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Exposure to Traffic-Related Particulate Matter and Prevalence of Respiratory Symptoms among Commercial Drivers in Abuja, Nigeria

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Abstract: Background: Traffic-related air pollution poses a significant occupational health risk, particularly for commercial drivers in rapidly urbanizing cities. This study assessed exposure to fine particulate matter ($PM_{2.5}$) and its association with self-reported respiratory symptoms among commercial drivers in Abuja, Nigeria. Methods: A cross-sectional study was conducted among 400 commercial drivers from two local government areas. Ambient $PM_{2.5}$ concentrations were measured using a calibrated Bosean portable dust detector at four motor parks over four weeks. Respiratory health data were collected using the American Thoracic Society Respiratory disease questionnaire (ATS-DLD-78) administered by interviewers. Logistic regression was used to explore associations between $PM_{2.5}$ and respiratory symptoms. Results: 24-h mean $PM_{2.5}$ concentrations ranged from 53.6 to 76.2 μg/m^3, exceeding WHO guideline limits at all sites. Prevalent respiratory symptoms included cough 81.0%, (95% CI: 77.0–84.5), phlegm production 68.4% (95% CI: 45.5–55), runny/blocked nose 70.8% (95% CI: 66.0–75.3), wheezing 19.5% (95% CI: 15.8–23.8) and breathing difficulty 21.8% (95% CI: 17.8–26.0). Higher $PM_{2.5}$ exposure was significantly associated with increased odds of doctor-diagnosed asthma (AOR = 13.2; 95% CI: 6. 9–25.4; $p < 0.001$), although this exploratory finding warrants further investigation using more robust exposure assessment and longitudinal study designs. Driving experience, daily work hours, age, and income were also significant predictors of respiratory symptoms. Conclusion: Commercial drivers in Abuja are exposed to $PM_{2.5}$ concentrations substantially exceeding WHO guidelines, with a high burden of associated respiratory morbidity. Targeted occupational health interventions, strengthened emission regulations, and improved road infrastructure are needed. Further, there is need to safeguard public health in Nigeria through regulatory standards that aligns with latest scientific evidence on $PM_{2.5}$.

Keywords: $PM_{2.5}$; traffic air pollution; respiratory symptoms; occupational exposure; commercial drivers; Abuja

1. Introduction

Globally, air pollution has been recognized as one of the leading environmental determinants of disease and premature mortality particularly in developing countries where rapid urbanization, industrialization, and increasing vehicular emissions contribute to deteriorating air quality [1–3]. Recent global assessments indicate that air pollution contributes substantially to the burden of non-communicable diseases, particularly cardiovascular and respiratory conditions [3]. According to the World Health Organization (WHO), approximately 99% of the global population live in areas where air quality levels exceed recommended guideline limits. Ambient air pollution alone was responsible for an estimated 4.2 million premature deaths worldwide in 2019, highlighting the substantial public health burden associated with poor air quality [4]. The World Health Organization estimates that the combined effects of ambient and household air pollution are associated with about 6.7 million premature deaths annually worldwide, including approximately 834,000 premature deaths each year in the WHO African Region [5,6].

Air pollution is a complex mixture of particulate and gaseous pollutants emitted by various anthropogenic and natural sources, including transportation, industrial production, energy generation, agricultural activities, and biomass burning. Fine particulate matter ($PM_{2.5}$) and coarse particles (PM_{10}) are among the most harmful air pollutants because of their ability to penetrate the respiratory tract and enter systemic circulation [7]. Evidence synthesized for the updated World Health Organization (WHO) air quality guidelines demonstrates that exposure to particulate matter is associated with adverse health effects even at relatively low concentrations and that air pollution remains a major global public health threat affecting multiple organ systems [7]. Traffic-related air pollution (TRAP) is recognized as one of the major sources of particulate matter in urban environments. Motor vehicles emit a mixture of pollutants, including nitrogen oxides (NO_2), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), and particulate matter generated from fuel combustion, brake wear, and road dust resuspension [8]. In many developing countries, vehicular emissions are a major contributor to urban air pollution due to the high number of aging vehicles, poor vehicle maintenance, and inadequate emission control policies [9]. Occupational groups that spend long hours in traffic environments are particularly vulnerable to these pollutants. Commercial drivers, for instance, spend prolonged periods on busy roads where they are continuously exposed to vehicular emissions and suspended particulate matter. Such prolonged occupational exposure increases their likelihood of inhaling harmful concentrations of pollutants, thereby elevating their risk of developing respiratory symptoms and other health complications.

Abuja, the capital city of Nigeria, has experienced rapid urban growth accompanied by increased vehicular activity and traffic congestion, which may contribute to elevated levels of ambient particulate matter. Commercial drivers in the city spend most of their working hours navigating busy roads and may therefore be exposed to substantial concentrations of traffic-related pollutants. However, studies examining the relationship between particulate matter exposure and respiratory symptoms among this occupational group remain limited. Understanding the extent to which exposure to traffic-related particulate matter contributes to respiratory health problems among commercial drivers is important for informing occupational health policies and public health interventions. Therefore, this study aims to assess the exposure to fine particulate matter ($PM_{2.5}$) from traffic pollution and its association with self-reported respiratory symptoms among commercial drivers in Abuja, Nigeria.

2. Methodology

2.1. Study Design

This study employed a cross-sectional study design to assess exposure to traffic-related particulate matter ($PM_{2.5}$) and associated respiratory symptoms among commercial vehicle drivers in Abuja, Nigeria. The study was conducted in Abuja, the capital city of Nigeria, located within the Federal Capital Territory (FCT). Abuja serves as the administrative center of the country and hosts major governmental institutions, commercial centers, transportation hubs, and residential districts. The population of the FCT was estimated to exceed 4 million in 2021 and is projected to increase to approximately 7.17 million by 2040, reflecting rapid urbanization and increased transportation activities within the city [10]. The study population consisted of commercial vehicle drivers aged 18 years and above operating within selected locations in Abuja. Participants were drawn from two Area Councils within the FCT namely Abuja Municipal Area Council (AMAC) and Gwagwalada Area Council. A multistage sampling technique was employed for participant selection. In the first stage, AMAC and Gwagwalada were purposively selected from the six Area Councils in the FCT because of their high traffic density, concentration of commercial transport activities, and relevance to the study objectives. In the second stage, major motor parks with substantial vehicular movement were purposively selected within the chosen councils. In the final stage, eligible commercial drivers present at the selected motor parks during the study period constituted the sampling frame and were recruited using a simple random sampling technique.

Eligibility criteria included drivers aged 18 years or older who were actively engaged in commercial driving activities. Drivers who reported a history of major heart or lung surgery were excluded from the study. Participation was voluntary, and informed consent was obtained from all respondents prior to data collection. A total of 450 eligible drivers were approached, out of which 400 consented to participate, yielding a response rate of 88.9%. The low proportion of female participants reflected the predominantly male nature of commercial driving activities within Abuja.

Major transportation hubs with high commercial driving activities in two local governments were selected as sampling points. The sample size was determined using the single population proportion formula. A total of 400 commercial vehicle drivers participated in the study.

2.2. Data Collection

2.2.1. Questionnaire Administration

A structured questionnaire adapted from the American Thoracic Society respiratory disease questionnaire (ATS-DLD-78) was administered to the respondents by trained research assistants to ensure clarity, completeness, and consistency of responses. To improve comprehension among respondents, certain medical terms were simplified during administration. For instance, the term "phlegm" was explained as "thick mucus", and "wheezing" was described as a "whistling sound in the chest". All respondents provided written informed consent before participating in the study.

Respiratory symptoms including cough, phlegm production, wheezing, breathing difficulty, and asthma status were self-reported by participants. Asthma was assessed based on self-report of previous physician diagnosis.

2.2.2. Air Quality Monitoring

Ambient air quality monitoring for particulate matter ($PM_{2.5}$) was conducted using a calibrated Bosean portable dust detector, which provides real-time measurements of particulate concentrations. Geographic coordinates of the sampling locations were recorded using a handheld Global Positioning System (GPS) device (Garmin 60Cx). All monitoring equipment was pre-calibrated prior to field measurements to ensure data accuracy and quality assurance. Air quality measurements were conducted over a four-week monitoring period between May and June during the dry season. Spot measurements of $PM_{2.5}$ were obtained three times daily on Mondays, Wednesdays, and Fridays Measurements taken during these sampling periods were averaged to estimate 24-h mean concentrations for each study location. Sampling times included morning (8:00–9:00 am), afternoon (2:00–3:00 pm), and evening (6:00–7:00 pm), representing periods of increased vehicular activity.

The measured concentrations of $PM_{2.5}$ were compared with permissible limits established by the Nigerian National Environmental Standards and Regulations Enforcement Agency (NESREA) and the World Health Organization (WHO) air quality guidelines. Traffic counts (for trucks, cars, minibuses and motorcycles) were made in each location.

Exposure assessment focused on the motor parks where commercial drivers spend substantial periods waiting for passengers between trips, rather than during active transit across different routes within Abuja. Exposure levels were determined using a combination of ambient particulate matter concentrations measured at the selected motor parks, daily working hours, and years of driving experience. Drivers who reported working for more than 8 h daily and had ≥5 years of driving experience were categorized as having higher occupational exposure, while those working 8 h or less daily and with <5 years of driving experience were categorized as having lower exposure. This classification was based on the assumption that longer working hours increase the duration of contact with traffic-related air pollutants.

2.3. Data Analysis

Data collected from the field were entered into Microsoft Excel and screened for completeness and consistency. Records with missing values were excluded from the analysis. The cleaned dataset was then exported to the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics including frequencies, percentages, means, and standard deviations were used to summarize the socio-demographic characteristics of respondents and the prevalence of respiratory health outcomes. Binary logistic regression analysis was used to determine predictors of respiratory symptoms and estimate adjusted odds ratios (AORs) with 95% confidence intervals. Multivariate logistic regression was conducted to assess the relationship of the health outcomes (cough, phlegm production, wheezing, breathing difficulty and doctor-diagnosed asthma) with $PM_{2.5}$ exposure, age, driving experience (years), daily working hours, monthly income and smoking status, as the co-variates. Exposure assessment was informed by ambient particulate matter ($PM_{2.5}$) measurements obtained at the selected motor parks and participants' occupational characteristics. For the purpose of exposure classification in the regression analysis, participants were categorized based on self-reported daily working hours. Drivers who reported working for more than 8 h per day and had ≥5 years of driving experience were classified as having higher occupational exposure, while those who reported working 8 h or less per day and had <5 years of driving experience were classified as having lower occupational exposure. This classification was based on the assumption that longer working hours increase the duration of exposure to traffic-related air pollutants within the occupational environment. Ambient

$PM_{2.5}$ measurements were used to characterize air quality conditions at the selected motor parks and provide environmental context for the exposure assessment. Additionally, one-way Analysis of Variance (ANOVA) was performed to compare the mean concentrations of particulate matter ($PM_{2.5}$) across the selected sampling locations and across the different weeks of monitoring. Statistical significance was determined at a p-value less than 0.05.

3. Result

Traffic density values presented in Figure 1 were derived by computing the mean of vehicle counts recorded during three peak periods of the day (morning, afternoon, and evening) across each sampling location. For each vehicle category (cars, buses, trucks, and motorcycles), the counts obtained during these periods were averaged to generate a representative mean traffic density (vehicles per hour) for each location.

Figure 1 shows the mean traffic density across the four sampling locations by vehicle type. SDP Park recorded the highest traffic density across all vehicle categories, with particularly high volumes of cars (807 vehicles/hour) and motorcycles (240 vehicles/hour). Jabi Park also recorded substantial traffic levels, especially for cars (593 vehicles/hour), while Wazobia Park showed moderate traffic density across all vehicle types. Berger Park consistently recorded the lowest traffic volumes across all categories, with markedly lower counts for buses and trucks. Across all locations, cars constituted the largest proportion of vehicles, followed by motorcycles, while trucks were the least frequent. This pattern reflects the dominance of private and commercial light-duty vehicles within the study area and indicates higher traffic-related emission potential in locations with elevated vehicle density, particularly SDP Park.

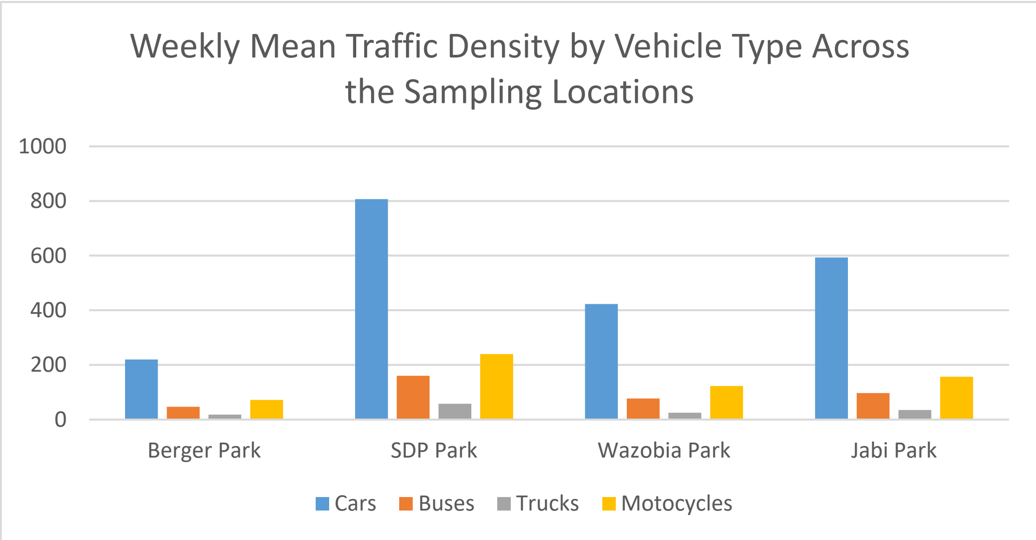

Figure 1. Weekly mean traffic density by vehicle type across the sampling locations.

3.1. Environmental Activity Indicators at the Four Study Locations

Table 1 shows that the environmental characteristics of the study locations varied across the four sites. Commercial activities were highly prevalent in SL1 (Jabi Park), SL3 (SDP Park), and SL4 (Wazobia Park), while SL2 (Berger Roundabout) recorded relatively lower commercial activity. Industrial activities were absent across all locations. Residential presence was moderate to high in all sites. All locations had well-developed paved road networks, with unpaved graded-earth roads present to varying degrees. Environmental activities such as bush burning, dumpsites, and generator emissions were observed in some locations, particularly in SL1 and SL3, but were minimal or absent in SL2.

Table 1. Environmental activity indicators and site characteristics at the four sampling locations.

Indicators	SL1 (Jabi Park)	SL2 (Berger Roundabout)	SL 3 (SDP Park)	SL 4 (Wazobia Park)
Commercial activity	+++	++	+++	+++
Industrial activity	-	-	-	-
Residential area	++	++	+++	++
Nature of road networks				
Paved roads	+++	+++	+++	+++
Graded earth roads (unpaved)	++	++	+++	++

Table 1. *Cont.*

Indicators	SL1 (Jabi Park)	SL2 (Berger Roundabout)	SL 3 (SDP Park)	SL 4 (Wazobia Park)
Activities within and around the study location				
Bush burning	+++	-	++	-
Dumpsite	++	-	+++	++
Generator emission	+++	-	++	++

Key Indicator: +++ Highly present; ++ Moderately present; + Present; - Absent.

3.2. Sociodemographic Characteristics of Respondents

The socio-demographic characteristics of the respondents showed that the mean age was 42.83 ± 9.90 years, with the majority aged 38–47 years (37.5%). Most respondents were male (98.5%), married (72.5%), and had secondary education (62.3%). 36.3% had been working as drivers for 6–10 years, while over half (51.3%) had worked in the area council for 2–5 years. Nearly half of the respondents (47.5%) earned above ₦51,000, and the majority (60.8%) reported working 6–8 h daily (Table 2). The low proportion of female participants (1.5%) reflects the male-dominated nature of commercial driving in Abuja and many parts of Nigeria.

Table 2. Sociodemographic characteristics of respondents.

Variables (n = 400)	Frequency	Percent (%)
Age		
Mean	42.83 ± 9.903	
18–27	16	4.0
28–37	116	29.0
38–47	150	37.5
48–57	87	21.8
58–67	26	6.5
68 and above	5	1.3
Sex		
Male	394	98.5
Female	6	1.5
Educational Level		
Primary	51	12.8
Secondary	249	62.3
Tertiary	100	25.0
Marital Status		
Married	290	72.5
Single	79	19.8
Divorced	8	2.0
Widowed	7	1.8
Separated	13	3.3
Cohabiting	3	0.8
Duration working as a driver		
2–5 years	116	29.0
6–10 years	145	36.3
11–16 years	65	16.3
16 years or more	74	18.5
Income		
20,000–30,000 Naira	15	3.8
31,000–40,000 Naira	46	11.5
41,000–50,000 Naira	149	37.3
>51,000 Naira	190	47.5
Duration of working in the Area Council		
More than a year	6	1.5
2–5 years	205	51.3
5–10 years	139	34.8
More than 10 years	50	12.5
Duration of work hours		
1–2 h	3	0.8
3–5 h	85	21.3
6–8 h	243	60.8
More than 10 h	69	17.3

3.3. Trend of Respirable Particulate Matter ($PM_{2.5}$) Concentration at Sampling Locations

Table 3 presents the weekly average $PM_{2.5}$ concentrations, estimated from 24-h measurements, across the four-week monitoring period. The results show clear temporal variation in $PM_{2.5}$ levels over time, with concentrations ranging from 53.64 µg/m^3 in Week 2 to 76.18 µg/m^3 in Week 1.

The concentrations of $PM_{2.5}$ across the four weeks showed considerable variation among the study locations based on estimated 24-h mean concentrations (Figure 2). In the first week, SDP Park recorded the highest 24-h mean concentration (88.7 µg/m^3), followed by Jabi Park (78.3 µg/m^3) and Wazobia Park (77.5 µg/m^3), while Berger Roundabout recorded the lowest (60.0 µg/m^3). $PM_{2.5}$ levels declined in the second week, with an overall 24-h mean of 53.64 µg/m^3, but increased again in the third and fourth weeks to 65.83 µg/m^3 and 72.00 µg/m^3, respectively. Across the monitoring period, SDP Park consistently recorded the highest estimated 24-h mean $PM_{2.5}$ concentrations, whereas Berger Roundabout maintained the lowest levels. All recorded 24-h mean concentrations exceeded the WHO recommended 24-h guideline value of 15 µg/m^3, indicating sustained exposure to elevated levels of fine particulate matter across all study locations. The analysis of variance (ANOVA) demonstrated statistically significant differences in $PM_{2.5}$ concentrations across the four locations in all weeks (Week 1: $F(3,32) = 7.831$, $p < 0.001$; Week 2: $F(3,32) = 5.245$, $p = 0.005$; Week 3: $F(3,32) = 4.440$, $p = 0.010$; Week 4: $F(3,32) = 18.019$, $p < 0.001$), as presented in Table 4.

Table 3. Weekly 24-h average concentrations of $PM_{2.5}$ across the study period.

Week	PM2.5 Average (µg/m^3)
Week 1	76.18
Week 2	53.64
Week 3	65.83
Week 4	72.00

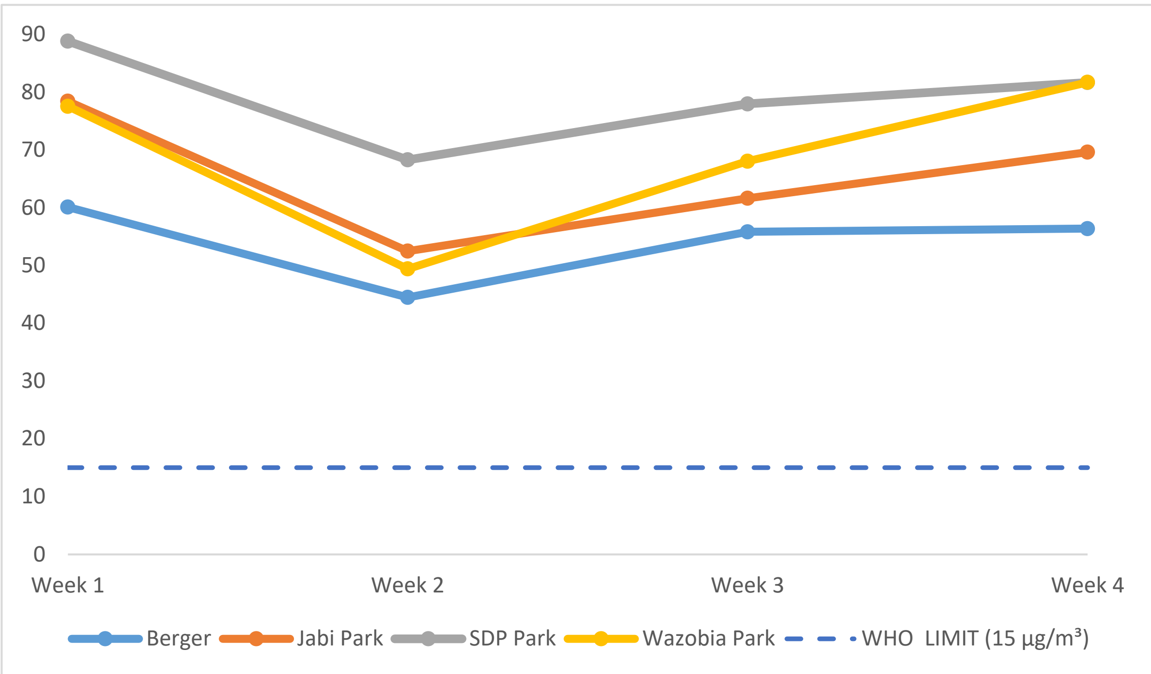

Figure 2. Comparison of $PM_{2.5}$ concentrations with WHO limit across all locations. (There is no NESREA limit for $PM_{2.5}$).

Table 4. One-way ANOVA results weekly $PM_{2.5}$ concentrations across the four monitoring locations.

Week	F Statistic	df (Between, Within)	*p*-Value
Week 1	7.831	(3, 32)	<0.001
Week 2	5.245	(3, 32)	0.005
Week 3	4.440	(3, 32)	0.010
Week 4	18.019	(3, 32)	<0.001

3.4. Prevalence of Respiratory Symptoms among Commercial Drivers

Figure 3 shows the prevalence of respiratory symptoms among the respondents, where cough was the most commonly reported symptom, affecting 81% of participants (95% CI: 77.0–84.5). This was followed by rhinitis, reported by 70.8% of respondents (95% CI: 66.0–75.3), and phlegm production, which was experienced by 68.4% of the study population. while morning phlegm was experienced by 50.3% (95% CI: 45.5–55.0). Chronic cough lasting more than three weeks was reported by 30.3% of participants (95% CI: 25.8–35.0). Regarding respiratory distress symptoms, breathing difficulty was reported by 21.8% of respondents (95% CI: 17.8–26.0), while wheezing was reported by 19.5% (95% CI: 15.8–23.8). Exercise-related wheeze was less common, occurring in 8.5% of respondents (95% CI: 6.0–11.5). Doctor-diagnosed asthma was reported by 27.3% of respondents (95% CI: 22.8–31.7), indicating a considerable burden of clinically recognized respiratory disease within the study population.

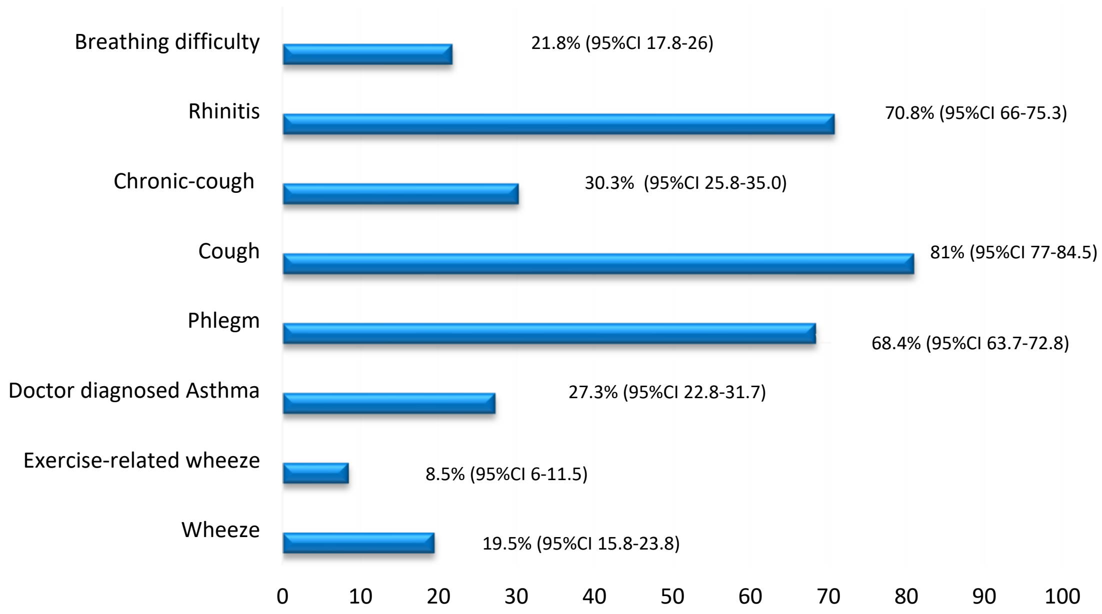

Figure 3. Respiratory symptoms reported by respondents.

3.5. Association between Traffic-Related $PM_{2.5}$ Exposure and Respiratory Symptoms among Commercial Drivers

Higher exposure to $PM_{2.5}$ was strongly associated with increased odds of doctor-diagnosed asthma (AOR = 13.2; 95% CI: 6.9–25.4). No other variables showed a meaningful positive association with asthma. For phlegm production, drivers with 6–10 years of driving experience had higher odds compared to those with 2–5 years of experience (AOR = 4.3; 95% CI: 1.6–11.7). Similarly, drivers working 6–8 h per day were more likely to report phlegm than those working 1–2 h (AOR = 3.3; 95% CI: 1.3–8.6). Drivers earning ₦20,000–₦30,000 also showed increased odds of phlegm compared with those earning higher income levels (AOR = 2.1; 95% CI: 0.5–8.3), although the confidence interval was wide. For cough, income was the main predictor. Drivers earning ₦31,000–₦40,000 had higher odds of reporting cough compared to those earning ≥₦51,000 (AOR = 8.2; 95% CI: 1.9–35.8). In addition, drivers working 6–8 h per day had increased odds of cough compared to those working 1–2 h (AOR = 3.7; 95% CI: 1.2–12.0). No significant positive association was observed between $PM_{2.5}$ exposure and cough (see Table 5). These findings indicate that particulate matter exposure is associated with doctor-diagnosed asthma, while occupational factors such as duration of driving and daily working hours are more closely related to phlegm production and cough among commercial drivers.

Table 5. Multivariate logistic regression analysis of factors associated with respiratory symptoms among commercial drivers.

Variables	Asthma	Phlegm	Cough
PM 2.5			
Low Exposure to PM 2.5	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Higher Exposure to PM 2.5	13.23(6.89–25.38) *	0.34(0.19–0.61) *	0.6(0.32–1.18)
Duration working as a driver			
2–5 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

Table 5. *Cont.*

Variables	Asthma	Phlegm	Cough
6–10 years	1.49(0.57–3.94)	4.34(1.61–11.73) *	1.39(0.47–4.13)
11–16 years	1.46(0.63–3.36)	2.15(0.88–5.24)	1.56(0.59–4.07)
16 years or more	1.41(0.57–3.48)	1.15(0.43–3.12)	1.06(0.36–3.09)
Income			
20,000–30,000 Naira	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
31,000–40,000 Naira	1.45(0.33–6.31)	2.06(0.51–8.34) *	8.17(1.87–35.84) *
41,000–50,000 Naira	1.23(0.49–3.08)	0.63(0.25–1.57)	1.41(0.53–3.74)
>51,000 Naira	1.38(0.71–2.69)	1.74(0.95–3.16)	1.51(0.74–3.06)
Duration of work hours			
1–2 h	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3–5 h	1.19(0.06–24.16)	1.45(0.07–30.89) *	0.00(0.00)
6–8 h	1.86(0.72–4.80)	3.28(1.25–8.60)	3.72(1.16–11.97)
More than 10 h	1.78(0.86–3.69)	1.31(0.58–2.96)	2.15(0.78–5.96)

*$p < 0.05$.

4. Discussion

24-h mean $PM_{2.5}$ concentrations ranged from 53.6 to 76.2 µg/m^3 across the four motor parks. These values exceeded the WHO 24-h guideline limits of 15 µg/m^3 indicating high levels of particulate exposure for drivers and commuters. When compared with findings from other studies, the levels reported in this study are notably elevated. A study conducted in Lagos, Nigeria at a busy road reported mean 24-h $PM_{2.5}$ concentrations ranging from 25.4 to 29.4 µg m^{-3}, which, although above WHO limits, were considerably lower than the values recorded in this study [11]. This suggests that the exposure environment in the present study may involve higher traffic density or additional pollution sources. In contrast, studies conducted in Nigeria among street sweepers reported even higher mean $PM_{2.5}$ concentrations, with values of 71 µg m^{-3} in Oyo, 94 µg m^{-3} in Lagos, and up to 135 µg m^{-3} in Ekiti [12,13]. These findings highlight that occupations involving prolonged outdoor exposure in polluted urban settings may experience substantially higher levels of particulate matter than those observed in the present study. All four sites in this study recorded PM concentrations far above the WHO guideline. Considering that it has been shown that even at relatively low concentrations, exposure to particulate matter is associated with adverse health effects [7], there is a need for Nigeria to align and update its air quality regulations with the 2021 WHO Air Quality guidelines [6].

Our results showed that SDP Park consistently recorded the highest $PM_{2.5}$ concentrations while Berger Roundabout recorded the lowest. The variation remained statistically significant across all weeks ($PM_{2.5}$ Week 1: F = 7.831, p = 0.000). Differences in traffic volume, road surface condition, and microenvironmental activities likely account for these disparities. Studies have found that vehicles traveling on unsealed roads or congested intersections produce higher levels of resuspended dust and non-exhaust particles compared with vehicles traveling on well-paved highways [14,15]. Additionally, ventilation modes, vehicle speed and proximity to high-emitting vehicles influence in-cabin particulate concentrations [16]. The high PM concentrations at SDP Park may stem from the combination of dense traffic, roadside trading and unpaved graded earth roads while the relatively lower levels at Berger Roundabout may reflect reduced traffic intensity and fewer commercial activities. With these, there is a need for targeted interventions that address site-specific pollution sources such as improved traffic management and road maintenance.

A notable proportion of respondents reported respiratory symptoms. Phlegm production was common (68.4%; 95%CI 63.7–72.8) as was chronic cough (81%; 95%CI: 77.0–84.5); wheezing was reported by 19.5% (95% CI: 15.8–23.8) and breathing difficulty by 21.8% (95% CI: 17.8–26.0). These symptoms are consistent with irritative and inflammatory responses to chronic particulate exposure. In the Malaysian bus driver study, 73.5% of drivers reported phlegm and 55.9% reported cough- and drivers with longer employment duration had higher odds of chronic phlegm [17]. Similarly, the Paris PUF TAXI study found that pre-lockdown exposure to ultrafine particles and black carbon was associated with nose irritation and reduced forced expiratory flows among taxi drivers [18]. Mustapha et al. also reported that exposure to traffic-related air pollutants significantly increased the risk of respiratory illness among exposed populations in Nigeria, particularly in areas with heavy traffic density. This suggests that the high prevalence of cough, phlegm, and wheeze observed among Abuja drivers may be occupational exposure-related respiratory effects [9].

The prevalence of physician-diagnosed asthma observed in this study (27.3%) was higher than estimates reported in previous studies among occupational groups and the general population. This finding should be interpreted cautiously. Asthma status was based on self-report of a previous physician diagnosis and was not verified using clinical records or objective measures such as spirometry. Consequently, some degree of outcome misclassification may have occurred. It is possible that some participants reported other chronic respiratory conditions or recurrent respiratory symptoms as asthma, thereby inflating the observed prevalence. Furthermore, commercial drivers are exposed to a complex mixture of traffic-related pollutants beyond $PM_{2.5}$, including nitrogen dioxide, carbon monoxide, and diesel exhaust emissions, which may contribute to a higher burden of respiratory disease. Participation bias may also have occurred if drivers with respiratory symptoms were more likely to participate in a study focused on respiratory health. Therefore, the observed prevalence may reflect a combination of true occupational risk, self-reporting limitations, and participation bias and should not be interpreted as a population estimate of clinically confirmed asthma.

Drivers with moderate $PM_{2.5}$ exposure had more than 13-fold higher odds of reporting doctor-diagnosed asthma compared with those in the highest exposure category (AOR = 13.23; 95 % CI = 6.90–25.38; $p < 0.001$). The finding underscores the strong link between fine particulate matter and asthma. Traffic emissions are a major source of $PM_{2.5}$ and epidemiological evidence shows that inhalation of these particles induces airway inflammation, oxidative stress and bronchial hyper-responsiveness [17]. Studies among transport workers have reported similar association. For example, bus drivers exposed to diesel exhaust and ambient PM exhibited reduced lung function and higher prevalence of respiratory symptoms, including asthma compared with non-exposed workers [19]. Exposure assessment studies have also shown that $PM_{2.5}$ concentrations inside vehicles can be two to ten times higher than ambient levels putting drivers at heightened risk [14].

The magnitude of the association observed between $PM_{2.5}$ exposure and physician-diagnosed asthma (AOR = 13.2) should be interpreted with considerable caution. Although the finding suggests a potential association between exposure to traffic-related particulate matter and asthma among commercial drivers, several methodological factors may have affected the estimate. Exposure classification relied on occupational proxies rather than personal exposure monitoring, potentially leading to misclassification. In addition, the cross-sectional design precludes assessment of temporality and therefore does not permit causal inference. Finally, the relatively small number of asthma cases within the exposure subgroups may have contributed to an unstable estimate of the odds ratio. Consequently, this finding should be regarded as exploratory and hypothesis-generating rather than confirmatory. Further longitudinal studies incorporating objective respiratory assessments and personal exposure monitoring are required to better characterize the relationship between particulate matter exposure and asthma among commercial driver.

Higher $PM_{2.5}$ exposure was associated with greater odds of phlegm production. Drivers in the moderate-exposure category had significantly lower odds of reporting phlegm compared with those in the highest-exposure category (AOR = 0.34; 95% CI = 0.19–0.61; $p < 0.001$), suggesting that high $PM_{2.5}$ levels exacerbate mucus hypersecretion. Experimental studies indicate that fine particles stimulate hypertrophy of mucous glands and hyperplasia of goblet cells- leading to increased sputum production [19]. Driving experience also mattered: drivers with 6–10 years of experience had over four times higher odds of phlegm (AOR = 4.34; 95 % CI = 1.61–11.73; $p = 0.010$). This aligns with prior findings that longer employment in traffic environments is linked to chronic bronchitis and sputum production [19]. Work duration influenced phlegm; working 6–8 h per day increased odds (AOR = 3.28; 95 % CI = 1.25–8.60; $p = 0.036$), perhaps because these hours coincide with peak traffic and high pollution periods. Overall, these results suggest that both long-term exposure (years in occupation) and short-term daily exposure (work hours) influence mucus production.

Most respondents were middle-aged (mean 42.8 years) male and had secondary education with many reporting extended work hours (6–8 h/day). Prolonged working hours in traffic increase cumulative exposure to pollutants and may exacerbate respiratory outcomes. A 2024 study carried out in Ghana, on driver education and awareness of in-vehicle air pollution found that carbon monoxide and particulate matter were the most common in-vehicle pollutants; breathlessness and coughing were more frequent among less educated drivers and many drivers lacked knowledge about pollutant health impacts [20]. These findings align with our cohort's characteristics and suggest that limited awareness may hinder the adoption of protective behaviours. Educational interventions targeting drivers could improve knowledge of air quality, encourage vehicle ventilation strategies and promote regular engine and filter maintenance.

5. Limitations of the Study

There are a number of limitations to the study. The low proportion of female participants (1.5%) may limit sex-based comparisons; however, this reflects the male-dominated nature of commercial driving in Abuja and similar settings in Nigeria rather than sampling bias. As a cross-sectional design, the study cannot establish cause and effect between the exposure and the health outcome. Potential limitations, including information bias, residual confounding, and exposure misclassification, were considered during interpretation of the study findings. As participation was voluntary and recruitment was limited to selected motor parks within two Area Councils, the possibility of selection bias cannot be excluded, and the findings may not be fully generalizable to all commercial drivers in Abuja. Although the questions used were from the ATS questionnaire, explanation of symptoms by interviewers might have affected responses. While the use of self-reported symptoms enabled rapid assessment within the occupational setting, the possibility of recall bias and reporting inaccuracies cannot be excluded. Indeed, this may result in over-reporting of respiratory symptoms as drivers may be eager to please the researcher or to show their understanding of the questions. However, for health outcome such as a doctor-diagnosed asthma, it is likely those who have been truly diagnosed that will report it. Moreover, residents of Abuja being the federal capital city has relatively more access to hospitals than rural part of Nigeria. Further, about 62% of the participants were educated to secondary school level and about 25% to tertiary level. Hence, it is expected that they have relatively good understanding of the questions and provided appropriate answers. Questionnaire information was not collected in exactly the same way as in other studies, which may affect comparability, but we do not anticipate any potential significant impact of this to be large. Self-reported health outcome may also be subjected to recall bias.

Measurements of PM were made only for very short time periods and therefore may not fully reflect usual or long-term exposures. $PM_{2.5}$ concentrations were measured at fixed locations within selected motor parks during the morning, afternoon, and evening on three days per week over a four-week period. These measurements were averaged to estimate ambient exposure levels at each site. However, $PM_{2.5}$ concentrations vary throughout the day due to changes in traffic volume, weather, and other environmental factors, meaning the sampled periods may not fully represent daily exposure patterns. Additionally, ambient $PM_{2.5}$ measurements at motor parks were used as proxies for individual exposure. This may not accurately reflect personal exposure because drivers spend varying amounts of time at different locations and along different routes, leading to potential exposure misclassification. Air quality monitoring was also limited to a four-week period during the dry season and may not capture seasonal variations, including Harmattan-related changes in particulate matter levels. The short monitoring period further limits assessment of long-term exposure to chronic respiratory outcomes. Therefore, the temporality problem in this study design does not support causal inference. These limitations require cautious interpretation of the findings. Future studies should incorporate personal exposure monitoring, longer and seasonal monitoring periods, and longitudinal designs to better characterize the relationship between $PM_{2.5}$ exposure and respiratory health among commercial drivers. The elevated adjusted odds ratio observed for doctor-diagnosed asthma should also be interpreted cautiously, as it may reflect residual confounding, exposure misclassification, or instability arising from relatively small subgroup sizes. Behavioral and occupational factors such as differences in driving routes, duration of exposure, and use of protective measures may also have influenced individual exposure levels and respiratory outcomes. However, our findings align with similar results from areas with high traffic density and lax environmental regulations. Air quality measurements with a network of low-cost sensors will provide more robust exposure characterization in future studies. Another limitation is that the study was restricted to two Area Councils (AMAC and Gwagwalada), both characterised by high traffic density and intense commercial transport activities. Including Area Councils with lower traffic density would have permitted direct comparisons across different exposure environments and may have provided stronger evidence regarding potential exposure-response relationships. Future studies should incorporate multiple Area Councils representing varying traffic conditions to improve the generalizability of findings and better characterize the relationship between traffic-related air pollution and respiratory health outcomes.

Notwithstanding, this study provides evidence on the occupational health implications of traffic-related air pollution in Nigeria and contributes to the growing body of literature highlighting the need for integrated environmental and public health policies aimed at reducing particulate matter exposure in urban transport environments.

6. Conclusions

The consistently high concentrations of $PM_{2.5}$ observed in this study underscore the need for improved air quality management strategies in rapidly urbanizing cities such as Abuja. Strengthening vehicular emission regulations, improving road infrastructure and promoting effective traffic management systems could help mitigate particulate pollution in transportation hubs. The association between exposure to traffic-related particulate matter and doctor-diagnosed asthma among commercial drivers in this study is worth further investigation in a more robust exposure assessment and study design. Further, there is need to safeguard public health in Nigeria through regulatory standards that aligns with latest scientific evidence on $PM_{2.5}$.

Author Contributions

A.T.: Conceptualization, methodology, investigation, data curation, formal analysis, writing—original draft preparation. C.A.: Formal analysis, data curation, visualization, writing—review and editing. S.B.: Formal analysis, interpretation of data, writing—review and editing. A.O.: Conceptualization, methodology, supervision, project administration, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical approval for the study was obtained from the Research Ethics Committee of Lead City University (Approval Number: LCU-REC/24/208). Additional approval was granted by the Federal Ministry of Health Research Ethics Committee in Abuja (Approval Number: FHREC/2024/01/272/19-11-24).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used Grammarly and Quillbolt to assist with spelling, grammar, and language refinement, including paraphrasing where appropriate. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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