\MES TRAVAUX\Mapping concentrations projet\Study erea_012.png | | |

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2. <https://minepded.gov.cm/wp-content/uploads/2021/09/NC-2856.pdf> [↑](#footnote-ref-2)