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# Effects of Air Pollution on the Incidence of Respiratory Pathologies in the Cities of Ouagadougou and Bobo-Dioulasso, Burkina Faso

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## Abstract

**Background**: Environmental pollutants are exogenous compounds that can cause disturbances, have multiple harmful effects on health by targeting different human body organs and systems. Environmental pollutants are responsible of hormonal disrupting causing chronic non-communicable diseases, such as neurological disorders, hormonal cancers, reduced fertility and respiratory diseases. The aim of the study was to characterize the chemicals compounds in atmospheric and their potential health effects on people in Burkina Faso, West Africa. **Methods**: A cross-sectional study was conducted from 4 June to 9 August 2024 at two major's towns in Burkina Faso (Ouagadougou and Bobo-Dioulasso). GRIMM EDM 107 was used to measure in real time the Particulate Matter (PM) $PM_{10}$, $PM_{2.5}$ and Total Suspended Particles in ambient air. Data analysis and graphing were performed using R and SPSS software.

Binary logistic regression reports different proportion. **Results**: Survey data showed that the highest incidence of respiratory illnesses was bronchitis (3%), followed by asthma (2%). The populations that live or work in an environment with heavy pollution (smoke, dust, industrial emissions) are 27%. Percentages of non-standard values compared with $PM_{10}$ and $PM_{2.5}$ WHO reference values show $PM_{10}$ (78.88% Ouagadougou vs. 60.63% Bobo-Dioulasso) and $PM_{2.5}$ (54.79% Ouagadougou vs. 40.52% Bobo-Dioulasso). Furthermore, a significant increase in activities in the city centre can lead to an increased risk of developing certain diseases due to $PM_{10}$ (OR = 0.906; 95% CI: 0.857 - 0.958 with $p < 0.0001$ Ouagadougou vs. OR = 20.497; 95% CI: 18.803 - 22.344 with $p < 0.0001$ Bobo-Dioulasso), $PM_{2.5}$ (OR = 4.353; 95% CI: 4.095 - 4.626 with $p = 0.503$ Ouagadougou vs. OR = 9.039; 95% CI: 8.344 - 9.793 with $p < 0.0001$ Bobo-Dioulasso). **Conclusion**: This study shows it emerged that the concentrations of airborne particles at all the sites in Ouagadougou were higher than at all the sites in Bobo-Dioulasso. These concentrations are well above the WHO standard of 25 $\mu g \cdot m^{-3}$ for $PM_{2.5}$ and 50 $\mu g \cdot m^{-3}$ for $PM_{10}$ in some places and depending on the site.

## Keywords

Air Pollution, Health Effects, Respiratory Diseases, $PM_{2.5}$, $PM_{10}$, TSP

## 1. Introduction

Air pollution is a major problem affecting public health systems worldwide. It has harmful effects both on environment (climate change) and human health. According to the World Health Organisation (WHO), over 25% of deaths worldwide are linked to air pollution [1]. The study of pollution involves a number of factors that need to be taken into account. Urban transport plays an important role in air quality, followed by population density, neighborhood location, building height and meteorological factors, such as air temperature, wind speed, relative humidity, precipitation and pressure [2]. Despite the facts that vehicular emissions constitute the majority of ambient ultrafine particles (UFPs) composition, industrial emissions also emit considerable amount of UFPs into ambient air which may vary based on the industry scale, process, and fuel sources [3]. Concentrations of pollutants in the atmosphere vary over time depending on the hour, day and season, and the diurnal variation is partly explained by urban traffic [4].

In fact, the general population is exposed to a mixture of compounds, and their additive effect or chemical interaction can exacerbate the harmful effects on human health [5]. It is worth noting that few studies evaluated mixtures of compounds, which made it difficult to analyze the effect of a single Endocrine Disruptor (ED) [6]. By the aerodynamic diameter (Di), PM can be divided into nanoparticles or $PM_{0.01}$ (Di < 0.01 μm), ultrafine particles or $PM_1$ (Di < 0.1 μm), fine particles or $PM_{2.5}$ (Di < 2.5 μm), and fine particles or $PM_{10}$ (Di < 10 μm) [7].

Previous studies have shown that 47% of fine particles (Particulate Matter or PM) are carcinogenic endocrine disruptors [8]. $PM_{2.5}$ is another environmental factor capable of inducing epigenetic modifications via pro-oxidant activity [9] [10]. DNA methylation induced by PM of the tumour suppressor *p16INK* could promote the development and progression of lung cancer [11]. Oxidative stress generated by PM alters DNA methylation, causing DNA damage [12]. The diseases implicated by pollutant emissions are respiratory diseases in large numbers, but also cardiovascular pathologies, acute bronchopneumonia and lung cancer. The people most affected by this pollution are the over-65s and other vulnerable individuals [13]. Exposure to $PM_{2.5}$, and $PM_1$ during the first and early second trimester was associated with the risk of de novo Hypertensive Disorders of Pregnancy (HDP). The fine PM before diagnosis of de novo HDP is positively associated with the systolic blood pressure [14]. Long-term exposures to air pollution are associated with increased risk of lung cancer, and this effect was modified by lifestyle or genetic risk [15]. A study indicated that exposure to elevated ambient air pollutants ($PM_1$, $PM_{2.5}$, $PM_{10}$, $NO_2$) was associated with ovarian reserve impairment, notably during the period from primary to secondary follicle stage. PMs with smaller size showed higher impact than others [16]. Associations among prenatal exposures and neurodevelopmental outcomes may vary depending on the timing of exposure. Findings from Utah provide initial evidence that prenatal $PM_{2.5}$ exposure may be a risk factor for intellectual disability ID [17]. $PM_{2.5}$ was associated with a higher risk of an infertility diagnosis in men, whereas road traffic noise was associated with a higher risk of an infertility diagnosis in women older than 35 years, and potentially in men older than 37 years [18]. The problem of ultrafine particles (UFPs; $PM_{0.1}$) has been prevalent since the past decades. Among the exposure effects studies, it showed that pro-longed UFPs exposure may cause increased hazard risk of respiratory diseases, pre-term birth, and cardiovascular disease while short-term UFPs exposure has been identified to cause certain changes in human heart rate variability, blood pressure, and increased cardiopulmonary effects [3].

This fact is accompanied by pollutions, particularly those of air by PM emission that can cause multiple adverse long-term as well short-term effects on the human wellbeing such as increased health problems [19]. Previous studies showed that road dust emissions can increase $PM_{10}$ by 21% - 35% at traffic stations, 17% - 34% at urban administrative sites, 17% - 22% at industrial sites and 9% - 22% at rural sites [20]. Particulate matter is one of the main air pollutants with 257,000 deaths per year in Africa [21].

In Burkina Faso, these concentrations are lower than the 24 hours total suspended particles recommended limit of 200 - 300 $\mu g \cdot m^{-3}$ by the authorities [22]. It will be noticed that there are no recommended limits especially for $PM_{2.5}$, $PM_{10}$ and other in Burkina Faso. $PM_{10}$ induced dose-dependent cytotoxicity to a greater or lesser extent by sampling district. Oxidative stress is a key source of toxic substances found in the endothelial cells of human pulmonary arteries that can trigger a proinflammatory response. $PM_{10}$, unlike larger particles that are filtered by the nasal and bronchial cilia, directly penetrates the upper respiratory tract and alveoli, causing inflammation and irritating the bronchi, thus affecting lung function, and exacerbating symptoms of respiratory diseases and other pathologies according to the intensity or duration of the inflammation [21]. At harmful levels in Ouagadougou, $PM_{2.5}$ caused primarily outpatient hospital visits rather than hospitalizations for respiratory diseases [23].

In 2012, the frequency of respiratory pathologies was 14.16% for hospital consultations. The most frequent cases of respiratory pathologies were noticed during the dry season, with a proportion of 57.37%. The majority were male children (74.85%). Male children hospitalized accounted for 62.43% of all cases combined. Regarding the distribution of respiratory diseases, acute bronchitis was the most frequent (46.87%), followed by pneumonia (38.57%) and rhinitis (37.08%). Forty-three deaths (3.42%) were reported, and all occurred among hospitalized patients. A high concentration of $PM_{2.5}$ was associated with increased outpatient consultations among children, a finding that could help prepare for such situations [23].

In West Africa in general and in Burkina Faso in particular, very little data and research exists on the potential effects of airborne particles as endocrine disruptors. This paper presents an analysis of particulate matter ($PM_{2.5}$ and $PM_{10}$) and Total Suspended Particles (TSP) concentrations in Ouagadougou and Bobo-Dioulasso during the rainy season linking these concentrations to potential health effects based on survey data of respiratory symptoms, risk factors and medical histories. The primary objective of this research was to characterize the chemicals compounds in atmospheric and their potential health effects on people in Burkina Faso, West Africa.

## 2. Material and Methods

### 2.1. Study Area

We had a total of 6 sites, three in Ouagadougou and three in Bobo-Dioulasso. The sites were chosen at random and animals were exposed to different atmospheres in the open air or in closed enclosures for the rest of the experiments. Site 1 in Ouagadougou was located inside a reference animal house. Site 2 was at the Institute of Research in Health Science (IRSS), and site 3 was in the Kossodo industrial zone. For the Bobo-Dioulasso sites, site 4 was located within the precincts of a reference animal house, that of the International Center for Research and Development on Livestock in Sub-humid Zones (CIRDES); site 5 was in the town centre, more precisely at the annex of the IRSS and site 6 was in the industrial zone in (**Figure 1**). Ouagadougou and Bobo-Dioulasso are the two largest cities in Burkina Faso, with a fairly large population and different centres of activity, with more than a dozen industries listed. The choice of sites 1 and 4 is due to the fact that they are reference pet shops with standard breeding conditions that comply with international standards. Sites 2 and 5 were chosen because they are located in the city centre. Sites 3 and 6 are in the industrial zone. Sites 2, 3, 5 and 6 were open-air as opposed to sites 1 and 4. A geographical positioning system (GPS), GARMIN etrex 20 model was used for recording the geographical coordinates of the sampling sites.

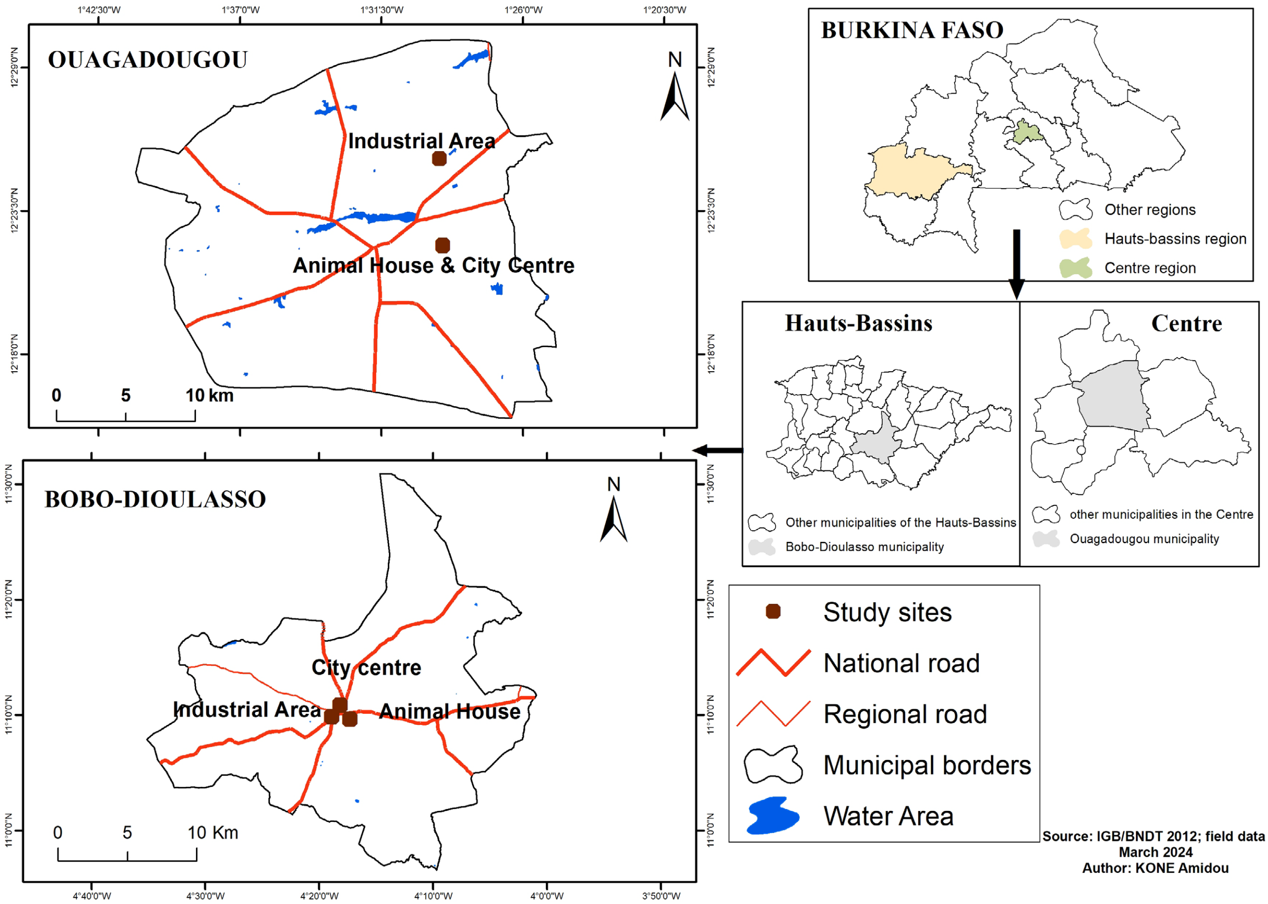



**Figure 1.** Maps of the sampling sites.

## 2.2. Study Population

The study population consisted of residents of the cities of Ouagadougou and Bobo-Dioulasso. These two cities were chosen because they are the most industrialized and densely populated of the country, Burkina Faso, with heavy road traffic [1].

## 2.3. Sampling and Data Collection

The GRIMM EDM (Environmental Dust Monitor) 107 by XEARPRO SRL stayed for 7 days or a week, *i.e.* 168 hours. Weekly, Hourly, and daily average concentrations reported here are arithmetic means of the respective 1-min readings in $\mu g \cdot m^{-3}$.

Air sampling for Total Suspended Particles (TSP) and fine particles in $\mu g \cdot m^{-3}$ ($PM_{2.5}$ and $PM_{10}$) took place from 4 June to 9 August 2024 in Burkina Faso's two major cities, Ouagadougou and Bobo-Dioulasso. The GRIMM EDM 107 is designed both for mobile and stationary use to measure in real time the $PM_{2.5}$, $PM_{10}$ and TSP simultaneously as a stand-alone measuring system. Sample flow 1.2 liter/min. Each measurement consisted of one-minute concentrations of $PM_{2.5}$, $PM_{10}$ and TSP and was recorded on a data storage card.

## 2.4. Survey

Before interview phase, data on respiratory illnesses were collected from participants of the cities of Ouagadougou and Bobo-Dioulasso. The interview was conducted to highlight the symptoms of respiratory illnesses that could be linked to air pollution in urban and industrial areas of Ouagadougou and Bobo-Dioulasso. Participants were selected at random.

The survey consisted in administering previously validated individual questionnaires to study participants through personal interviews. The questionnaire, which included closed and open questions, was tested, and adjusted during a pilot phase. The questionnaire included questions about the demographic information, medical history, environmental and lifestyle factors, health awareness and prevention. The interviews were conducted in French. Answers were recorded through KoboCollect, a smartphone-based questionnaire tool. Data collected was then stored on the KoboToolbox platform.

## 2.5. Ethical Approval

Our study was conducted in accordance with the declaration of Helsinki. Each participant was agreeing and gave his free verbal approval before the interview phase. Data collected from participants were kept confidential and anonymous.

## 2.6. Data Analysis

The measurement relative uncertainties are deduced from the GRIMM EDM 107 measurement accuracy of ±5%. The average concentrations and the measurement relative uncertainties were determined by Microsoft Excel. R version 4.2.3, QGIS version 3.28, ArcGis version 10.8.0.12790 and GraphPad Prism version 5.03 were performed for the graphics. The qualitative interview was carried out using kobocollect v2024.2.4.

Data were analyzed with SPSS version 20 software (SPSS Inc., Chicago, IL, USA). Categorical variables were summarized as numbers and percentages. Mean values of continuous variables and proportions were compared by T-test and Chi-square or Fisher's exact test, respectively at the bivariate level. Differences were considered significant at the 5% probability level.

## 2.7. Limits of the Study

One of the limitations of our study is the discrepancy between the period of peak particulate emissions in Burkina Faso, according to the National Meteorological Agency, and the period of fine particle data collection.

# 3. Results

## 3.1. Socio-Demographic Characteristics

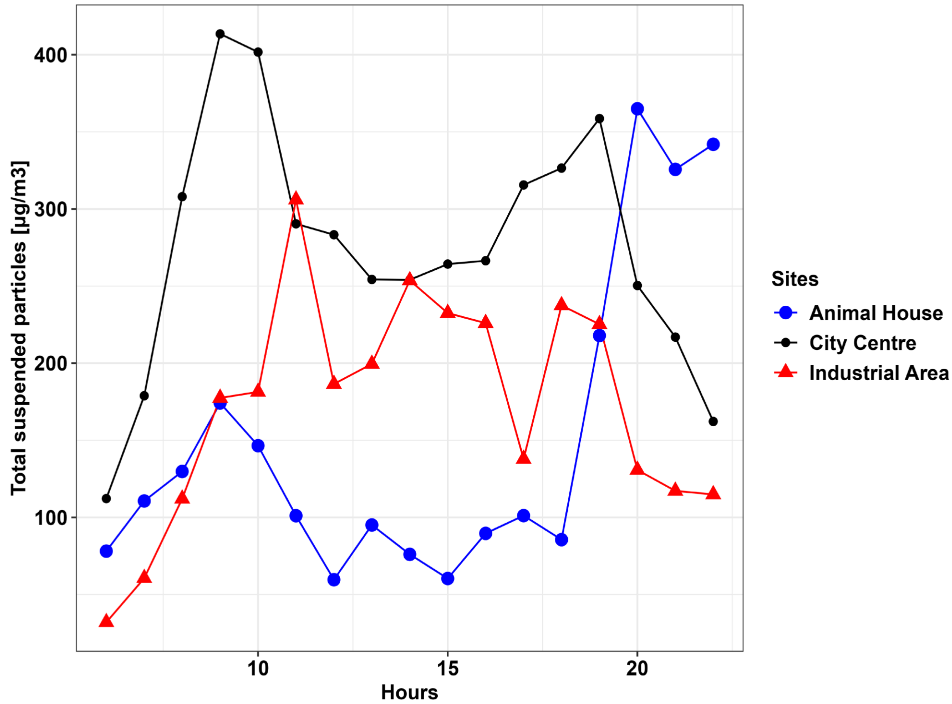
The interview on the respiratory effects of particulate pollution in the city centres of Bobo and Ouagadougou showed that 86.87% of respondents lived in the city of Bobo-Dioulasso and 82.70% in the city of Ouagadougou. Proportion from survey data of men in Bobo-Dioulasso (68.35%) showed no significant difference from those surveyed in Ouagadougou ($p = 0.484$). Participants aged between 21 and 40 were in the majority in both cities (Table 1).

**Table 1.** Socio-demographic characteristics.

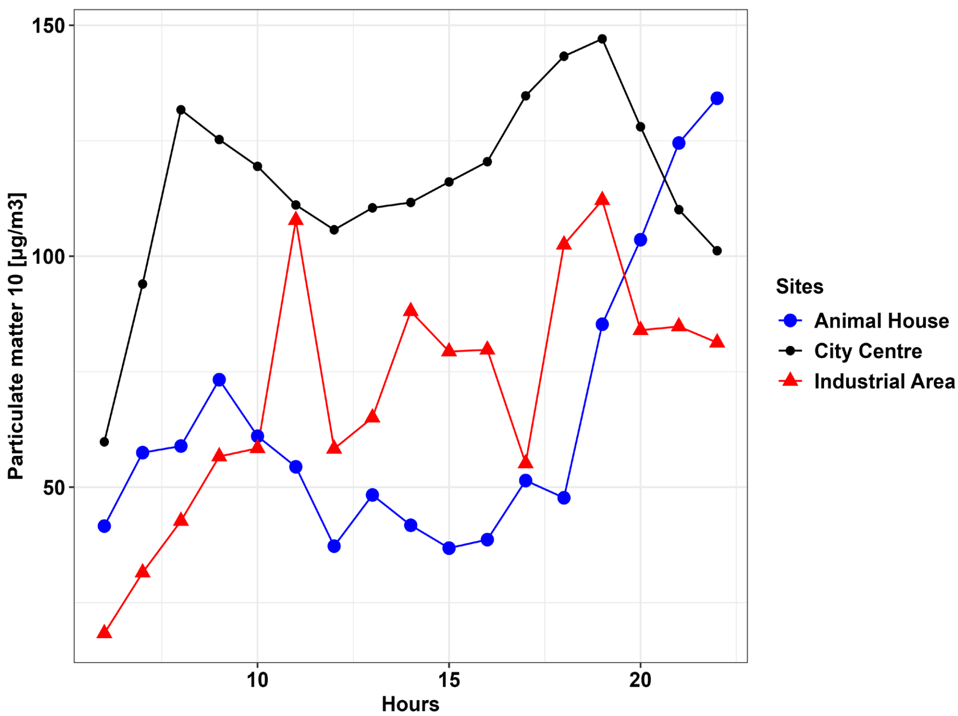
| Socio-demographic characteristics | Bobo-Dioulasso n (%) 297 | Ouagadougou n (%) 607 | p-value |
|---|---|---|---|
| **Residence** | | | **0.437** |
| City Centre | 258 (86.87) | 502 (82.70) | |
| Industrial Area | 39 (13.13) | 105 (17.30) | |
| **Sex** | **297 (100)** | **607 (100)** | **0.484** |
| Women | 94 (31.65) | 207 (34.10) | |
| Men | 203 (68.35) | 400 (65.90) | |
| **Age group (by year)** | **297** | **607** | **0.170** |
| 0 - 10 | 3 (1.01) | 10 (1.65) | |
| 11 - 20 | - | 74 (12.19) | |
| 21 - 40 | 268 (90.24) | 480 (79.08) | |
| 41 - 60 | 17 (5.72) | 34 (5.60) | |
| 61 and above | 9 (3.03) | 9 (1.48) | |
| **Occupation** | **297** | **607** | **0.449** |
| Student | 122 (41.08) | 253 (41.68) | |
| Office worker | 59 (19.86) | 142 (23.39) | |
| Manual laborer | 46 (15.49) | 35 (5.77) | |
| Unemployed | 26 (8.75) | 60 (9.88) | |
| Others | 44 (14.81) | 117 (19.27) | |

## 3.2. Daily $PM_{2.5}$, $PM_{10}$ and TSP Concentrations Profiles in the Both Cities

Our results reveal the highest peak concentrations of particulate matter in the city of Ouagadougou in the morning at 8 a.m., 9 a.m. and 11 a.m. (Figure 2). In the city of Bobo-Dioulasso the highest concentration peaks were measured at 7 a.m., 8 a.m., 9 a.m. and 12 a.m. in the morning (Figure 3). At evening, the highest concentration peaks were measured at 7 p.m., 9 p.m. and 10 p.m. in Ouagadougou and at 8 p.m. in Bobo-Dioulasso respectively. The lowest peak concentrations of particulate matter were measured at 6 a.m., 3 p.m. and 5 p.m. respectively for Ouagadougou and Bobo-Dioulasso (**Figure 2** and **Figure 3**).




(a)

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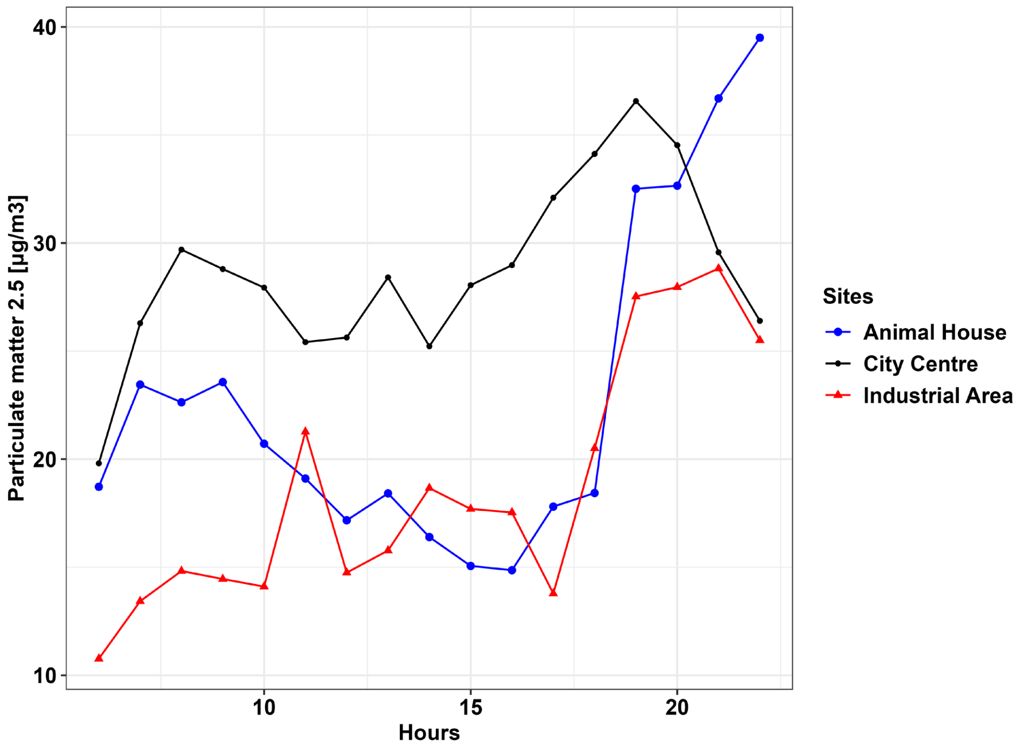
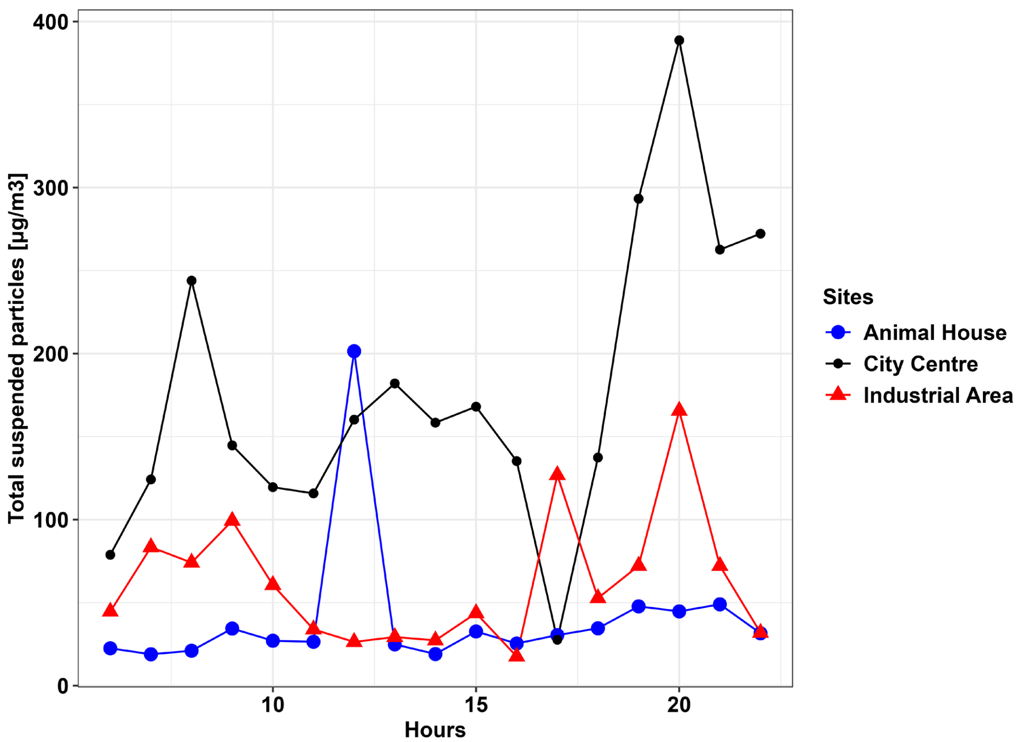
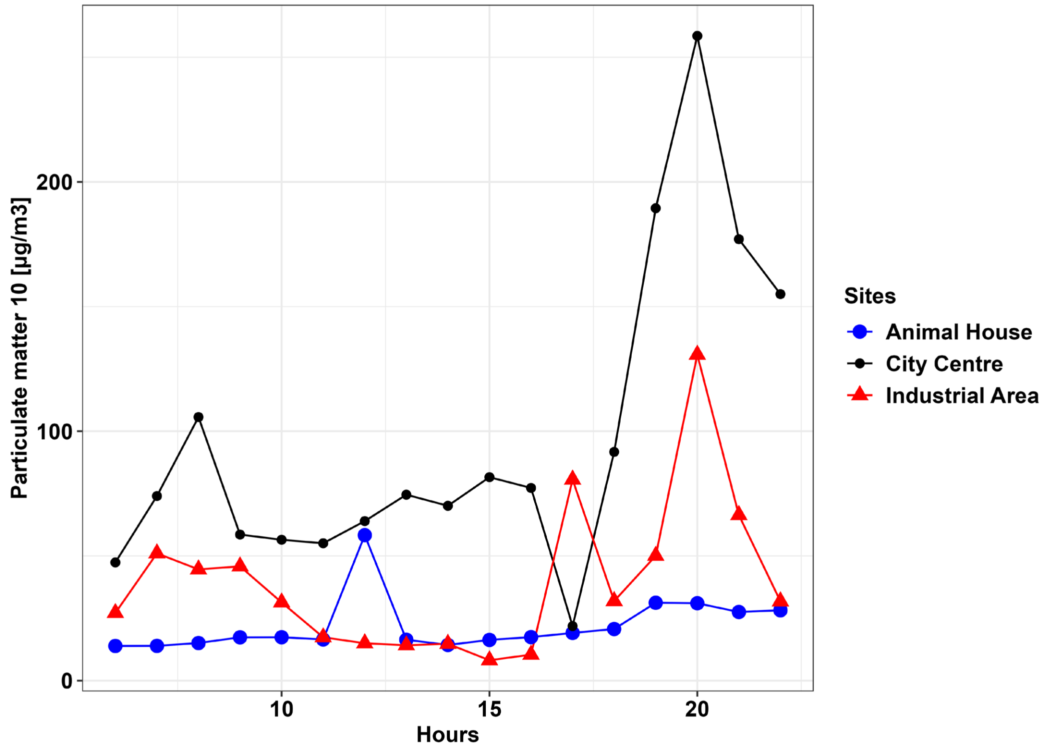



(c)

**Figure 2.** Particulate matter concentrations in the city of Ouagadougou from 6 a.m. to 10 p.m. Legend: (a) Total Suspended Particle, (b) Particulate Matter less than 10 microns in diameter, (c) Particulate Matter less than 2.5 microns in diameter.




(a)

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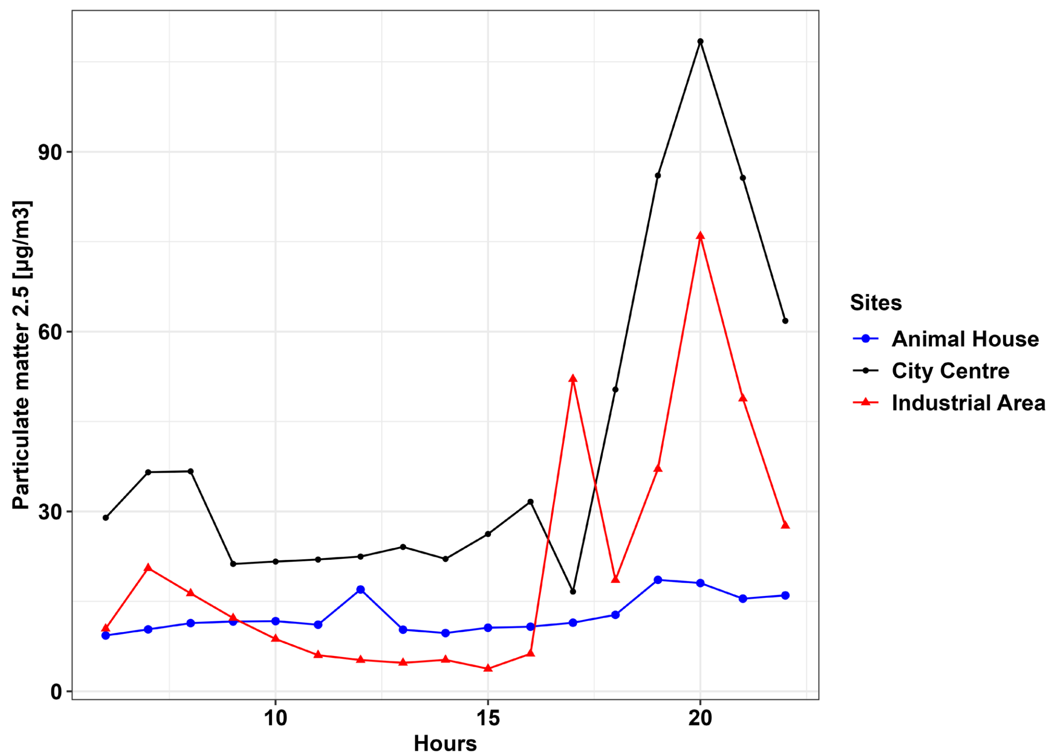


(c)

**Figure 3.** Particulate matter concentrations in the city of Bobo-Dioulasso from 6 a.m. to 10 p.m. Legend: (a) Total Suspended Particle, (b) Particulate Matter less than 10 microns in diameter, (c) Particulate Matter less than 2.5 microns in diameter.

### 3.3. Hourly and Daily Concentrations Mean

Hourly PM concentrations averages shown a maximum concentration in Ouagadougou city centre ($PM_{2.5}$ = 36.563 µg·m$^{-3}$; $PM_{10}$ = 147.065 µg·m$^{-3}$; TSP = 358.585 µg·m$^{-3}$) and average hourly maximum concentrations in Bobo-Dioulasso town centre ($PM_{2.5}$ = 31.700 µg·m$^{-3}$; $PM_{10}$ = 106.800 µg·m$^{-3}$; TSP = 182.761 µg·m$^{-3}$). Daily PM maximum concentration of particulate matter was measured in the centre of Ouagadougou ($PM_{2.5}$ = 26.278 µg·m$^{-3}$; TSP = 196.853 µg·m$^{-3}$). The daily maximum PM concentration was measured in the city centre of Bobo-Dioulasso ($PM_{2.5}$ = 39.519 µg·m$^{-3}$; TSP = 159.652 µg·m$^{-3}$). However, we note a similarity in average $PM_{10}$ = 93.183 µg·m$^{-3}$ across the city centres of Ouagadougou and Bobo-Dioulasso in (Table 2).

Table 2. Hourly and daily concentrations mean.

| | Ouagadougou City | | | Bobo-Dioulasso City | | | Reference |
|---|---|---|---|---|---|---|---|
| | Animal House | City Centre | Industrial Area | Animal House | City Centre | Industrial Area | |
| **PM and TSP measurement for 1 hour (µg·m$^{-3}$)** | | | | | | | |
| $PM_{2.5}$ | 33.593 | 36.563 | 22.251 | 11.146 | 31.700 | 21.306 | 35[a], 25[b], 300[d] |
| $PM_{10}$ | 117.72 | 147.065 | 85.345 | 21.256 | 106.800 | 32.415 | 150[a], 50[b,c], 300[d] |
| TSP | 273.915 | 358.585 | 266.915 | 42.085 | 182.761 | 52.851 | 300[d] |
| **PM and TSP measurement for 24 hours (µg·m$^{-3}$)** | | | | | | | |
| $PM_{2.5}$ | 22.995 | 26.278 | 18.120 | 14.915 | 39.519 | 20.291 | 35[a], 25[b,c], 300[d] |
| $PM_{10}$ | 62.611 | 93.322 | 61.213 | 30.782 | 93.044 | 39.058 | 150[a], 50[b,c], 300[d] |
| TSP | 146.832 | 196.853 | 137.047 | 72.665 | 159.652 | 59.058 | 300[d] |

[a]US Environmental Protection Agency [USEPA, 2011]; [b]World Health Organization [WHO, 2006]; [c]European Environment Agency [EEA, 2011]; [d]Burkina Faso authorities, [22].

### 3.4. PM and TSP Measurement for 48 Hours' Mean

Findings in Figure 4 shown the proportion of 48-hours concentration of fine particles and TSP in the cities of Ouagadougou and Bobo-Dioulasso. The concentrations of the week-end data in the city of Ouagadougou and the industrial zone of Bobo-Dioulasso are higher than the Monday-Friday concentrations.

### 3.5. Weekly Concentrations Mean

The measurement of concentration means in the Ouagadougou and the Bobo-Dioulasso were presented in Table 3.

### 3.6. Percentages of Non-Standard Values Compared with $PM_{10}$ and $PM_{2.5}$ WHO Reference Values

The city centres of Ouagadougou ($PM_{10}$ = 78.881%; $PM_{2.5}$ = 54.792%) and Bobo-Dioulasso ($PM_{10}$ = 60.633% et $PM_{2.5}$ = 40.524) represented percentages of non-standard values, WHO reference values raised respectively for the $PM_{10}$ and the $PM_{2.5}$ in (Table 4).

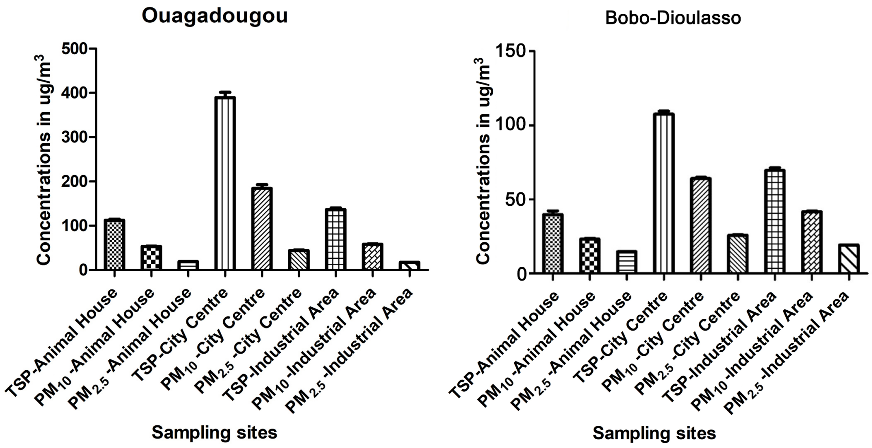


**Figure 4.** PM and TSP measurement for 48 hours mean.

**Table 3.** Weekly concentrations mean.

| | Weekly PM and TSP concentrations ($\mu g \cdot m^{-3}$) | | | | | |
|---|---|---|---|---|---|---|
| | City Ouagadougou | | | City Bobo-Dioulasso | | |
| | Animal House | City Centre | Industrial Area | Animal House | City Centre | Industrial Area |
| $PM_{2.5}$ | 20.701 | 31.341 | 19.438 | 15.975 | 27.356 | 16.949 |
| $PM_{10}$ | 61.025 | 120.205 | 57.426 | 30.855 | 72.850 | 35.206 |
| TSP | 139.230 | 267.247 | 121.861 | 66.455 | 129.602 | 58.530 |

**Table 4.** Percentages of non-standard values compared with $PM_{10}$ and $PM_{2.5}$ WHO reference values.

| | | >50 $\mu g \cdot m^{-3}$ for $PM_{10}$ | >25 $\mu g \cdot m^{-3}$ for $PM_{2.5}$ |
|---|---|---|---|
| | | n (%) | n (%) |
| Ouagadougou | Site 1 | 4689 (46.43) | 2281 (22.58) |
| | Site 2 | 7967 (78.88) | 5534 (54.79) |
| | Site 3 | 4442 (43.98) | 2174 (21.52) |
| Bobo-Dioulasso | Site 4 | 706 (6.99) | 491 (4.86) |
| | Site 5 | 6124 (60.63) | 4093 (40.52) |
| | Site 6 | 1972 (19.52) | 1319 (13.06) |

### 3.7. Association between $PM_{10}$, $PM_{2.5}$ and Study Sites

For $PM_{10}$ the highest measure was found in the Bobo-Dioulasso city centre (OR = 20.497% IC: 18,803 - 22,344) ($p < 0.0001$), while the lowest was observed in the Ouagadougou industrial zone. For $PM_{2.5}$, the highest measure was also found in the Bobo-Dioulasso city centre (OR = 9.039% CI: 8,344 – 9,793) ($p < 0.0001$) in **Table 5**.

**Table 5.** Association between $PM_{10}$, $PM_{2.5}$ and study sites.

| Particulate Matter (PM) | City | Sampling | OR (95% CI) | p-value |
|---|---|---|---|---|
| $PM_{10}$ | Ouagadougou | Site 1 | Ref | |
| | | Site 2 | 4.309 (4.051 - 4.583) | 0.0001* |
| | | Site 3 | 0.906 (0.857 - 0.958) | 0.0001* |
| | Bobo-Dioulasso | Site 4 | Ref | |
| | | Site 5 | 20.497 (18.803 - 22.344) | 0.0001* |
| | | Site 6 | 3.228 (2.948 - 3.536) | 0.0001* |
| $PM_{2.5}$ | Ouagadougou | Site 1 | Ref | |
| | | Site 2 | 4.353 (4.095 - 4.626) | 0.0001* |
| | | Site 3 | 1.023 (0.958 - 1.092) | 0.503 |
| | Bobo-Dioulasso | Site 4 | Ref | |
| | | Site 5 | 9.039 (8.344 - 9.793) | 0.0001* |
| | | Site 6 | 2.008 (1.839 - 2.193) | 0.0001* |

R: Odds ratio; CI: Confidence Interval, *Significant level at p-value < 0.05.

## 3.8. Risk Factors

Table 6 shows that no risk factors have been associated to certain types of respiratory disease ($p > 0.5$).

**Table 6.** Risk factors.

| Risk factors | Bobo-Dioulasso | Ouagadougou | p-value |
|---|---|---|---|
| | n (%) | n (%) | |
| | 297 | 607 | |
| **Duration of Stay in Current City** | | | **0.983** |
| Less than 1 year | 28 (9.43) | 64 (10.54) | |
| 1 - 5 years | 71 (23.90) | 230 (37.89) | |
| More than 5 years | 198 (66.66) | 313 (51.56) | |
| **Smoke or have you been exposed to secondhand smoke regularly** | **297** | **607** | **0.810** |
| Yes | 44 (14.81) | 118 (19.44) | |
| No | 253 (85.18) | 489 (80.56) | |
| **Live or work in an environment with heavy pollution (e.g., smoke, dust, industrial emissions)** | **297** | **607** | **0.840** |
| Yes | 81 (27.27) | 236 (38.88) | |
| No | 216 (72.73) | 371 (61.12) | |

Continued

| | | | |
|---|---|---|---|
| **Frequently exposed to indoor air pollution (e.g., cooking with wood, kerosene, or charcoal)** | **297** | **607** | **0.373** |
| Yes | 64 (21.55) | 140 (23.06) | |
| No | 233 (78.45) | 467 (76.93) | |
| **Suffer from allergies that affect your respiratory system** | **297** | **607** | **0.182** |
| Yes | 35 (11.78) | 73 (12.02) | |
| No | 262 (88.21) | 534 (87.97) | |
| **Protective measures (e.g., face masks) in environments with poor air quality** | **297** | **607** | **0.889** |
| Always | 44 (14.81) | 86 (14.17) | |
| Sometimes | 139 (46.80) | 278 (45.80) | |
| Rarely | 102 (34.34) | 182 (29.98) | |
| Never | 12 (4.04) | 61 (10.05) | |

## 3.9. Medical History

Table 7 shows that 3.03% and 4.61% of respondents in Bobo-Dioulasso and Ouagadougou respectively had a history of bronchitis. In addition, 37.04% and 39.70% of the estimated respondents respectively had respiratory symptoms at least once or twice a year.

Table 7. Medical history.

| Medical History | Bobo-Dioulasso | Ouagadougou | p-value |
|---|---|---|---|
| | n (%) | n (%) | |
| | 297 | 607 | |
| **Diagnosed with any respiratory disease in the past 12 months** | | | 0.952 |
| Yes | 35 (11.78) | 96 (15.81) | |
| No | 262 (88.21) | 511 (84.18) | |
| **Previous history** | | | |
| Asthma | 8 (2.69) | 16 (2.63) | |
| Asthma and Bronchitis | - | 5 (0.82) | |
| Bronchitis | 9 (3.03) | 28 (4.61) | |
| Tuberculosis | 3 (1.01) | 1 (0.16) | |
| Tuberculosis and Pneumonia | 1 (0.33) | - | |
| Pneumonia | 5 (1.68) | 10 (1.65) | |
| Other | 271 (91.24) | 547 (90.11) | |

Continued

| | | | |
|---|---|---|---|
| **Experienced respiratory symptoms (cough, difficulty breathing, chest tightness) in the last 12 months** | | | 0.566 |
| 1 - 2 times | 110 (37.03) | 241 (39.70) | |
| 3 - 5 times | 48 (16.16) | 76 (12.52) | |
| More than 5 times | 14 (4.71) | 43 (7.08) | |
| Never | 125 (42.08) | 247 (40.69) | |
| **Receive treatment for your respiratory condition** | 297 | 607 | 0.43 |
| Yes | 96 (32.32) | 223 (36.74) | |
| No | 201 (67.68) | 384 (63.26) | |
| **Type of treatment did you receive** | | | 0.999 |
| Hospitalization | 2 (0.67) | 7 (1.15) | |
| Hospitalization and Medication | - | 3 (0.49) | |
| Hospitalization, Medication and Home remedies | - | 4 (0.66) | |
| Medication only | 75 (25.25) | 175 (28.83) | |
| Medication and Home remedies | 11 (3.70) | 22 (3.62) | |
| Home remedies | 9 (3.03) | 14 (2.30) | |
| Other | 200 (67.34) | 382 (62.93) | |

## 4. Discussion

The World Health Organization (WHO), the European Environment Agency (EEA), and the Environmental Protection Agency (EPA) have set limit values for human exposure to particulate matter based on 1-hour and 24-hour concentrations of $PM_{2.5}$ and $PM_{10}$. The results discussed will primarily focus on these particle sizes. Additionally, the results for TSP have been includes due to their significant impact on human health, although no specific limit values have been recommended for TSP. The level of $PM_{2.5}$, $PM_{10}$ and TSP in the air varies according to the twon of Ouagadougou and Bobo-Dioulasso.

### 4.1. Socio-Demographic Characteristics

Our interview obtained a total of 904 participants, including 297 in the city of Bobo-Dioulasso and 607 in the city of Ouagadougou. Of the participants in Bobo-Dioulasso, 86.87% were in the city centre, compared with 82.70% in the city of Ouagadougou. Around 13% were in the Bobo-Dioulasso industrial zone compared with 17.30% in the Ouagadougou industrial zone. The largest age group was between of respondents was those between 21 - 40 years. Over 60% of participants were men in both cities. Students accounted for 40% of respondents in both cities.

Bobo-Dioulasso and Ouagadougou are 360 kilometers apart.

### 4.2. Daily $PM_{2.5}$, $PM_{10}$ and TSP Concentrations Profiles in the Cities of Ouagadougou and Bobo-Dioulasso

Our results reveal that the highest and lowest peak concentrations of particulate matter in the city of Ouagadougou and Bobo-Dioulasso were measured in the morning and in the evening respectively. Demay [24] obtained high peak concentrations of $PM_{10}$ at 8 a.m., 12 a.m., 4 p.m., 5 p.m. and 9 p.m. Our results corroborate those obtained by Ouarma *et al.* [1] with high concentration peaks at the same times. The difference intra-urban trends in PM concentrations between day and night could be explained by the difference between the sources of PM. Indeed, there is probably a greater influence of traffic dust suspension on paved and unpaved roads, the exhaust emissions in the morning to that adds the effect of using biomass as a source of energy as we move forward in the day. More stable night conditions favor a mixture of suspended dust with particles generated by combustion and circulation, resulting in more uniform levels of $PM_{2.5}$ in the evening. However, the main origin of air pollutants and air pollution, is urban such as resuspension related to traffic on paved and unpaved roads, the use of biomass as domestic energy and waste incineration. Some natural sources contribute also to PM such as the Saharan desert, which is the world's largest source of wind dust [25].

### 4.3. Hourly and Daily Concentrations Mean

Ouagadougou's road network extends over a distance of 2700 kilometers with 200 km of paved roads, 400 km of laterite and 2100 km on tracks (a mixture of laterite, sand and clay), on which traffic contributes through suspension to particulate matter. Approximately 1,003,997 people travel in and out of the city centre every day. The breakdown of vehicles is as follows: 74% motorised two-wheelers, 18% private vehicles, 7% public transport vehicles and 1% heavy goods vehicles. Dusty residential sites near unpaved roads are characterised by high $PM_{10}$ emissions [1]. Some studies on air pollution in the city of Ouagadougou shown that this pollution is mainly due to PM and hydrocarbons [26] [27]. Bobo-Dioulasso population was estimated at 812.574 in 2012 and 984.603 in 2022 by the National Institute of Statistics and Demography. This could be explained by the difference between the number of people living in Ouagadougou and Bobo-Dioulasso, the dynamism of the people of Bobo-Dioulasso and the different types of activity in the city centre. There is an international road that crosses the centre of Bobo-Dioulasso, resulting in almost constant traffic. Our results differ from those of Ouarma *et al.* [1] who obtained in one hour measurement, a concentration of $PM_{2.5}$ = 15.241 $\mu g \cdot m^{-3}$ and $PM_{10}$ = 109.275 $\mu g \cdot m^{-3}$ in downtown Ouagadougou during the rainy season. Our results also differ from those obtained by Demay [24] who found $PM_{10}$ values below 100 $\mu g \cdot m^{-3}$ in Senegal throughout the rainy season as opposed to $PM_{10}$ = 106,800 $\mu g \cdot m^{-3}$, above 100 $\mu g \cdot m^{-3}$ in the city centre of Ouagadougou and Bobo-

Dioulasso. This difference may be due to the climatic conditions in these two West African countries and the type of apparatus used.

Our results of the 24-hour measurement can permit to explain the industrial and business activity of the region, even of the country is mainly concentrated in the city of Ouagadougou. This explains the dynamics of the population of Burkina Faso towards the city of Ouagadougou. The population was estimated at 1,700,000 in 2010 and 2,415,226 in 2022 by the National Institute of Statistics and Demography. The centres of activity are concentrated in the city centre and in a few outlying districts, hence the massive daily movement of inhabitants towards the business parks [1]. Average daily concentrations maximum in the city centre of Bobo-dioulasso can lead the differences between the stations can be partly explained by their geographical location and by local precipitation condition, meteorological and climatic factors (precipitation, pressure, wind, heat radiation, humidity). During the rainy season, Bobo-Dioulasso recorded rainfall of 1107 mm, a temperature of 28.9˚C and average humidity of 82.54%. In Ouagadougou, rainfall was 1017 mm, with an average temperature of 30.2% and average humidity of 73.84%, according to the National Meteorological Agency. When precipitation is high, the air is washed of these fine particles [28]. The residence time of fine particles in the atmosphere varies according to their size and composition. $PM_{10}$ are the largest and therefore the heaviest, and have the shortest residence time [29]. One study showed that 60% of households used biomass (wood or charcoal) as their main fuel, while 40% used gas [30]. By analogy with the latter study, we can deduce the same thing for the population of Bobo-Dioulasso. In addition, this can be attributed to road congestion and heavy traffic at certain sites, which is a road junction where there is a long wait for vehicles. However, it should be noted that $PM_{10}$ is higher in Ouagadougou, and this is certainly linked to the greater volume of urban traffic. These values are of the same order as those generally obtained on air pollution in West African cities [1]. Our results differ from those obtained by Ouarma *et al.* [1] who obtained a concentration of $PM_{2.5} = 29\ \mu g \cdot m^{-3}$ in the industrial zone of Ouagadougou; higher than our results of $PM_{2.5} = 26.278\ \mu g \cdot m^{-3}$ from the city of Ouagadougou, but lower than the $PM_{2.5} = 39.519\ \mu g \cdot m^{-3}$ from the city of Bobo-Dioulasso. $PM_{10} = 281\ \mu g \cdot m^{-3}$ in the outskirts of the city of Ouagadougou in the rainy season during 24 h obtained by Ouarma *et al.* [1].

## 4.4. PM and TSP Measurement for 48-Hour Mean

The concentration of TSP, $PM_{10}$ and $PM_{2.5}$ in the city centre is well above the concentrations in the pet shop followed by the industrial zone in the city of Ouagadougou.

In the city of Bobo-Dioulasso, the average concentrations of TSP, $PM_{10}$ and $PM_{2.5}$ in the city centre are higher than the concentrations in the monitoring animal house in the industrial zone.

Our results differ from Demay [24], who obtained $PM_{10}$ concentrations greater than or equal to 150 $\mu g \cdot m^{-3}$; because the concentrations vary little, although a reduction in $PM_{10}$ concentrations between Saturday and Sunday can be noted. During the week, concentrations do not vary in the same way.

### 4.5. Weekly Concentrations Mean

During the week, concentrations do not vary in the same way. Wind direction can also play a role in differences in concentrations from one day to the next. Wind influence pollutant concentrations through its speed and direction. Urban traffic could explain the weekly variations, such as the discrepancy in concentrations between weekdays and weekends. There may be less traffic on the streets of the two major cities on Saturdays and Sundays than on weekdays, depending on the location and the city. A proportion of the population can get to work by car or on two wheels, which means less traffic at weekends. Our results are similar to those obtained by Ouarma *et al.* [1], Guissou *et al.* [31] who said that this means that the $PM_{10}$ pollution in Ouagadougou is more acute than the $PM_{2.5}$ pollution. An urban area with mainly exhaust fumes is a strong source of PM, especially during the rainy season [32] [33].

### 4.6. Percentages of Non-Standard Values Compared with $PM_{10}$ and $PM_{2.5}$ WHO Reference Values

The prevalence of Respiratory Syncytial Virus (RSV), viral infections in infants suffering from respiratory infections consulted and hospitalized in the city of Ouagadougou, and to evaluate the clinical characteristics associated with the identification of RSV infection. The age group under 6 months was the most affected, with 66.7% of cases of RSV ARI (Acute Respiratory Infections). The main histories of atopy found in the children were rhinitis 14 (58.3%) and asthma 2 (8.3%); clinical signs observed during RSV ARI were dominated by cough, 22 (91.66%), followed by fever (temperature ≥ 38.5˚C) (79.2%), rhinitis 19 (79.2%) and respiratory distress (moderate if score between 3 and 4 and severe if score ≥ 4 - 5) 16 (66.7%). The frequency of RSV ARI (16.2%) and its predilection (age < 6 months) are a real public health problem in paediatrics [34]. In Burkina Faso (West Africa), ARIs are also a major cause of child admissions to hospital [35]. Two hundred and nine children (boys: 58.4%) were included in this study. They were all aged less than three years, and 60.8% of them were less than 1 year old. Seventy-three children (34.9%) attended outpatient consultation, and 136 (65.1%) were admitted to hospital. Children with positive results were mostly identified by RT-PCR (n = 149, 71.3%), and only 21 (10%) were detected by DFA (Direct Immunofluorescence Assay) [36]. In Burkina Faso, respiratory illness is the second reason why outpatients consult physicians and the fourth reason why women aged ≥ 15 years are hospitalized, after malaria, anemia, and abortion complications [37]. Emissions from cars, dust, cockroaches and mouldy bits were the most common exposure factors in the environment at respectively 89.2%, 85.3%, 85.3% and 68.6%. A notion of smoking was found in 38 patients (4 active and 34 second-hand smoking). Atopic disorder was attested in 86 patients (84.3%). The comorbidities were dominated by allergic rhinitis (70.6%), gastroesophageal reflux disease (GERD) (37.3%), overweight (24.5%), and obesity (20.6%). Previous study showed that 26.5% of asthmatics were well controlled, 34.3% partially controlled and 39.2% uncontrolled. Adherence to treatment was investigated and 37.3% of the patients were found to be non-adherent. The cost of treatment was the leading cause of non-adherence and non-compliance (59.8%) followed by geographic access to healthcare facilities (34.3%). One hundred and two asthmatic patients were included (76 women and 26 men) with a mean age of 38.7 ± 18.6 years. Asthma was found to be well controlled in 26.5% of cases, partially controlled in 34.3% of cases and uncontrolled in 39.2% of cases [38].

In Burkina Faso, women and their young children are the most exposed to the effects of indoor air pollution. This study looked at the risk factors associated with indoor air pollution during cooking in the occurrence of Acute Respiratory Infections (ARI) in children under 5 years of age. The prevalence of ARI was 3.5% in children under 5 [30]. In Burkina Faso, indoor air pollution is thought to be responsible for 8.5% of general morbidity. In 2002, 21,500 deaths were attributable to indoor air pollution [39]. Seventy per cent of men had a chronic irreversible airway dilatation [40].

The data show that concentrations of $PM_{10}$ and $PM_{2.5}$ are well above WHO standards at almost all sites in Burkina Faso's two major cities. Individual and collective awareness is needed for optimum protection against air pollution, with its corollary of respiratory pathologies. The department in charge of health would be well advised to use the preventive method, *i.e.* awareness-raising, to control the problem as effectively as possible.

### 4.7. Association between $PM_{10}$, $PM_{2.5}$ and Study Sites

The highly significantly association due to $PM_{10}$, $PM_{2.5}$ and other sites can explain a high risk of exposure in the city centre of Bobo-Dioulasso. Our results are similar to those obtained by Ouédraogo *et al.* [23], that say harmful levels in Ouagadougou, $PM_{2.5}$ caused primarily outpatient hospital visits rather than hospitalizations for respiratory diseases. Hospital visits for respiratory diseases accounted for 14.16% of all visits. Children were males in the majority (54.57%) and aged between 29 days - 30 months (74.85%). Rise in PM2.5 concentrations was associated with slightly more outpatients than inpatients (ORc = 0.996 95% CI: 0.993 - 0.998; p = 0.003). Most respiratory cases arose during the dry season (1114/2012, 55.37%). The majority (54.57%) were males, 1506 (74.85%) were infants. Inpatients represented 62.43% (1256 cases) of all cases. Regarding the distribution of respiratory diseases, acute bronchitis was the most frequent (46.87%), followed by pneumonia (38.57%) and rhinitis (37.08%). Forty-three deaths (3.42%) were reported, and all occurred among hospitalized patients. A high concentration of $PM_{2.5}$ was associated with increased outpatient consultations among children, a finding that could help prepare for such situations [23]. In sub-Saharan Africa, the prevalence of asthma ranges from 6% to 20% and Chronic Obstructive Pulmonary Disease (COPD) from 4.1%

to 24.8% [41].

This significant rise in $PM_{10}$ and $PM_{2.5}$, combined with the risk factors observed at the various sites, undoubtedly reveals the risks of exposure of the population to these fine particles, which is only increasing, with its attendant death toll and rise in the incidence of respiratory pathologies in both the elderly and children [30]. Once again, we are sounding the alarm and calling on the Ministry of Health to take proper account of these effects. The best way to reduce air pollution is to use public transport, good quality oil and petrol, and to pave and maintain roads regularly.

### 4.8. Risk Factors

In terms of risk factors, in Bobo-Dioulasso 66.67% had stay in current city for more than 5 years, 14.81% were exposed to secondhand smoke regularly, 27.28% live or work in an environment with heavy pollution (e.g., smoke, dust, industrial emissions), 21.55% are frequently exposed to indoor air pollution (e.g., cooking with wood, kerosene, or charcoal), 11.79% suffer from allergies that affect their respiratory system, 61.61% take protective measures (e.g., face masks) in environments with poor air quality.

In Ouagadougou, 51.56% of people stay in current city for more than 5 years, 19.44% were exposed to secondhand smoke regularly, 38.88% live or work in an environment with heavy pollution (e.g., smoke, dust, industrial emissions), 23.06% frequently exposed to indoor air pollution (e.g., cooking with wood, kerosene, or charcoal), 12.03% suffer from allergies that affect their respiratory system. 59.97% takes protective measures (e.g. protective mask) in environments with poor air quality. No significant association ($p > 0.05$) was found.

### 4.9. Medical History

The city of Bobo-Dioulasso was the residency for 11.78% of people diagnosed with any respiratory disease in the past 12 months, compared with 15.81% in Ouagadougou. Bronchitis was the most common, followed by asthma and then pneumonia in both towns. Our results are similar to those obtained by Ouédraogo *et al.* [23] who mentioned acute bronchitis as a frequent respiratory pathology (46.87%) in children's visits to hospital for respiratory illnesses. Around 37% of participants in Bobo-Dioulasso experienced respiratory symptoms (cough, difficulty breathing, chest tightness) in the last 12 months 1 - 2 times, compared with 39.70% in Ouagadougou for 1 - 2 times. Thirty percent (32.32%) of participants in Bobo-Dioulasso received treatment for their respiratory condition compared with 36.74% of participants in Ouagadougou. In the type of treatment for respiratory conditions, 25.25% of people in Bobo-Dioulasso used medication only, compared with 28.83% of people in Ouagadougou.

## 5. Conclusion

Environmental toxicology data for a number of sites in the two major cities in

Burkina Faso in West Africa, Ouagadougou and Bobo-Dioulasso are revealing. These two cities are the most densely populated in Burkina Faso, with more than a dozen industries inventoried in each city. Coupled with the activities and population movements towards these urban centres, this gives us an idea of the level of weekly air pollution during the rainy season. The particulate matter levels stipulated by certain organizations are exceeded in these city centres. Since air is a moving element, the suspended particles we breathe undoubtedly have an impact on people's health. These include chronic respiratory disorders, such as asthma, pneumonia, bronchitis and Chronic Obstructive Pulmonary Disease (COPD), as well as disrupting the functioning of the hormonal system and directly affecting the endocrine glands and DNA, which appears to play a very important role through epigenetics and its various mechanisms. Another alternative could be the use of medicinal plants known to be used in the treatment of respiratory pathologies. Further, studies will be needed to consolidate the results of this study. This will involve studying the endocrine disrupting effect of the particles collected and taking particle measurements during the peak period.

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## Informed Consent Statement

See ethical approval.

## Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Author Contributions

Conceptualization, data curation, formal analysis, methodology, writing—original draft, Writing—review and editing by TZJFR.

TA, BMB, BBVEJT, and KDJN was responsible for the formal analysis, methodology, supervision, validation, visualization and writing—review and editing.

DWF, TL, OTC, BS, BSI, OKZT, DWF and SJ realize the investigation, supervision, validation and visualization. All authors read and approved the final manuscript.

## Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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