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PARTICULATE EXPOSURE AND RISK FACTORS FOR RESPIRATORY SYMPTOMS AMONG TERTIARY INSTITUTION STUDENTS

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Background: Ambient and indoor air quality have important health impacts and are primarily determined by the concentration of pollutants in the environment. Particulate matter (PM) is a mixture of solid and liquid particles suspended in the air and occurs in a variety of sizes, shapes, origins, and compositions. Understanding particulate matter levels and their health effects in microenvironments such as educational institutions is key for implementing targeted actions against exposure to this recognized environmental hazard. **Objectives:** This study aimed to assess the concentrations of particulates and examine the reported risk factors associated with respiratory symptoms among students in a higher institution, in Benin City, Nigeria. **Methods:** Indoor and outdoor particulate matter ($PM_{2.5}$ and PM_{10}) concentrations were measured for three months via a handheld portable air monitoring device. A cross-sectional survey was conducted using 330 modified respiratory symptom questionnaires (RSQs) to assess respiratory symptoms within the same period. Descriptive (mean, SD) and inferential (ANOVA, chi-square, logistic regression) analyses were performed using SPSS v22.0. Model fitness was confirmed (VIF = 1.12, HL test, $p < 0.05$), and adjusted odds ratios (aORs) were used to interpret associations. **Results:** The mean ranges of the $PM_{2.5}$ and PM_{10} concentrations throughout the sampling sites were 43.7 ± 2.8 – 52.2 ± 5.0 μg/m^3 and 56.6 ± 4.1 – 69.8 ± 6.9 μg/m^3, respectively. The level of particulates was above the recommended WHO air quality guidelines at all the sampling locations. The calculated indoor and outdoor ratios were greater than 1 for the $PM_{2.5}$ and less than 1 for the PM_{10} in most of the sampling sites. There was no clear association between increased concentrations of PM and respiratory symptoms, but a tendency to increase the risk of shortness of breath (adjusted odds ratios = 1.77; Cl = 1.042 – 3.021), wheezing (aOR = 1.56; Cl = 0.002 – 10.187) and chest tightness (aOR = 1.40; Cl = 0.001 – 84.446) among respondents. Gender (aOR = 2.12; Cl = 1.118 – 4.03) smoking status (aOR = 3.70; Cl = 1.19 – 6.91) and the presence of visible moulds in the classroom (aOR = 1.77; Cl = 1.042 – 3.021) were significant independent predictors of reported shortness of breath, wheezing and chest tightness among the respondents. **Conclusion:** The study found that the indoor and outdoor concentrations of particulates at all the sampling sites were higher than the prescribed WHO air quality standards, suggesting that the health of the exposed students is at risk. Although a positive association was found between elevated particulate matter concentrations and respiratory symptoms reported by respondents, this relationship was not statistically significant. The current study revealed that only sex, smoking status and the presence of visible moulds in classrooms were independent determining risk factors for reported respiratory symptoms among the students.

Keywords: particulate matter; respiratory symptoms; risk factors; behavioural characteristics; higher institution.

INTRODUCTION

The school serves as a major indoor and outdoor environment; hence, a critical part of exposure to air pollution could occur in school (Kanchanasuta et al., 2020). Studies related to indoor and outdoor air quality are crucial to understanding the effects of air pollution on the health and performance of students (Toyinbo et al., 2016). Air pollution is one of the leading determinants of mortality and morbidity in humans worldwide (Gordon et al., 2014). Ambient and indoor air have important implications for health and are mainly determined by the concentrations of pollutants in the environment (Godwin & Batterman, 2007). PM is an established air pollutant largely linked to a high potential risk to human health (Osimobi & Nwankwo, 2018). PM is a mixture of solid and liquid particles suspended in the air, and it occurs in different sizes, shapes, origins, and compositions (PHE, 2018). Exposure to airborne particulates has been associated with a wide range of negative health outcomes, such as increased risk of lung and heart-related illnesses, including coughing, running nose, difficulty in breathing, and wheezing, caused by oxidative stress and inflammation (Kim et al., 2005; Lin et al., 2015; Viegi et al., 2020; Tran et al., 2020). Respiratory symptoms can persist for short periods of acute respiratory infections (ARIs) or can persist for relatively long periods of chronic respiratory disease (CRD) and can impact socioeconomic status, including poor performance of students at school. Generally, the prevalence of respiratory symptoms, especially in developing countries, is reported to increase as the number of deaths from chronic respiratory diseases increases by 39.8% and 28.5%, respectively, from 1990 to 2019 (Global Burden of Disease, 2018). Major sources of airborne particulates in and around school environments include the infiltration of outdoor sources such as emissions from nearby car parks, the burning of wastes on school premises (Leung, 2015; Shrestha et al., 2019; Becerra et al., 2020), cleaning materials, chalk particles, chalk dust and the resuspension of previously agitated floor dust (Hailu et al., 2023). Other factors reportedly influencing air pollution concentrations in and around school environments include the proximity of classrooms to nearby roads (Alzuhairi, et al., 2016). vehicle drop-offs and idling (Adams & Requia, 2017), and meteorological conditions (Boniardi et al., 2019). On-site assessment of the classrooms across the university under study revealed that they are naturally ventilated. Mechanical ventilation systems such as ceiling fans are barely functional due to the epileptic power supply, which contributes to poor air quality in these classrooms, which are usually crowded. The indoor air quality in classrooms can be improved through natural ventilation, resulting in less dependence on energy sources from mechanical ventilation systems. On the other hand, overdependence on the opening of windows and doors as a means of ventilation has been reported to be challenging because the increased infiltration of air decreases the level of carbon monoxide but increases the level of other criteria gaseous air pollutants (Zhang & Zhu, 2011). It is therefore important to create a suitable mitigation strategy for air pollution in naturally ventilated classrooms to prevent the increasing trend in air pollution-related health effects among students (Rawat & Kumar, 2022). Individual lifestyle factors such as smoking and housing (hostel) characteristics and the type of cooking fuel have been linked to an increased risk of respiratory symptoms in previous studies (Gordon et al., 2014; Eghomwanre & Oguntoke, 2022;). Hence, this study considered various self-reported factors within the school and in the student hostels that could predispose them to respiratory symptoms. In many developing countries such as Nigeria, national or state programmes aimed at improving the air quality in schools are non-existent. Additionally, there is no standard protocol available for air quality assessment in developing countries. Scientific knowledge of air quality in school buildings is essential for developing control strategies for mitigating air quality issues. The 24-hour averages, according to WHO guidelines for outdoor and indoor air quality for $PM_{2.5}$ and PM_{10}, are 5 μg/m^3 and 25 μg/m^3, respectively (WHO, 2021). However, these guidelines do not guarantee the protection of exposed individuals, especially those with underlying illness (Gilbert et al., 2019). At present, only a few studies have been conducted on indoor and outdoor air quality in educational settings, especially in higher education institutions in Nigeria (Osimobi et al., 2019; Abulude et al., 2022). These studies have shown that the particulate concentrations in classrooms are above the air quality standards. Nonetheless, the above studies investigated only the particulate matter concentrations in schools and did not consider the associations between reported environmental and individual risk factors associated with respiratory symptoms among students. The quantitative method, by utilising low-cost hand-held monitors for particulate matter measurements, was used to determine the level of particulates inside and outside the classrooms. In addition, since students are also exposed to air pollution from hostels and other locations within the school environment, it is unrealistic to consider the direct impact of particulate exposure on their respiratory health. Hence, it is necessary to predict the risk of respiratory outcomes among exposed university students using logistic regression analysis with explanatory and outcome variables from a questionnaire survey. This study was conducted to determine the concentration of particulate matter (PM) in and around the institution's classrooms and to evaluation the relationship between self-reported student behaviour, housing-related risk factors, and the occurrence of respiratory symptoms in the institution's students.

MATERIALS AND METHODS

Study area

In this study, particulate matter ($PM_{2.5}$ and PM_{10}) pollutant levels were measured in various indoor and outdoor environments at a tertiary institution in Benin city, Nigeria. The school is located in the Ovia local government area of the city, with an area of approximately 500 km^2, along a major expressway an route to Lagos, Nigeria. The buildings where the classrooms were selected as the sampling sites for indoor and outdoor air monitoring are shown in Figure 1.

The campus is one of the oldest in the country and has several faculties, including Arts, Social Sciences, Medical Sciences, Law, Agriculture, Education, Engineering, Life Sciences, Environmental Sciences, and Physical Sciences. The university has approximately 74,000 active registered students (from November 2023 data). Generally, classrooms depend predominantly on open ventilation with the use of windows and doors. The electricity supply is irregular, and most mechanical ventilators are not functional in classrooms. The classrooms are often congested when the number of students exceeds the number recommended per class by the National University Commission due to the lack of buildings available to accommodate the increasing student population.

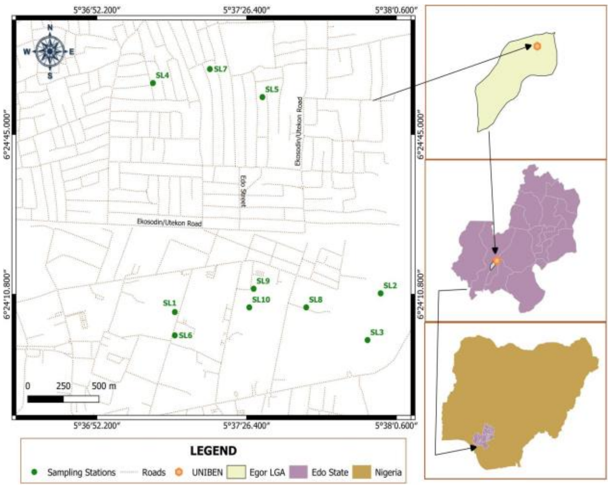

Figure 1. Map of study area showing the sampling sites

The classrooms are all close to roads and car parks within the school, which normally experience high traffic due to the increased number of vehicles accessing the school. The use of gasoline-powered generator sets near classrooms and nearby offices also contributes to pollution sources in the school environment. Ten buildings and 30 classrooms, three classrooms per faculty, were randomly selected across the university for this study. The Air quality measurements and questionnaire survey was done on a weekly basis over a period of six months from January to March 2023.

Measurement of air quality parameters

The particulate matter levels were measured using a BR- Smart-126S hand-held meter. The meter is a portable real-time air quality monitoring device built with a high-precision sensor chip. Air pollutants are monitored via a light scattering mechanism, and atmospheric particulate concentrations are converted into visual data. The meter has a precision range of 0 – 999 μg/m^3 with a resolution of 1.0 μg/m^3. The calibration of the samples was performed before and after each sampling activity in line with the manufacturer's instructions to ensure that the collected data were reliable and met the objectives of the study. At each site, several measurements were taken before the exact readings were recorded to ensure high-quality data. The meter was placed 2 m above ground level inside and outside the school building to ensure that the readings were not influenced by fugitive dust. The measurements were performed daily (24 hours) in triplicate for three months across the thirty selected classrooms. The data obtained were cleaned for outliers, and the average particulate concentrations were determined and then compared with the WHO 24-hour air quality standard.

Questionnaire survey

To determine the percentage of reported respiratory symptoms among the students, a well-structured questionnaire was administered to the students of the selected faculties. The sample size of three hundred thirty questionnaires (330) was determined using the Kasiulevicius formula (Kasiulevicius et al., 2006) based on the prevalence rate of respiratory symptoms of 31.14% in a previous study according to Hailu et al. (2023). A total of three hundred and thirty-one modified respiratory symptom questionnaires (RSQs) were administered to the students, and the questionnaires were completed during interviews with them by the researchers. Informed consent was obtained from the Deans of the faculties and students before the survey commenced. The questionnaire was divided into four sections, namely, A, sociodemographic; B, respiratory symptoms, which comprises four validated questions: "In the past 4 weeks, have you had shortness of breath", "Have you had wheezing", "have you had a cough", and "have you had chest tightness during the day", to assess the frequency of respiratory symptoms and their impact on exposed individuals. C: behavioural characteristics of respondents and D: school environmental factors.

Inclusion and exclusion criteria

Students who were currently in year two and above indicating that they had been in the institution for more than a year were included in the survey, whereas students who were in a year and direct entry students, including those who had a history of asthma, tuberculosis, chest or respiratory disorders or who were previously diagnosed by a physician, were excluded since they could bias the results.

Statistical analysis

The air quality data obtained were subjected to descriptive (mean, standard deviation) and inferential (analysis of variance) statistical analyses using SPSS for Windows version 22.0. The questionnaire data are represented as frequencies and percentages, while the relationships between the reported behavioural and school environment characteristics and respiratory symptoms among the respondents were determined using the χ-square test of significance and a logistic regression model. The data were subjected to the multicollinearity test to determine the variance inflation factor (VIF) and the Hoshmer–Lemeshow (HL) test and to check the model fitness for the datasets obtained (Hosmer & Hjort, 2002). It was found that the model was fit (VIF = 1.12, HL-goodness of fit; $p < 0.05$). In the model, self-reported respiratory symptoms (shortness of breath, chest tightness, cough, and wheezing in the past month) were the dependent variable (y), while individual and environmental factors were the explanatory variables (x). After adjusting the model for possible confounding factors, the odds were expressed as adjusted odds ratios (aORs). A value of $p < 0.05$ was considered to indicate statistical significance.

RESULTS AND DISCUSSION

Concentrations of particulates at the sampling sites

In this study, the concentrations of particulates of aerodynamic sizes 2.5 and 10 were determined inside and outside the selected classrooms of a university environment in Benin City, Nigeria. The concentrations and ratios of indoor and outdoor particulates are presented in Table 1. The mean concentrations of indoor $PM_{2.5}$ ranged between 43.7 ± 2.8 and 52.2 ± 5.0 $\mu g/m^3$. Throughout the sampling regime, the maximum indoor $PM_{2.5}$ concentration (52.2 $\mu g/m^3$) was measured at the Faculty of Arts, while the minimum $PM_{2.5}$ concentration (43.7 $\mu g/m^3$) was measured at the Faculty of Physical Sciences. Moreover, the obtained indoor concentrations of PM_{10} ranged from 56.6 ± 4.1 to 69.8 ± 6.9 $\mu g/m^3$, with the highest concentrations recorded in classrooms from the Faculty of Arts, while the lowest level of PM_{10} was detected in the classrooms at the Faculty of Physical Sciences. The increased level of particulates in the indoor classrooms of the sampling sites could be attributed to the level of activity in the classrooms resulting from the high number of students taking lectures in the classrooms at the time of sampling. This finding can also be explained by the infiltration of particulates from outdoor pollution sources, including emissions from vehicles at the drop-off zones near the classrooms, which are common sites across the faculties in the institution. The school authorities should develop alternative routes and drop-off zones far away from the classrooms to avoid emissions from vehicles near classrooms. There have been few investigations on indoor particulate matter concentrations in Nigerian universities. Some studies, such as (Osimobi et al., 2019; Abulude et al., 2022; Abulude et al., 2023), reported higher concentrations of indoor particulates in classrooms than did the present study. The increased level of indoor particulates was due to the variability in the sampling periods and study areas. The concentrations of indoor particulates obtained in this study were also slightly lower than the average indoor concentrations of $PM_{2.5}$ reported by (Bhat et al., 2022; Babaoglu et al., 2022) in different indoor environments at a university campus in Turkey. This was because the measurements obtained from the cafeteria areas of the university are prone to smoke and other heating activities known to generate particulates but were not part of the sampling areas in the present study.

The concentrations of particulates obtained in the outdoor environment at the schools ranged from 40.9 ± 4.1 – 48.6 ± 4.1 $\mu g/m^3$ ($PM_{2.5}$) to 56.6 ± 4.1 – 69.8 ± 6.9 $\mu g/m^3$ (PM_{10}). The maximum outdoor levels of $PM_{2.5}$ were recorded at the Faculty of Social Sciences, but the lowest was observed at the Faculty of Education. At the same time, the maximum concentrations of PM_{10} fractions were obtained at the Faculty of Agriculture, while the minimum concentrations of PM_{10} were recorded in the outdoor areas of the Faculty of Social Sciences. The variations in the levels of outdoor particulates across the sampling sites could be explained by the varying pollution sources at the various sampling locations (Babaoglu et al., 2022). The levels of particulates obtained in this study were higher than the World Health Organisation indoor and outdoor air quality standard guidelines. The concentrations of indoor and outdoor $PM_{2.5}$ and PM_{10} were 3.0 and 1.5 times greater, respectively, than the WHO (2022) standard. Several epidemiological studies have shown that exposure to high concentrations of coarse and fine particulates could pose serious health threats, such as asthma and respiratory health problems (Fromme et al., 2008; Paterson et al., 2021; Eghomwanre et al., 2022).

Indoor and outdoor particulate matter ratio

The quality of air in the indoor environment is most often evaluated using the indoor/outdoor ratio (I/O ratio) (Bhat et al..2022). The I/O ratios were obtained by using the average indoor and outdoor concentrations of PM from the sampling locations (Table 1). The I/O ratios for $PM_{2.5}$ from the Faculties of Arts, Social Sciences, Law, Engineering and Environmental Science were greater than 1. The high indoor concentrations of $PM_{2.5}$ in most of the classrooms across the faculty revealed that there were indoor sources of $PM_{2.5}$ in these classrooms. The I/O ratio of $PM_{2.5}$ in the faculty of education was 1, indicating an equilibrium state where the indoor and outdoor concentrations of $PM_{2.5}$ were relatively the same.

In the classrooms located in the Faculties of Medical Sciences, Agriculture and Life Sciences and Physical Sciences, the I/O ratios were less than 1 (Table 1). This can be explained by the ambient air pollution sources, including emissions from the traffic of cars within the school, predominant gasoline-powered generator sets for power in the corridors or behind the classrooms during lecture hours, and the movement of students within the campus. In the case of PM_{10}, the indoor and outdoor ratios were lower than 1 at the Faculty of Medical Sciences, Law, Agriculture, Life Sciences, Physical Sciences, Engineering and Environmental Sciences. They showed that there were more sources of PM_{10} outdoors, except in the classrooms at Arts, Social Sciences and Education, where the I/O ratios exceeded 1. In the present study, the I/O ratios for

PM2.5 and PM10 ranged between 0.92 and 1.13 and between 0.93 and 1.21, respectively. This finding is similar to the reports of several authors who reported I/O ratios between 0.8 and 1.12 in different indoor and outdoor environments (Chen & Zhao, 2011; Singrakphon et al., 2024).

Sociodemographic, behavioural and building characteristics

The sociodemographic characteristics of the respondents considered in the present study included age and gender, while the perceived individual and environmental risk factors were the number of occupants in hostels, current smoking status, presence of ventilators in classrooms, presence of mould in classrooms, type of fuel used for cooking and location of the kitchen in hostels. These were important parameters for assessing the respiratory health of the respondents in the study area. The frequency distribution of the variables is presented in Table 2. The mean age of the respondents was 20.8 ± 2.5 years, with a range of 19 years. There are 50% of female and male students in the sample population. In the present study, the percentage of students occupying a room in the hostel was highest for less than one to two persons (58.5%), followed by three to five persons (25.8%), while the percentage of respondents who were between 2 and 3 in a room was 15.8%. Of the 330 respondents, 30 (9.1%) were current smokers. Two hundred thirty-three participants had ventilators in their classrooms. Approximately 75% of the respondents reported that there was mould in their classrooms. of occupants in a room in the hostels were three hundred and thirty students who participated in the survey. The percentages of respondents who utilised firewood, charcoal, kerosene, natural gas and light for cooking were 0.3%, 1.9%, 19.4%, 16.8% and 61.8%, respectively. Ninety-seven of the 330 respondents cooked inside the rooms in their hostels.

Table 1. Concentrations of the measured particulates at all sampling points

Sampling points	PM2.5, μg/m^3		Indoor/Outdoor ratio	PM10, μg/m^3		Indoor/Outdoor ratio
	Indoor	Outdoor		Indoor	Outdoor	
Arts	52.2 ± 5.0	46.0 ± 4.7	1.13	69.8 ± 6.9	57.7 ± 6.7	1.21
Social sciences	46.0 ± 3.4	40.9 ± 4.1	1.12	60.2 ± 4.8	57.0 ± 5.5	1.06
Medical sciences	43.8 ± 2.9	47.5 ± 4.1	0.92	57.1 ± 3.9	61.4 ± 5.0	0.93
Law	46.8 ± 3.7	45.9 ± 3.8	1.02	60.1 ± 4.9	60.8 ± 5.1	0.99
Agriculture	46.9 ± 4.0	47.5 ± 4.0	0.99	61.3 ± 5.4	62.2 ± 5.4	0.99
Education	48.7 ± 4.3	48.6 ± 4.1	1.00	63.1 ± 5.8	61.9 ± 5.3	1.02
Life sciences	45.2 ± 3.3	46.0 ± 3.6	0.98	58.4 ± 4.5	60.2 ± 5.0	0.97
Physical sciences	43.7 ± 2.8	45.7 ± 2.9	0.96	56.6 ± 4.1	57.3 ± 4.4	0.99
Engineering	44.9 ± 3.5	43.7 ± 3.2	1.03	57.4 ± 4.8	58.3 ± 4.5	0.98
Environmental science	44.8 ± 3.5	44.7 ± 3.6	1.00	57.8 ± 4.8	59.2 ± 4.8	0.98
WHO, 2021	**15**			**45**		

Table 2. Sociodemographic, personal and environmental variables (n = 330)

Variables	Frequency, n	Percentage, %	Variables	Frequency, n	Percentage, %
Current age			**Presence of mould in classrooms**		
Mean ± SD	20.8 ± 2.5	50.0	Yes	83	74.8
Range	19.0	36.3	No	247	25.2
Gender			**Fuel type used in hostels**		
Male	165	50.0	Electrical	204	61.8
Female	165	50.0	Natural gas	55	16.7
Number of occupants			Kerosene	64	19.4
1 – 2 persons	193	58.5	Charcoal	6	1.8
2 – 3 persons	52	15.8	Firewood	1	0.3
3 – 5 persons	85	25.8	**Location of kitchen in hostels**		
Current smoking status			Outside	233	70.6
Yes	30	9.1	Inside	97	28.4
No	300	90.9			
Presence of ventilator					
Yes	233	70.5			
No	97	29.4			

Occurrence of reported respiratory symptoms

Table 3 shows the percentage of reported respiratory symptoms among the 330 respondents. Shortness of breath, wheezing, cough and chest tightness were 16.1%, 17.6%, 49.7% and 16.7%, respectively. This finding was lower than that reported by (Hailu et al., 2023) but higher than that reported by (Erhabor et al., 2016). The variation in the prevalence of respiratory symptoms could be due to the differences in sample size (n = 822 and n = 2750), the inclusion of teachers and other staff members in their survey and variations in the procedures of data collection and reporting. Other explanations for the inconsistencies in the occurrence of respiratory symptoms among different studies could be variations in ventilation systems, writing materials on the board, proximity of classrooms to outdoor pollution sources, building materials for the construction of schools and the population of students in classrooms (Ojukwu et al., 2020). The prevalence of respiratory symptoms among students in the present study is similar to that reported in studies conducted in India (Vaidya et al., 2007; Jayachandran, 2019).

Table 3. Occurrence of self-reported respiratory health symptoms

Respiratory symptoms	Frequency, n	Percentage, %	Respiratory symptoms	Frequency, n	Percentage, %
Shortness of breath			**Cough**		
Yes	53	16.1	Yes	164	49.7
No	277	83.9	No	166	50.3
Wheezing			**Chest tightness**		
Yes	58	17.6	Yes	55	16.7
No	272	82.4	No	275	83.3

Associations between self-reported variables and respiratory health symptoms

There was a significant difference in the occurrence of shortness of breath (11.5, 20.6%, $p = 0.025$) and chest tightness (16.0, 23.6%, $p = 0.001$) among the male and female students, respectively, indicating that the occurrence of shortness of breath and chest tightness was significantly greater among female students than among male students (Table 4). The risk of respiratory effects diminishes in males but increases in females, particularly at puberty. This transition period is often characterised by an increased risk of respiratory symptoms such as continuous wheezing in females (Sekerel, 2006). This finding is similar to the reports of (Vrijlandt et al., 2005; Tollefsen et al., 2007; Groeneveld, et al., 2019). The occurrence of wheezing and chest tightness among the students who smoked (23.3, 33.3%) was significantly ($p = 0.017$) greater than that among the nonsmokers (15.3, 15.0%). This finding is similar to the results of several studies that reported a greater incidence of chronic respiratory symptoms among current adolescent smokers (Saracen et al., 2017; Sargent et al., 2022; Eghomwanre & Oguntoke, 2022; Hailu et al., 2023). The presence of mould in classrooms was significantly associated with cough ($p = 0.026$) among respondents. A greater percentage of the respondents who took lectures in classrooms with visible moulds had coughs (60.2%) than did those who studied in classrooms without moulds (46.2%). Several authors have reported significant associations between exposure to mould in classrooms and respiratory symptoms in students (Borràs-Santos et al, 2013; Toyinbo, 2018). The occurrence of cough and chest tightness was greater among respondents who cooked inside the room in hostels (50.5, 18.6%) than among those who cooked outside (49.5, 15.9%). However, the association was not statistically significant ($p = 0.848, 0.552$).

Multivariate logistic regression for independent risk factors for respiratory health symptoms

To determine the independent risk predictors for respiratory health effects among the exposed students, a multivariate regression analysis was performed with the reported individual and building characteristics, such as gender, smoking status, and presence of mould in classrooms, as the predicting or explanatory variables, while the reported respiratory symptoms were the outcome variables. Table 5 shows the results of the multivariate regression analysis. The model revealed that gender was a significant independent predictor of shortness of breath among the exposed students. After adjusting the model, the female students were two times more likely to experience shortness of breath (aOR = 2.12; Cl = 1.11 – 4.03) and three times more likely to experience chest tightness (aOR = 3.70; Cl = 1.85 – 7.37) than their male counterparts were. This could be explained from the perspective of the age range (19 years) of the respondents in this study. Tollefsen et al. (2017) suggested that compared to girls, fewer boys develop respiratory symptoms during adolescence. This could be due to increasing awareness and sensitivity to their bodies and willingness to accept a disease status among girls and women during this period of development (Tollefsen et al., 2017). Additionally, the growth of airways is proportional to the growth of lung parenchyma, whereas, in boys, there is a lag between the growth of airways and lung parenchyma, resulting in a discrepancy between airway and lung sizes in both sexes (Boezen et al., 2004). The model also revealed that smoking among students resulted in a twofold increase in the odds of experiencing wheezing (aOR = 2.87; Cl = 1.51 – 9.10) and a threefold increase in the odds of experiencing chest tightness (aOR = 3.70; Cl = 1.19 – 6.91) among students compared to nonsmokers. This association was statistically significant ($p = 0.019, 0.004$). This indicates that active smoking is a significant contributor to poor indoor air quality and significantly increases wheezing among the respondents, even though only 9.1% of the 330 respondents were smokers. This study confirms several reports that smoking increases the risk of respiratory outcomes in young people (USDHHS., 2014; Chen et al., 2018). It has since been reported that adolescents who engage in regular smoking manifest increased symptoms and reduced lung function within a few years after initiation (Hailu et al., 2023).

The study also revealed that exposure to increased concentrations of indoor $PM_{2.5}$ resulted in a sixfold and approximately twofold increase in the odds of experiencing shortness of breath (aOR = 6.05; Cl = 0.01 – 36.059) and cough (aOR = 1.56; Cl = 0.002–10.187) among the respondents (Table 5). Similarly, exposure to indoor PM_{10} resulted in a one-fold increase in the odds of chest tightness (aOR = 1.40; Cl = 0.000 – 84.446) among respondents.

Table 4. Associations between self-reported variables and respiratory health symptoms

Variables	Shortness of breath			Wheezing			Cough			Chest tightness		
	Yes, n %	No, n %	χ^2, p-value	Yes, n %	No, n %	χ^2, p-value	Yes, n %	No, n %	χ^2, p-value	Yes, n %	No, n %	χ^2, p-value
Gender												
Male	19 (11.5)	146 (88.5)	5.058 (**0.025**)*	26 (15.8)	139 (84.2)	0.753 (0.386)	83 (50.3)	82 (49.7)	0.048 (0.825)	16 (9.7)	149 (90.3)	11.542 (**0.001**)
Female	34 (20.6)	131 (79.4)		32 (19.4)	133 (80.6)		81 (49.1)	84 (50.9)		39 (23.6)	126 (76.4)	
No of Occupants												
1 – 2 persons	32 (16.6)	161 (83.4)	2.203 (0.332)	36 (18.7)	157 (81.3)	1.874 (0.392)	92 (47.4)	101 (52.3)	4.753 (0.093)	29 (15.0)	164 (85.0)	4.710 (0.095)
2 – 3 persons	11 (21.2)	41 (78.8)		11 (21.2)	41 (78.8)		33 (63.3)	19 (36.5)		14 (26.9)	38 (73.1)	
3 – 5 persons	10 (11.8)	75 (88.2)		11 (12.9)	74 (87.1)		39 (45.5)	46 (54.1)		12 (14.1)	73 (85.9)	
Current smoking												
Yes	7 (23.3)	23 (76.7)	1.295 (0.225)	10 (33.3)	20 (66.7)	5.656 (**0.017**)*	19 (63.3)	11 (36.7)	2.455 (0.117)	10 (33.3)	20 (66.7)	6.600 (**0.001**)*
No	46 (15.3)	254 (84.7)		48 (16.0)	252 (84.0)		145 (48.3)	155 (51.7)		45 (15.0)	255 (85.0)	
Mould in classrooms												
Yes	16 (19.3)	210 (85.0)	0.851 (0.356)	20 (24.1)	63 (75.9)	3.25 (0.071)	50 (60.2)	33 (39.8)	4.932 (**0.026**)*	18 (21.7)	65 (78.3)	20.12 (0.156)
No	37 (15.0)	67 (80.7)		38 (15.4)	209 (84.6)		114 (46.2)	133 (53.8)		37 (15.0)	210 (85.0)	
Fuel type used												
Electrical	39 (19.1)	165 (80.9)	4.453 (0.348)	44 (21.6)	160 (78.4)	11.299 (**0.023**)*	164 (49.7)	166 (50.3)	6.147 (0.188)	36 (17.6)	168	1.732 (0.785)
Natural gas	7 (12.7)	48 (87.3)		11 (20.0)	44 (80.0)		103 (50.5)	101 (49.5)		8 (14.5)	47 (85.5)	
Kerosene	7 (10.9)	57 (89.1)		3 (4.7)	61 (95.3)		32 (58.2)	23 (41.8)		11 (17.2)	53 (82.8)	
Charcoal	0 (0.0)	6 (100.0)		0 (0.0)	6 (100.0)		28 (43.8)	36 (56.3)		0 (0.0)	6 (100.0)	
Firewood	0 (0.0)	1 (100.0)		0 (0.0)	1 (100.0)		1 (16.7)	5 (83.3)		0 (0.0)	1 (100.0)	
Location of the hostel kitchen							0 (0.0)	1 (100.0)				
Outside	39 (16.7)	194 (83.3)	0.270 (0.603)	43 (18.5)	190 (81.5)	0.423 (0.515)	115 (49.4)	118 (50.6)	0.037 (0.848)	37 (15.9)	196 (84.1)	0.353 (0.552)
Inside	14 (14.4)	83 (85.6)		15 (15.5)	82 (84.5)		49 (50.5)	48 (49.5)		18 (18.6)	79 (81.4)	

Note: * – statistically significant at $p < 0.05$

Table 5. Multivariate logistic regression for independent risk factors for respiratory health symptoms

Variables	Adjusted OR (95%Cl)			
	Shortness of breath	Wheezing	Cough	Chest tightness
Gender				
Male[R]	–	–	–	–
Female	***2.12 (1.118 – 4.03)****	1.49 (0.808 – 2.757)	1.00 (0.637 – 1,595)	***3.70 (1.857 – 7.371)****
Smoking status				
No[R]	–	–	–	–
Yes	1.88 (0.734 – 4.836)	***2.87 (1.191 – 6.914)****	1.70 (0.736 – 3.811)	***3.70 (1.511 – 9.105)****
Fuel type				
Electricity[R]	–	–	–	–
Natural gas	–	–	–	–
Kerosene	–	–	0.16 (0.017 – 1.573)	–
Charcoal	0.48 (0.171 – 1.351)	0.13 (0.036 – 0.525)	0.60 (0.297 – 1.246)	0.71 (0.274 – 1.860)
Firewood	0.65 (0.244 – 1.777)	0.83 (0.344 – 0.244)	1.303 (0.639 – 2.657)	0.83 (0.313 – 2.224)
Kitchen location				
Outside[R]	–	–	–	–
Inside	1.13 (0.564 – 2.284)	1.17 (0.592 – 2.337)	0.95 (0.579 – 1.597)	0.71 (0.359 – 1.411)
Mould in classroom				
No[R]	–	–	–	–
Yes	1.52 (0.768 – 3.022)	***1.96 (1.018 – 3.788)****	***1.77 (1.042 – 3.021)****	1.73 (0.878 – 3.442)

Note: * – statistically significant at $p < 0.05$

The model also revealed an increase in the odds of wheezing (aOR = 1.40; Cl = 0.000 – 84.446), cough (aOR = 1.40; Cl = 0.000 – 84.446) and chest tightness (aOR = 1.40; Cl = 0.000 – 84.446) due to exposure to increased levels of outdoor PM_{10}. However, the associations were not statistically significant. Several studies have suggested that elevated levels of particulate matter are associated with various respiratory health outcomes and hence should be of public health concern (Aliu & Botai 2018; Ibeneme et al., 2022).

The presence of mould in classrooms was found to increase the odds of wheezing (aOR =1.96; Cl = 1.018 – 3.788) and chest tightness (aOR = 1.77; Cl = 1.042 – 3.021) by approximately twofold in exposed students compared to those who studied in classrooms without mould. On-site assessment of the classrooms at the institution showed that some of the roofs are leaking, which could result in damp and moist ground floors and walls in the classrooms and consequently aid in the growth of visible mould. The presence of mould in indoor environments has been previously reported to increase the risk of respiratory outcomes such as asthma in exposed individuals (Eghomwanre and Oguntoke, 2022).

Interventions aimed at repairing damaged roofs in classroom buildings at institutions could help reduce exposure to indoor pollution sources such as moulds and consequently decrease the occurrence of respiratory symptoms among students. There are several limitations related to the methods of assessment and study design in the present study. A more comprehensive assessment would be required in the institution to accommodate the long-term measurements of airborne particulates in and out of other microenvironments, such as libraries, laboratories, hostels, and staff office canteens where students also patronise. This study did not perform a lung function test on the respondents to better understand the determinants of respiratory symptoms among the students. The qualitative data obtained for this study were entirely based on self-reports from participants; therefore, the challenges of difficulty with recall and bias could not be ruled out.

CONCLUSION

This study presents the results of the concentrations of $PM_{2.5}$ and PM_{10} inside and outside the classrooms of a higher institution and further examines the associations between student behaviour, building characteristics and reported respiratory effects among students. The indoor and outdoor concentrations of particulates at all the sampling sites were higher than the prescribed WHO air quality standards, suggesting that the health of the exposed students is at risk. The I/O ratios for $PM_{2.5}$ were greater than 1 at most of the sampling locations, indicating that the indoor sources were more effective for $PM_{2.5}$ during the period of measurement. The I/O ratios for PM_{10} were less than 1 at most of the sites, indicating that the outdoor sources were more effective for PM_{10}.The present study also revealed positive but statistically insignificant associations between increased particulate matter concentrations and reported respiratory symptoms among the respondents. It is therefore pertinent to implement measures to decrease the concentrations of particulates inside and outside the classrooms in the institution, as failure to prevent or reduce the levels of ambient and indoor particulates inside and outside the classrooms can increase the chance of chronic and acute health problems for students. The study also revealed significant increases in the number of respondents who were females, active smokers and studied in classrooms with visible moulds and those who cooked inside the hostel rooms. However, the present study revealed that only sex, smoking status and the presence of visible moulds in classrooms were independent determining risk factors for reported respiratory symptoms among the students. Increased insight into behavioural change campaigns in institutions, especially on the risks of smoking and cooking indoors, can assist in creating awareness among students to reduce exposure to indoor pollutants. Routine air quality monitoring, improved ventilation, and classroom cleaning should be prioritised by the relevant school authorities and stakeholders in the institution.

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Author's statements

Contributions

Conceptualization: A.F.E., V.A.O-I.; Data curation: all authors; Formal and statistical analysis: A.F.E., V.A.O-I., O.O.; Investigation: all authors; Methodology: all authors; Visualization: J.U.O., E.E.I.; Writing – original draft: V.A.O-I.; Writing – review & editing: all authors.

Declaration of conflicting interest

The authors declare no competing interests.

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Data availability statement

Data used for the study would be made available on request.

AI Disclosure

The authors declare that generative AI was not used to assist in writing this manuscript.

Ethical approval declarations

This study adhered to ethical guidelines for research involving human participants, as approved by the Institutional Research Committee. Informed consent was obtained from all individuals who participated in the study.

Additional information

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REFERENCES

Abulude, F. O., Acha, S., Gbotoso, O. A., Arifalo, K. M., Ademilua, S. O., Bello, L. J., ... & Aladesaye, C. (2022). Environmental education: A tertiary institution's indoor air quality assessment in Nigeria. *ASEAN Journal for Science Education*, 1(1), 41–48.

Abulude, F. O., Suriano, D., Oluwagbayide, S. D., Akinnusotu, A., Abulude, I. A., & Awogbindin, E. (2024). Study on indoor pollutants emission in Akure, Ondo State, Nigeria. *Arab Gulf Journal of Scientific Research*, 42(4), 1643–1663. https://doi.org/10.1108/AGJSR-05-2023-0201.

Adams, M. D., & Requia, W. J. (2017). How private vehicle use increases ambient air pollution concentrations at schools during the morning drop-off of children. *Atmospheric Environment*, 165, 264–273. https://doi.org/10.1016/j.atmosenv.2017.06.046.

Aliyu, Y. A., & Botai, J. O. (2018). An exposure appraisal of outdoor air pollution on the respiratory well-being of a developing city population. *Journal of Epidemiology and Global Health*, 8(1), 91–100. https://doi.org/10.2991/j.jegh.2018.04.002.

Alzuhairi, A., Aldhaheri, M., Sun, Z. B., Oh, J. S., & Kwigizile, V. (2016). Vehicular emissions and concentrations in school zones: A case study. *Journal of Central South University*, 23(7), 1778–1785. https://doi.org/10.1007/s11771-016-3231-9.

Babaoglu, U. T., Ogutcu, H., Erdogdu, M., Taskiran, F., Gullu, G., & Oymak, S. (2022). Assessment of indoor air quality in schools from Anatolia, Turkey. *Pollution*, 8(1), 57–67. https://doi.org/10.22059/poll.2022.317521.1003.

Becerra, J. A., Lizana, J., Gil, M., Barrios-Padura, A., Blondeau, P., & Chacartegui, R. (2020). Identification of potential indoor air pollutants in schools. *Journal of Cleaner Production*, 242, 118420. https://doi.org/10.1016/j.jclepro.2019.118420.

Bhat, M. A., Eraslan, F. N., Awad, A., Malkoç, S., Üzmez, Ö. Ö., Döğeroğlu, T., & Gaga, E. O. (2022). Investigation of indoor and outdoor air quality in a university campus during COVID-19 lock down period. *Building and Environment*, 219, 109176. https://doi.org/10.1016/j.buildenv.2022.109176.

Boezen, H. M., Jansen, D. F., & Postma, D. S. (2004). Sex and gender differences in lung development and their clinical significance. *Clinics in Chest Medicine*, 25(2), 237–245. https://doi.org/10.1016/j.ccm.2004.01.012.

Boniardi, L., Dons, E., Campo, L., Van Poppel, M., Panis, L. I., & Fustinoni, S. (2019). Annual, seasonal, and morning rush hour Land Use Regression models for black carbon in a school catchment area of Milan, Italy. *Environmental Research*, 176, 108520. https://doi.org/10.1016/j.envres.2019.06.001.

Borràs-Santos, A., Jacobs, J. H., Täubel, M., Haverinen-Shaughnessy, U., Krop, E. J., Huttunen, K., ... & Hyvärinen, A. (2013). Dampness and mould in schools and respiratory symptoms in children: the HITEA study. *Occupational and Environmental Medicine*, 70(10), 681–687. https://doi.org/10.1136/oemed-2012-101286.

Chen, C., & Zhao, B. (2011). Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. *Atmospheric Environment*, 45(2), 275–288. https://doi.org/10.1016/j.atmosenv.2010.09.048.

Chen, Z., Liu, G., Chen, J., Li, S., Jiang, T., Xu, B., & Ye, X. (2018). Frequency–risk relationships between second-hand smoke exposure and respiratory symptoms among adolescents: a cross-sectional study in South China. *BMJ Open*, 8(4), e019875. https://doi.org/10.1136/bmjopen-2017-019875.

Eghomwanre, A. F., & Oguntoke, O. (2022). Concentrations of indoor gaseous air pollutants and risk factors associated with childhood asthma in Benin City, Nigeria. *Environmental Monitoring and Assessment*, 194(5), 391. https://doi.org/10.1007/s10661-022-10026-7.

Eghomwanre, A. F., Oguntoke, O., & Taiwo, A. M. (2022). Levels of indoor particulate matter and association with asthma in children in Benin City, Nigeria. *Environmental Monitoring and Assessment*, 194(7), 467. https://doi.org/10.1007/s10661-022-10135-3.

Erhabor, G. E., Obaseki, D. O., Awopeju, O. F., Ijadunola, K. T., & Adewole, O. O. (2016). Asthma in a university campus: a survey of students and staff of Obafemi Awolowo University, Ile-Ife, Nigeria. *Journal of Asthma*, 53(1), 30–36. https://doi.org/10.3109/02770903.2015.1060609.

Feuyit, G., Nzali, S., Lambi, J. N., & Laminsi, S. (2019). Air quality and human health risk assessment in the residential areas at the proximity of the Nkolfoulou landfill in Yaoundé Metropolis, Cameroon. *Journal of Chemistry*, 2019(1), 3021894. https://doi.org/10.1155/2019/3021894.

Fromme, H., Diemer, J., Dietrich, S., Cyrys, J., Heinrich, J., Lang, W., ... & Twardella, D. (2008). Chemical and morphological properties of particulate matter (PM10, PM2. 5) in school classrooms and outdoor air. *Atmospheric Environment*, 42(27), 6597–6605. https://doi.org/10.1016/j.atmosenv.2008.04.047.

Godwin, C., & Batterman, S. A. (2007). Indoor air quality in Michigan schools. *Indoor Air*, 17 (2007), 109–121. https://doi.org/10.1111/j.1600-0668.2006.00459.x.

Gordon, S. B., Bruce, N. G., Grigg, J., Hibberd, P. L., Kurmi, O. P., Lam, K. B. H., ... & Martin, W. J. (2014). Respiratory risks from household air pollution in low and middle income countries. *The Lancet Respiratory Medicine*, 2(10), 823–860. https://doi.org/10.1016/S2213-2600(14)70168-7.

Groeneveld, J. M., Ballering, A. V., van Boven, K., Akkermans, R. P., Olde Hartman, T. C., & Uijen, A. A. (2020). Sex differences in incidence of respiratory symptoms and management by general practitioners. *Family Practice*, 37(5), 631–636. https://doi.org/10.1093/fampra/cmaa040.

Hosmer, D. W., & Hjort, N. L. (2002). Goodness-of-fit processes for logistic regression: simulation results. *Statistics in Medicine*, 21(18), 2723–2738. https://doi.org/10.1002/sim.1200.

Jayachandran, P. (2019). Teaching an occupational hazard for respiratory insult contributing to burden of respiratory diseases in the society. *Chest*, 155(4), 19A. https://doi.org/10.1016/j.chest.2019.02.039.

Kanchanasuta, S., Sooktawee, S., Patpai, A., & Vatanasomboon, P. (2020). Temporal variations and potential source areas of fine particulate matter in Bangkok, Thailand. *Air, Soil and Water Research*, 13, 1178622120978203.

Kasiulevičius, V., Šapoka, V., & Filipavičiūtė, R. (2006). Sample size calculation in epidemiological studies. *Gerontologija*, 7(4), 225–231.

Kim, J. L., Elfman, L., Mi, Y., Johansson, M., Smedje, G., & Norbäck, D. (2005). Current asthma and respiratory symptoms among pupils in relation to dietary factors and allergens in the school environment. *Indoor Air*, 15(3). https://doi.org/10.1111/j.1600-0668.2005.00334.x.

Leung, D. Y. (2015). Outdoor-indoor air pollution in urban environment: challenges and opportunity. *Frontiers in Environmental Science*, 2, 69. https://doi.org/10.3389/fenvs.2014.00069.

Lin, C. C., Lee, M. K., & Huang, H. L. (2015). Effects of chalk use on dust exposure and classroom air quality. *Aerosol and Air Quality Res*earch, 15(7), 2596–2608. https://doi.org/10.4209/aaqr.2015.04.0216.

Momtazmanesh, S., Moghaddam, S. S., Ghamari, S. H., Rad, E. M., Rezaei, N., Shobeiri, P., ... & Ibitoye, S. E. (2023). Global burden of chronic respiratory diseases and risk factors, 1990–2019: an update from the Global Burden of Disease Study 2019. *EClinicalMedicine*, 59. https://doi.org/10.1016/j.eclinm.2023.101936.

Ojukwu, C. P., Ogualaji, P. C., Ede, S. S., Ativie, R. N., Obaseki, C. O., Okemuo, A. J., & Irem, F. O. (2022). Pulmonary functions and associated risk factors among school teachers in a selected Nigerian population. *International Journal of Occupational Safety and Ergonomics*, 28(2), 883–889. https://doi.org/10.1080/10803548.2020.1840033.

Osimobi, O. J., & Nwankwo, C. A. (2018). Assessment of particulate matter concentrations in a university campus in Nigeria. *Journal of Environmental Studies*, 4(1), 1–4. Available: https://www.avensonline.org/wp-content/uploads/JES-2471-4879-04-0024.pdf.

Osimobi, O. J., Yorkor, B., & Nwankwo, C. A. (2019). Evaluation of daily pollutant standard index and air quality index in a university campus in Nigeria using PM10 and PM2. 5 particulate matter. *Journal of Science, Technology and Environment Informatics*, 7(2), 517–532. https://doi.org/10.18801/jstei.070219.54.

Paterson, C. A., Sharpe, R. A., Taylor, T., & Morrissey, K. (2021). Indoor PM2. 5, VOCs and asthma outcomes: A systematic review in adults and their home environments. *Environmental Research*, 202, 111631. https://doi.org/10.1016/j.envres.2021.111631.

PHE. (2018). Health matters: air pollution. Available: https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

Rawat, N., & Kumar, P. (2023). Interventions for improving indoor and outdoor air quality in and around schools. *Science of The Total Environment*, 858, 159813. https://doi.org/10.1016/j.scitotenv.2022.159813.

Saracen, A. (2016). Cigarette smoking and respiratory system diseases in adolescents. *Respiratory Treatment and Prevention*, 81–85. https://doi.org/10.1007/5584_2016_60.

Sargent, J. D., Halenar, M. J., Edwards, K. C., Woloshin, S., Schwartz, L., Emond, J., ... & Brunette, M. (2022). Tobacco use and respiratory symptoms among adults: findings from the longitudinal Population Assessment of Tobacco and Health (PATH) study 2014–2016. *Nicotine & Tobacco Research*, 24(10), 1607–1618. https://doi.org/10.1093/ntr/ntac080.

Sekerel, B. E., Civelek, E., Karabulut, E., Yildirim, S., Tuncer, A., & Adalioglu, G. (2006). Are risk factors of childhood asthma predicting disease persistence in early adulthood different in the developing world?. *Allergy*, 61(7), 869–877. https://doi.org/10.1111/j.1398-9995.2006.01082.x.

Shrestha, P. M., Humphrey, J. L., Carlton, E. J., Adgate, J. L., Barton, K. E., Root, E. D., & Miller, S. L. (2019). Impact of outdoor air pollution on indoor air quality in low-income homes during wildfire seasons. *International Journal of Environmental Research and Public Health*, 16(19), 3535. https://doi.org/10.3390/ijerph16193535.

Singrakphon, V., Chart-asa, C., & Chaikaew, P. (2024). Meteorological Conditions and PM2. 5 Impact on COVID-19 Case Fatality Ratios (CFR) in Bangkok Metropolitan Region. *Applied Environmental Research*, 46(2). https://doi.org/10.35762/AER.2024016.

Tesfaye, A. H., Gebrehiwot, M., Aragaw, F. M., & Dessie, A. (2023). Prevalence and risk factors of chronic respiratory symptoms in public and private school teachers in north-western Ethiopia: results from a multicentre cross-sectional study. *BMJ Open*, 13(4), e069159. https://doi.org/10.1136/bmjopen-2022-069159.

Tollefsen, E., Langhammer, A., Romundstad, P., Bjermer, L., Johnsen, R., & Holmen, T. L. (2007). Female gender is associated with higher incidence and more stable respiratory symptoms during adolescence. *Respiratory Medicine*, 101(5), 896–902. https://doi.org/10.1016/j.rmed.2006.09.022.

Toyinbo, O. (2018). School buildings and indoor environmental quality in Nigerian elementary schools and their potential health effects on students. Available: https://erepo.uef.fi/server/api/core/bitstreams/dfe8be6f-380b-4250-b2cc-4476a66b2edc/content.

Toyinbo, O., Shaughnessy, R., Turunen, M., Putus, T., Metsämuuronen, J., Kurnitski, J., & Haverinen-Shaughnessy, U. (2016). Building characteristics, indoor environmental quality, and mathematics achievement in Finnish elementary schools. *Building and Environment*, 104, 114–121. https://doi.org/10.1016/j.buildenv.2016.04.030.

Tran, D. T., Alleman, L. Y., Coddeville, P., & Galloo, J. C. (2012). Elemental characterization and source identification of size resolved atmospheric particles in French classrooms. *Atmospheric Environment*, 54, 250–259. https://doi.org/10.1016/j.atmosenv.2012.02.021.

U.S. Department of Health and Human Services. (2014). The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2014. Available: https://www.ncbi.nlm.nih.gov/books/NBK179276/pdf/Bookshelf_NBK179276.pdf.

Vaidya, P., Kashyap, S., Sharma, A., Gupta, D., & Mohapatra, P. R. (2007). Respiratory symptoms and pulmonary function tests in school teachers of Shimla. *Lung India*, 24(1), 6–10. https://doi.org/10.4103/0970-2113.44195.

Viegi, G., Baldacci, S., Maio, S., Fasola, S., Annesi-Maesano, I., Pistelli, F., ... & Forastiere, F. (2020). Health effects of air pollution: a Southern European perspective. *Chinese Medical Journal*, 133(13), 1568–1574.

Vrijlandt, E. J., Gerritsen, J., Boezen, H. M., Duiverman, E. J., & Dutch POPS-19 Collaborative Study Group*. (2005). Gender differences in respiratory symptoms in 19-year-old adults born preterm. *Respiratory Research*, 6(1), 117. https://doi.org/10.1186/1465-9921-6-117.

WHO. Air Quality & Health. (2021). Available: https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf?sequence=1.

Zhang, Q., & Zhu, Y. (2011). Performance of school bus retrofit systems: ultrafine particles and other vehicular pollutants. *Environmental Science & Technology*, 45(15), 6475–6482. https://doi.org/10.1021/es201070t.