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The Effect of PM_{10} and NO_x on COPD and Asthma Patients in Abuja Nigeria

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Abstract

Objective: Air pollution can contribute to the development and worsening of respiratory health problems. This study was conducted to study the effect of PM_{10} and NO_x on COPD and asthma patients because the effect of PM_{10} and NO_x on COPD and asthma patients has not been well studied in Nigeria. We investigated the effect of PM_{10} and NO_x on registered COPD and asthma patients in two government-owned hospitals in Abuja Nigeria. **Methods:** Data were collected on monthly FVC, FEV_1, using spirobank and dyspnoea with MRC dyspnoea scale from a study sample of 402 hospital-recruited COPD or asthma patients for 16 months. Routine air quality monitoring data and meteorological data were collated over the same time period. Correlation and multiple regression analyses were performed to calculate the correlation between respiratory disease (COPD and asthma) and the pollutants (PM_{10}, NO_x) concentration. **Results:** The 24-hour mean of PM_{10} in the study was 296.7μg/m^3, and the NO_2 1-hour mean was 253.1μg/m^3, which are both higher than the WHO guidelines. The PM_{10} increase was significantly associated with decreased FEV_1 and FVC in the participants (-786, P=.000); with a moderate significant association between NO_x and FVC (-.582, P= .018). A significant association was also observed between PM_{10} with Dyspnoea (-.786, P=.000). When we stratified for gender, it was observed that women had a higher significance P= .001. **Conclusions:** The observed consistency of the adverse health effects of PM_{10} across the tested variables and the health outcomes and diseases supports policy measures to control PM_{10} and NO_x. This study provides evidence that exposure to ambient air pollution has adverse effects on lung function in adults.

Keywords

PM_{10}, NO_x, COPD, asthma, effects, Nigeria

1. Introduction

Globally, air pollution is a risk factor for the morbidity of cardiorespiratory diseases [1, 2]. Air pollution in Abuja, Nigeria, is a significant problem, like in many other cities in developing countries [3]. In most cities including Abuja, traffic accounted for about 80% of NO_x in highly congested areas and NO_x is more likely to increase O_3, PM_{10} and NO_x concentrations in the area, thus posing a significant threat to health [2, 4]. Wambebe and Xiaoli [4] showed that the $PM_{2.5}$ daily average concentration air quality index (AQI) varies from 15.30 μg/m^3 to 70.20 μg/m^3, and is above the WHO AQI (25 μg/m^3) limit. Wambebe and Xiaoli [4] imply that the Abuja AQI of $PM_{2.5}$ fell under the very unhealthy AQI value index (air quality index value above 200. Ozone (O_3), $PM_{10,}$ and NO_x pollution is severe in Abuja and may get worse in the future due to climate change and economic growth [4, & 5].

Poor air quality in Abuja is caused mainly by emissions from fairly used (second-hand) cars referred to as "Tokunbo cars". Other sources of air pollution are power generators, the burning of agricultural waste, and open burning of solid waste [6, 7].

Also, epidemiological studies showed a strong association between particulate matter (PM) and respiratory diseases [2, 8-11]. The most affected of these are sufferers of chronic respiratory illnesses such as asthma and chronic obstructive pulmonary disease (COPD), which are among the top leading cause of death [2, 13]. Urbanisation exposed the respiratory system to outdoor air pollution.

Meta-analyses studies suggest that PM exposure can exacerbate COPD conditions [14, 15, 16]; some other studies showed that PM and other air pollutants increased the risk of severe acute exacerbations [17, 18]. Air pollutants can also worsen symptoms, lung function, and quality of life (QOL) in COPD and asthma patients [2, 19, 20].

NO_x is a group of deleterious air pollutants that can be airway irritants and exert tissue damage at high concentrations. The toxicity can prompt cell damage and inflammatory process all over the respiratory system, from the nose to the pulmonary alveoli [21]. Oxides of nitrogen and NO_2 are known precursors to the formation of ground-level ozone [22]. Also, NO_x can react in the presence of sunlight with volatile organic compounds (VOCs) to form photochemical smog. This typical brown cloud covers larger cities and can lead to poor air quality [22, 2]. Most of the NO_x is emitted as NO. This reacts in the presence of light (photochemically) with O_3 to form O_2 and NO_2. Also, NO_2 decomposes to O and NO at less than 420nm wavelength of ultraviolet radiation. NO_2 and O_3 form a photochemical equilibrium during the day [23]. In contrast, PM pollution is mostly caused by industrial regions and partially by fossil fuels used for heating [2, 23]. Exposure to NO_x was found to be associated with increased prevalence of respiratory symptoms, such as wheezing and shortness of breath; and respiratory mortality [25]; increased risk of asthma [24]; and exacerbation of a previously occurred respiratory disease [25, 26] increased prevalence of respiratory symptoms, such as wheezing and shortness of breath [27]. Therefore, the aim of the study was first to determine the concentration of PM_{10} and NO_X, and secondly to determine the effect of PM_{10} and NO_x air pollution on the worsening of asthma and COPD.

2. Method

2.1 Study population

A total of 402 participants are COPD and asthma patients diagnosed and registered in the two hospitals used for the research in Abuja Nigeria. Participants were contacted through the respiratory clinic/department of the hospitals. The procedures of data collection were previously described in detail [3]. In brief, we obtained data on demographic characteristics, and medical history, and measure lung function using Spirometry.

PM_{10} and NO_x data

The PM_{10} and NO_x and meteorological data monitoring were conducted at the Nigerian Meteorological Agency (NIMET) air monitoring station in Abuja.

2.2 Statistical analyses

To investigate the association of PM_{10} and NO_2 with COPD and asthma patients' conditions (FEV_1, FVC, and dyspnoea), descriptive epidemiological analysis was performed followed by correlation and multiple regression. Correlation and multiple regression were performed to evaluate the relationship between FEV_1 and FVC between PM_{10}, NO_2 concentrations, and meteorological conditions. Software: SPSS 27.0 was used to describe the air pollutants, meteorological factors, and the symptoms of COPD and asthma. The statistical significance of all analyses was set as $P< 0.05$.

3. Result

3.1 Characteristics of the CODA cohort participants

Four hundred and two (402) participants were recruited for this study (Fig. 1). The characteristics of the cohort give baseline information about the group. It shows information about lung function (FVC, and FEV_1), smoking, BMI, dyspnoea scale, age, height, weight percentage that have smoked, and demography. Table 1 illustrated some notable results, as the age of the participants indicates that they have developed the condition early, while FVC confirmed that the participants have the condition and FEV_1 the level of the severity. Also, Table 1 shows that the percentage of participants that smoked in this study was low. All data are presented as mean.

PM_{10} and NO_x Data

The pollutants (PM_{10} and NO_x) data were obtained to determine if the changes in the respiratory health condition of the participants had any association with the corresponding changes in the concentration of these pollutants in Abuja, Nigeria. Figure 1 below presents the average monthly PM_{10} and NO_x data.

Table 1. Baseline characteristics of the cohort

Variables	Male (157)	Female (245)
Age	51.9	50.7
Height	168.8	164.3
Weight	67	71.1
%Smoked	13.4	9.3
%FVC	45.6	48.5
%FEV1	25.4	28.8
MRC Dyspnoea scale	3.3	3.2
BMI	24.7	26.3

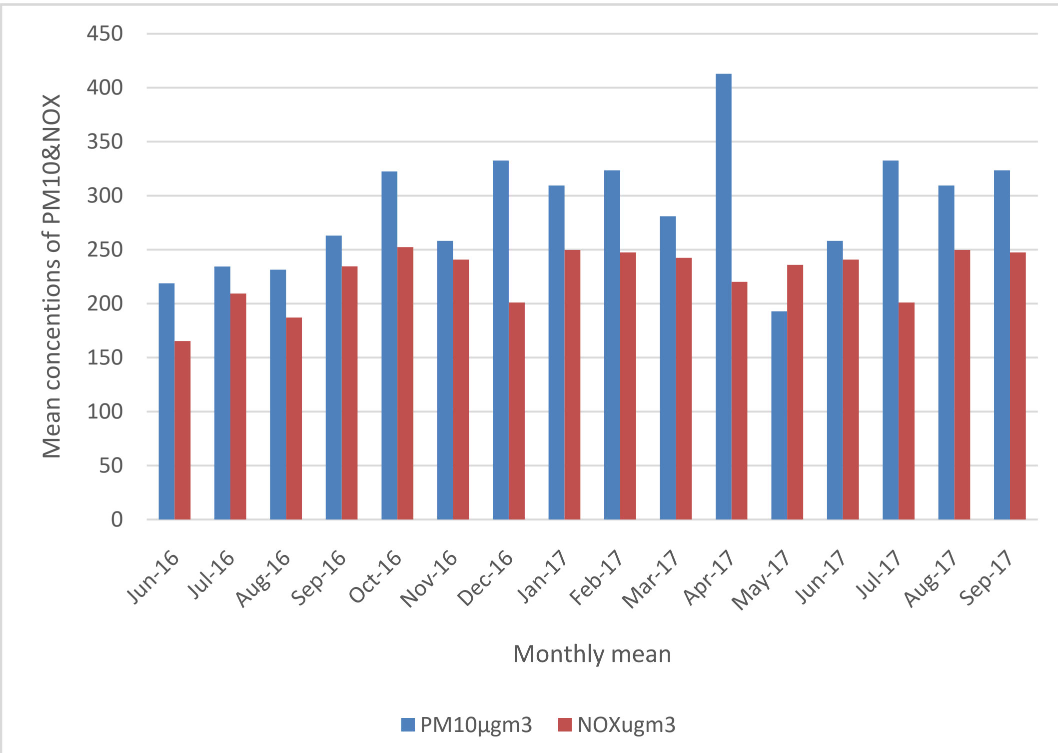

Figure 1. Monthly Mean of PM_{10} and NO_x Jun 2016-Sept 2017.

Figure 1 shows the average monthly variation of the pollutants (PM_{10} and NO_x) between June 2016 to September 2017. The figure above shows that in 2016 the highest concentration of PM_{10} was 332.6 in December followed by 322.5 in October and the lowest was 218.9 in June followed by 234.4 in July. While in 2017 the highest concentration was in April with 413.05 followed by 332.6 in July. However, the lowest concentration was 192.90 in May followed by 258.10 in June Whilst the NO_x highest concentration in 2016 was 252.40 in October followed by 240.80 in November and the lowest concentration was 165.40 in June followed by 187.10 in August. In 2017, NOx's highest concentration was 249.67 in January and August followed by 247.50 in February.

The chart above presents the weighted average concentrations of PM_{10} and NO_X in a 24-hour, 1-hour, and year duration for Abuja, Nigeria by the National Environmental Standard and Regulations Enforcement Agency (NESREA) and WHO global standard with the data obtained in this study. Comparing the data obtained during this study with WHO and NESREA, it was observed that obtained one-year PM_{10} was 3 times higher than NESREA and 12 times than WHO and a similar trend in 24 hours and one hour and with NO_x.

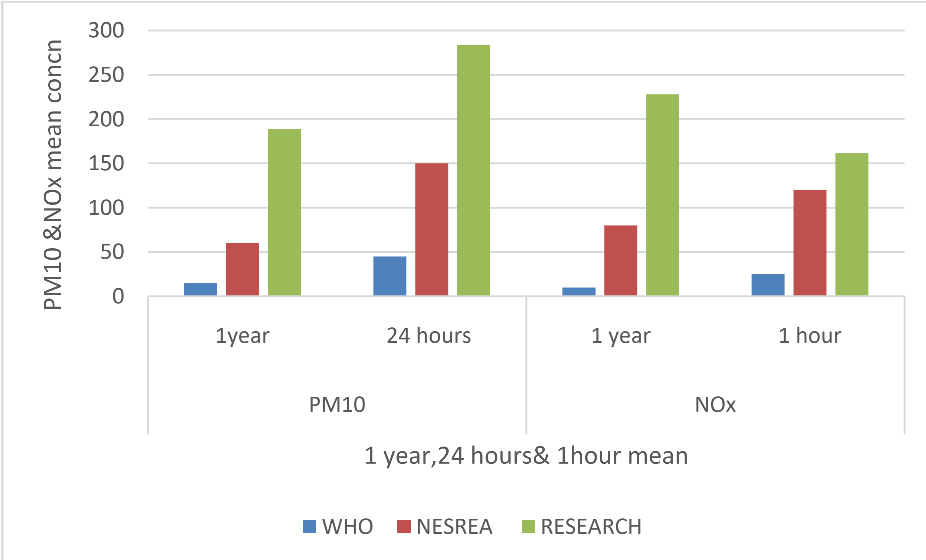

Figure 2. Chart of WHO, NESREA limit, and Research Data.

3.2 Association between PM_{10} and NO_x and lung function

The recruited participants were COPD and asthma patients that are diagnosed and registered in the two hospitals used for this study. Furthermore, 34.8% (140) of the participants are asthma patients and 65.2% (262) are COPD patients; 60.94% of the participants were females, and 39.05% were male. The reason for the higher proportion of females as compared to males may be that women are more likely to seek medical attention.

Also, the respiratory data was collected via the lung function test which was carried out to understand the participants' lung function as it relates to COPD and asthma symptoms. The monthly lung function data comprises FVC and FEV_1 of the 402 participants.

Table 2. Association between the pollutants and FVC and FEV_1

			FVC	FEV1
Spearman's rho	PM_{10}	Correlation Coefficient	-.582*	-.148
		Sig. (2-tailed)	.018	.584
		N	16	16

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2 illustrates a strong negative statistically significant correlation between PM_{10} and FVC (-.582, P=.018), indicating that as PM_{10} increases, FVC decreases.

Association between the pollutants and dyspnoea

Table 3. Correlations between PM_{10} and NO_X and dyspnoeascale

			PM_{10}	NO_X	Dyspnoea
Spearman's rho	PM_{10}	Correlation Coefficient	1.000	.246	.786**
		Sig. (2-tailed)	.	.359	.000
		N	16	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3 presents the correlation between PM_{10} and dyspnoea. The outcome of the analysis indicates that the correlation between PM_{10} and dyspnoea was a strong positive and statistically significant p=.000.

Association between the PM_{10} FVC, $FEV_{1,}$ and Dyspnoea by gender.

Table 4. Correlation between the PM_{10} FVC, $FEV_{1,}$ and Dyspnoea by gender

			Male FVC	Female FVC	Female FEV_1	Male FEV_1	Dyspnoea Male	Dyspnoea Female
Spearman's rho	PM_{10}	Correlation Coefficient	-.430	-.578*	-.757**	-.759	.706**	.765**
		Sig. (2-tailed)	.096	.019	.001	.001	.002	.001

The Table above illustrates the correlation between PM_{10}, NO_X, and male and female FVC and FEV1. The outcome of the analysis indicates that the correlation between PM10 and FVC and FEV1 was a strong negative statistically significant correlation and stronger in females. Whilst the analysis showed a stronger correlation between PM_{10} and male and female dyspnoea. The above outcome of the correlation analysis apparently showed that an increase in correlation strength was observed.

3.3 Multiple Regression

Multiple regression was conducted to investigate whether the air pollutants (PM_{10}, $NO_{X,}$) and meteorological factors (temperature, wind, and relative humidity) can predict FVC, FEV_1, and dyspnoea. The result of the regression indicated that the model explained 85.4% of the variance and that the model was a significant predictor of FVC, $F(5,10) = 11.68$, $p=.001$; 85.9% of the variance, and that the model was a significant predictor of $FEV_{1,}$ $F(5,10) = 12.21$, $p=.001$, 75.4% of dyspnoea $F(5,10) =6.14$, $p=.007$. PM_{10} and temperature were statistically significant predictors of the effect of the pollutant and meteorological factors on respiratory conditions, while $NO_{X,}$ temperature, humidity, and wind were not significant predictors of the effect. The effect on COPD and asthma were statistically dependent on the type of pollutants and meteorological conditions in Abuja, Nigeria.

4. Discussion

In this study PM_{10} and NO_x, data collected for the period of sixteen months were used to examine the pollutants' effect on corresponding data collected from COPD and asthma patients (dyspnoea scale scores, $FEV_{1,}$ and FVC). In this study, the pollutants' concentrations were higher than the WHO and NESREA standards Figure 2. The PM_{10} increase was significantly associated with decreased FEV_1 and FVC in the participants. For NO_x, there was a weak significant association with FVC. The 24-hour mean of PM_{10} in the study was 296.7µg/m^3, and the NO_2 1-hour mean was 253.1µg/m^3, which are both higher than the WHO guidelines and data from studies from different cities in China [28]. A high concentration of the pollutants was associated with decreased lung function. From the outcome of the analysis, there was an association between PM_{10} and $NO_{x,}$ with increased breathlessness associated with increasing PM_{10} concentrations (.786, P=.000). This finding was similar to some studies that examined the effect of outdoor PM_{10} and NO_x on lung function and breathlessness in respiratory diseases, such as asthma and COPD, in adults [4, 29].

There have been some studies on the worsening of respiratory symptoms in patients with respiratory disease [3, 11, 30]. However, there have not been any studies on the effects of PM_{10} and NO_x on respiratory disease (COPD and asthma) in Abuja, Nigeria at the time this study was conducted. Examining PM_{10} and NO_x effects on lung function was one of the main study objectives. A statistically significant association was observed between PM_{10} and FVC (-582, P= .018). PM_{10} and NO_x have shown to have a varied effect on lung function as observed in this study FVC and FEV1 decreased as PM_{10} and NO_x concentrations increased. Thus, the results of this study demonstrated that PM_{10} and NO_x had an adverse effect on COPD and asthma patients. Similar studies observed an adverse association between PM_{10}, $NO_{x,}$ and respiratory symptoms [11, 29, 30]. The evidence of the effect of the pollutants on COPD and asthma patients was clear in this study and similar to the findings of a study conducted by Weinmayr and colleagues on the occurrence of asthmatic symptoms [31].

NO_x is an oxidising agent and has been documented to cause damage to the tissues of the lungs [32, 30]. NO_x contributes to the formation of O_3 and PM which are linked with an adverse effect on COPD and asthma [33, 34]. As observed in this study, there were few significant effects of NO_x on the FVC and $FEV_{1,}$ unlike PM_{10} which had a substantial significant effect. As highlighted in a study conducted in 2001 that though some authors found a positive association with NO_x, most epidemiological studies found no association between respiratory function and $NO_{x.}$ However, in this study, a weak association between NO_x and $FEV_{1,}$ and FVC was observed [35]. Other authors that observed an association stated that it is likely that the association, if any, was weaker than other pollutants, such as PM_{10} and O_3. In some studies, NO_x is a substitute as a surrogate for pollutants, such as O_3 whose concentrations strongly match NO_2 [34-37]. The general problem in studies that observed an association with FVC and $FEV_{1,}$ when examining the effect of NO_x was that they fail to show whether the effect was independent of other pollutants and that was why multiple regression was included in the analysis. This is also a problem in this study and caused by the lack of monitoring equipment and maintenance; for example, there was no O_3 monitor when this research began. Nevertheless, studies such as [38] found an association between higher concentrations of NO_x and COPD exacerbation, which is similar to the findings of this study, that an increased concentration of NO_x was associated with decreased FVC and FEV_1. Also, [39] highlighted that there was a significant association between decreased FVC and FEV1 with a high concentration of NO_x.

The findings result observed in this study demonstrated that PM_{10} had a substantial adverse effect on COPD and asthma patients FVC and FEV_1 Table 2. The finding from this study was similar to the findings from other studies which confirm that particulate pollutants can be critical in affecting COPD [29, 31]. Other studies also found an association between the concentration of PM_{10} and the worsening of asthma and COPD patients FVC and FEV_1, they observed a reduction in lung function (FVC and FEV) because of exposure. The authors also found that, in Kuwait, PM_{10} had a significant association with asthma and other lower respiratory disease, thus findings from the above studies provide evidence of the health effects of PM_{10} in developing and developed countries [2, 9, 12, 18]. Thus, the effect of PM_{10} as observed in this study decreased FVC and FEV_1 and increased symptoms such as dyspnoea (Table 3) in COPD and asthma patients' conditions are similar to [3, 31, 37].

Other studies that observed similar outcome includes: [31] found strong evidence of PM_{10} as an aggravating asthma symptom Their meta-analysis presented a strong effect of PM_{10} on cough and symptoms of asthma. However, a Swiss study on air pollution and lung disease in adults, including approximately 10,000 Swiss adults, showed that an increase of 10µg/m3 of PM_{10} was linked with a 3.4% FVC decrease [40]. Equally, previous-day outdoor PM_{10} high concentration was linked with a 20.1mL FEV_1 decrease and a 30.6mL decrease for NO_2 in non-smoking adults. Rice et al. [41] concluded that the pollutants were associated with decreased lung function in an adult cohort. Annual exposure to a high concentration of PM_{10} was associated with decreased FEV_1 and a faster rate of lung function decrease. The association of NO_x with FVC was similar to that of PM_{10} in this study. [41] concluded that long-term exposure to PM_{10} and traffic at relatively low concentrations were associated with decreased FEV_1 and FVC. However, some studies found associated PM_{10}, and NO_x long- and short-term exposure increased respiratory symptoms and decreased lung function [3, 29, 41, 42, & 43].

Over the years, COPD was thought to be a disease affecting mainly the elderly indicating high smoking prevalence in men. Meanwhile, asthma was considered to be predominantly a respiratory disease of childhood due to narrowed airways. However, now COPD is more recognised in women, and the increased disease and death from COPD in the last few decades has been especially pronounced in women [43-45]. In this study, the effect of PM_{10} and NO_x was observed to a greater extent in females than in males Table 4, despite the young age of the disease onset and the low number of smoking exposures among participants Table 1. Similar to the findings of this study, a study in China observed that increase in PM_{10} concentration had a positive association in female participants and decreased [45]. [46]. It was observed by Bell and colleagues that women experiencing an increase in the concentration of pollutants had increased mortality, slightly higher than the estimate for men [46]. Other studies observed that women are at greater risk of the effect of pollutants such as PM_{10} and NO_x [3, 47, 48]. In contrast, a study on gender, after adjusting for acute exposure and other potential confounders, showed a significant association among both men and women [49]. However, the evidence of higher associations in women than in men is limited. In this study, gender differences in decreased lung function were associated with increased exposure to outdoor air pollution in the female population with COPD and asthma.

5. Conclusion

In conclusion, this study evaluated the effect of PM_{10} and NO_X on COPD and asthma patients in Abuja using a 402-adult cohort. Effects on Lung function and dyspnoea were determined using the MRC dyspnoea scale and Spiro bank basic II and outdoor concentrations of PM_{10} and NO_X were monitored for 16 months by NIMET.

The findings from this study showed that high concentrations of PM_{10} and NO_X increase dyspnoea (breathlessness) and decreased FVC and FEV_1. Therefore, demonstrating an adverse effect of PM_{10} and NO_x on lung function (FVC and FEV_1) and symptoms for patients suffering from COPD and asthma in Abuja.

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7. Authors' contributions

C.I conducted the research and wrote the manuscript with the support and supervision of J.L and J.M. J.L and J.M. and J.F., read the drafted manuscript. All authors discussed the results and commented on the manuscript.

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