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Investigation of the Health Effects of Indoor and Outdoor Air Pollution from Aerosol Emission on School Children in Abakaliki, Ebonyi State, Nigeria

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Abstract

The health effects of exposure of children to indoor and outdoor air pollution from aerosols (particulate matter) at schools in Abakaliki have been studied. The aim of this study was to investigate how aerosol particles are dispersed within schools in Abakaliki and their health related issues. The aerosol dataset used for computation and analysis was obtained by direct monitoring and measurement of air pollution from aerosol emissions at schools in the area of study. From the results, the highest air quality indices (AQIs) values of 360 and 282 for particulate matter 2.5 ($PM_{2.5}$) were obtained for outdoor and indoor air pollution at Ogoja Road Primary School. The results obtained also showed that the mean concentrations and air quality indices (AQIs) of particulate matter 2.5 ($PM_{2.5}$) and particulate matter 10 (PM_{10}) were relatively greater during the dry season than during the rainy season, mostly in the school closer to the generating sources than the schools farther from the sources. Similarly, the concentrations of $PM_{2.5}$ and PM_{10} obtained in the study areas were greater than the World Health Organization (2021) guidelines for healthy air quality, which, if inhaled, may cause health problems such as difficulty in breathing and bizarre catarrh in schoolchildren. Additionally, sources such as dust, overcrowded classrooms, school locations close to busy roads, and combustion sites were the major contributors to air pollution from aerosols in schools at Abakaliki. This study may aid atmospheric/environmental researchers in monitoring air pollution from aerosols and its associated impacts on our environment for application to the good health of schoolchildren. These findings can aid policy makers in enacting guidelines and requirements for establishing new schools. To that effect, a clean environment for the safety and good health of schoolchildren in Abakaliki and beyond should be ensured.

Keywords: Aerosol emission, Air pollution, Children, Health effects, Schools.

INTRODUCTION

Indoor and outdoor air pollution due to aerosol contamination of atmospheric air is a major global and public health threat that causes a range of adverse health effects, even at the lowest observable concentrations. Aerosols, also known as particulate matter (PM) or airborne dust

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(liquid or solid), are pollutants that contribute to environmental damage (Liu *et al*., 2018). PM concentrations are used as an indicator of air quality (Chen and Hoek., 2020).
Millions of Nigerians are at risk of deadly diseases, ranging from cardiovascular to respiratory disorders, as lingering outdoor and indoor air pollution from particulate matter leaves the air quality in many parts of the country largely unhealthy (Tamitayo, 2022). Nigeria and many other low-middle income countries are most likely to face the highest risk of exposure to particulate matter pollution compared with any other place in the world due to their inability to adequately comply with Ambient Air Quality Standards (AAQS) (Tamitayo, 2022). All of these adverse effects on human health worldwide, particularly on schoolchildren, are attributed to constant exposure to indoor and outdoor air pollution due to particulate matter emission in our environment, especially the emission of $PM_{2.5}$ (particulate matter with an aerodynamic diameter less than 2.5 µm) and PM_{10} (particulate matter with an aerodynamic diameter less than 10 µm).

Owing to the rapid demographic growth and lack of clean-energy infrastructure in Africa, it is noted as the region most affected by indoor and outdoor air pollution due to aerosols worldwide (Analí *et al.,* 2007*)*. For instance, $PM_{2.5}$ and PM_{10} are the primary contaminants affecting indoor and outdoor air quality and the health of schoolchildren (Egide *et al.,* 2023). High levels of $PM_{2.5}$ and PM_{10} in both indoor and outdoor air pollution in sub-Saharan Africa are estimated to result in more than 700,000 premature deaths per year, more than the combined effects of unsafe water, poor sanitation, and childhood malnutrition (Rees, Wickham and Choi, 2019).

Children are vulnerable to air pollution because of their developing respiratory, nervous, and immune systems (Wispriyono, *et al.,* 2020*)*. Children also inhale more particles per unit of body mass than adults because of their higher oxygen consumption rates (Burtscher and Schüepp, 2012; Salvi, 2007). In addition, children perform less nasal breathing, reducing particle deposition in the nasal airways and increasing deposition in the lower respiratory tract (Maynard, 2015). According to Oliveira *et al.* (2019) *and* Wispriyono *et al.* (2020), as reported by Egide *et al.* (2023), children of school age in cities worldwide spend most of their time indoors, with 6 to 8 hours of their day being spent at school and approximately 2 hours in transit to or from school to their destination of residence.

Temitayo (2022) reported that the latest World Health Organization (WHO) database on ambient air quality, which includes recommendations for concentration limits of pollutants such as particulate matter (PM) and nitrogen dioxide, shows that only three percent of Africa has complied with particulate matter (PM) guidelines and interim targets. There is a need for more empirical evidence on the impact of air pollutants due to aerosols on schoolchildren in most countries in Africa.

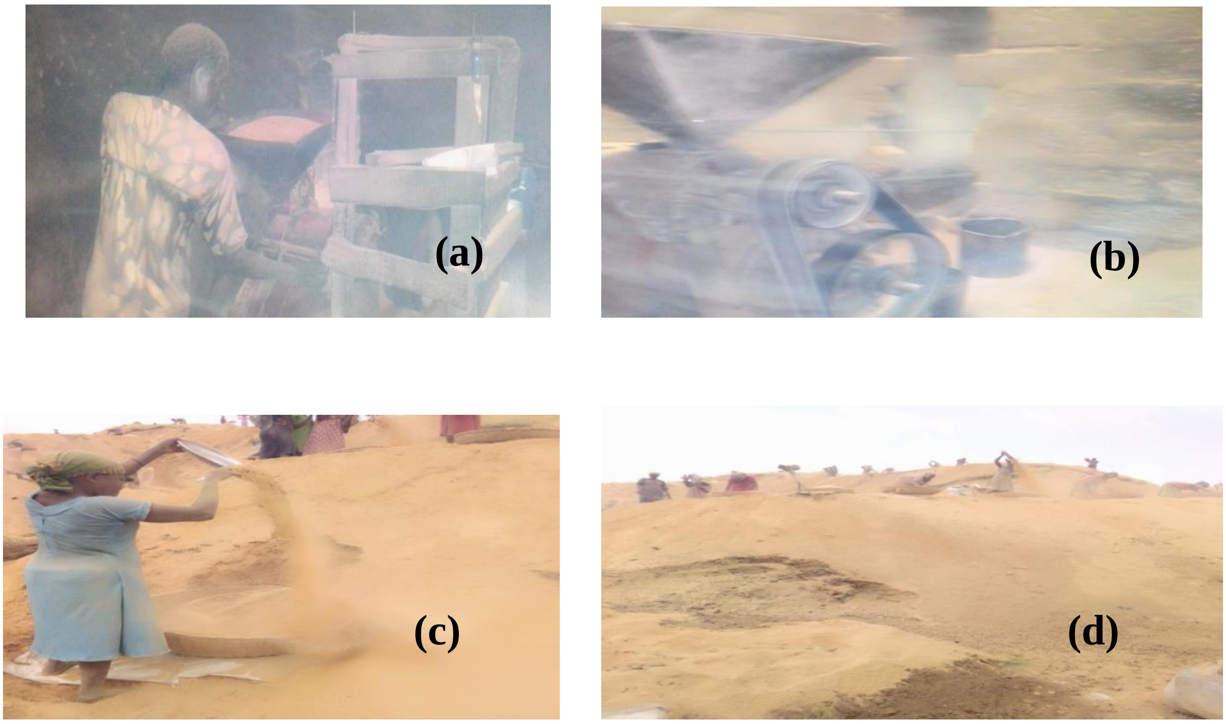
Particulate matter (PM) may be emitted directly or may be a product of chemical processes in the atmosphere, where it may be transported over long distances (WHO, 2023). As a consequence, transboundary PM occurs, which makes it even more difficult to control local air quality (Maas and Grennfelt, 2021). PM can be transported through the air for extremely long distances (Galon-Negru *et al.,* 2019) and remain suspended for long periods of time (Sandra *et al.,* 2008).

Depending on their origin, PM can be classified as primary (direct emission of particles as such into the atmosphere) or secondary (generated in the atmosphere due to transformations of gases into particles) (Quijano *et al.*, 2010). According to Mauricio *et al.* (2023), the characterization of these pollutants provides information about their chemical components, their origin, and emission sources. Particulate matter (PM) is equally generated by several emission sources, such as biomass burning, traffic, wildfires, industrial processes and natural sources (Nagar *et al.,* 2017).

The early focus on PM reflected its worldwide ubiquity, and it is the most widely used indicator for assessing the health effects of exposure to air pollution (WHO, 2021). PM can penetrate deep into the lung and enter the bloodstream, causing cardiovascular, cerebrovascular (stroke) and respiratory diseases (Thurston *et al.,* 2017). There is emerging evidence that PM also affects other organs and diseases (Schraufnagel *et al.,* 2019; Wei *et al.,* 2019).

Together, indoor and outdoor air pollution due to PM accounted for approximately 12% of all deaths in 2019. Air pollution currently ranks fourth among major risk factors for global disease and mortality, second only to hypertension, smoking and dietary factors (Murrey *et al*., 2020).

At different locations in Abakaliki as shown in Figure 1, schoolchildren are exposed to high levels of indoor and outdoor air pollution due to $PM_{2.5}$ and PM_{10} emissions from the use of aging diesel and gasoline from the Ebonyi State Rice Mill Company; second-hand vehicles; generator smoke; emission from rice husk; dusty roads/school environment; trash burning; and solid-fuel combustion for cooking. Thus, these diseases may include increased respiratory symptoms, reduced cognitive and academic performance, constant feverish conditions, headache, catarrh and absence from school could likely ensue.



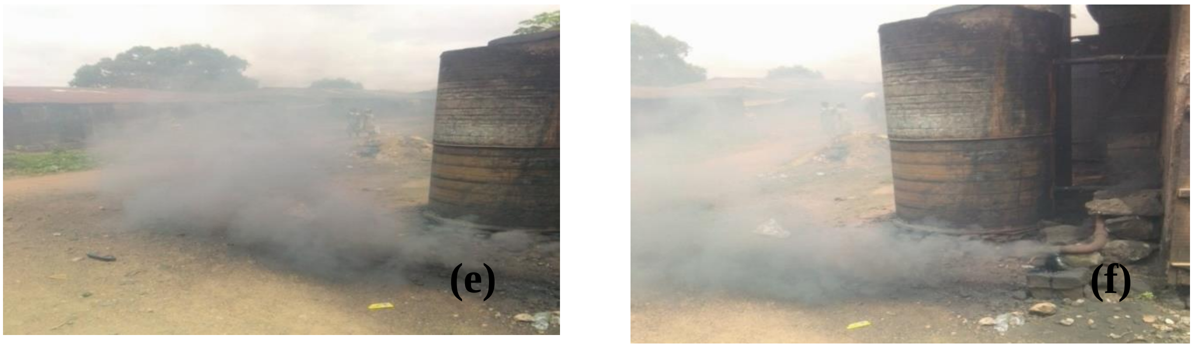


Figure 1 Aerosol sources in Abakaliki: (a) Indoor emission from rice hust removal, (b) Indoor emission from a rice husk removal engine, (c, d) Outdoor emissions from rice husk removal via the manual wind sieving method, and (e, f) emission sources from a rice mill combustion engines.

PM can be inhaled and enter the lungs, causing harmful health effects, while finer particles may reach the alveolar region of the lungs. According to Xiao-Yue *et al.* (2021), the negative effects of PM_{10} and $PM_{2.5}$ depend on their complexity and variation in parameters, which include particle size, heterogeneity, chemical composition, etc. Furthermore, depending on their concentration, exposure time, and toxicity, they can be lethal or cause major health problems in the short or long term (Analí *et al.,* 2007). In addition, Mauricio *et al*. (2023) mentioned that these characteristics may change over time and with different weather conditions.

According to a World Health Organization (2018) report, more than seven million people die each year because of PM-related disease, while more than 80 % of the population in urban areas lives in places where air quality increases above the WHO (2020) standard guideline limits. Apte *et al.* (2018) suggested that from both a global and a national perspective, life expectancy has decreased drastically owing to air pollution in the environment.

METHODOLOGY

Study Area

This research was carried out in Abakaliki, the Ebonyi State Capital City, Nigeria. The survey covered two primary schools located on Ogoja Road and Inyimagu Onu-Ebonyi. They are located at longitudes and latitudes of 6.316°N and 8.127°E and at 6.312°N and 8.140°E, respectively. Primary School Ogoja Road and Primary School Inyimagu Onu-Ebonyi are located 1.82 km and 2.1 km, respectively, near the popular Abakaliki Rice Mill Industry and the Mechanic Village (Site), which are believed to generate a very high percentage of particulate matter in the area due to the combustion of 100 s of diesel engines, as well as the dust particles from rice husk generated during rice processing, which are directly emitted into the atmosphere. The areas of study are characterized by three major weather conditions, which are often described as wet weather conditions (rainy period), which represents the time when there is predominant rainfall in the area. Hazy or Harmattan weather conditions, which represent periods in which weather condition is dry and are marked with dew, cold, harsh weather and excessive north trade winds, that are usually blown across study locations from time to time, especially during afternoon periods, and dust particles spread through the atmosphere. Dry weather conditions represent periods with intense and dominant sunshine across locations and are characterized by intense heat and very hot weather conditions due to solar radiation reaching the Earth’s surface. During this period, there is little or no rainfall within the area.

Data collection

The outdoor and indoor particulate matter (PM) concentrations in the ambient air of the schools were monitored and collected using digital readout photometric-laser particle counter equipment with the specifications Aerocet Model 531-9800 Rev. C (Metone, Inc., USA). This equipment was designed with an inbuilt particle data count for particle sizes of up to eight (8) different ranges, which include $PM_{2.5}$, PM_{10}, etc. This equipment is also endowed with a proprietary algorithm that can help to determine the mass concentration of the particulate matter of interest within a given location. During data monitoring and collection, the equipment was held at a height of 6 feet (1.8 m) from ground level, which falls within the height where human breathing takes place. During the process, the ambient outdoor and indoor air pollution concentrations due to $PM_{2.5}$ and PM_{10} emissions were monitored for 8 hours (8am-4pm) within 2 days (Monday and Friday) in a week at an interval of 30 minutes. The procedure was carried out between December 2022 and August 2023 under Harmattan weather conditions (December–February), dry weather conditions (March–May) and rainy weather conditions (June–August).

Data analysis

After the data were collected, weekly mean values for the concentrations of the parameters ($PM_{2.5}$ and PM_{10}), as well as the standard deviation and air quality index (AQI), were computed and recorded accordingly for all the study areas using the Minitab 19 application package. The aim of the analysis is to determine the $PM_{2.5}$ and PM_{10} concentration distributions and risk assessments within the study areas.

Health implications

The mean values of $PM_{2.5}$ and PM_{10} obtained from the computed data were compared with the updated WHO (2021) global air quality guidelines. According to Lala, Onwunzo, Adesina, and Sonibare (2023), the recommended $PM_{2.5}$ concentrations are 5 and 15 μg/m³ for annual and 24-hour averaging times, respectively, while PM_{10} concentrations are 15 and 45 μg/m³ for annual and 24-hour averaging times, respectively. By using the formula below according to Wambebe and Duan (2020), Greenhouse gas emissions and sinks (2018), and the USEPA (2018), as reported by Lala *et al.* (2023), the mean values obtained were subsequently used to calculate the air quality index (AQI). That is,

$$\mathrm{AQI_{PM}} = \frac{\text{PM concentration}}{\text{WHO Standard}} \times 100$$

Table 1 Air quality index characteristic classifications

Air pollutant level	AQI range	Health concern level	AQI daily colour code
Level 1	0 – 50	Good	Green
Level 2	51 – 100	Moderate	Yellow
Level 3	101 – 150	Unhealthy for sensitive group	Orange
Level 4	151 – 200	Unhealthy	Red
Level 5	201 – 300	Very unhealthy	Purple
Level 6	301 and above	Hazardous	Maroon

According to the USEPA (2018 1 & 2), as reported by Lala *et al.* (2023), the AQI provides daily air quality levels. It equally provides crucial information on how healthy or unhealthy a given unit of ambient air is available for inhalation, and provides information on health concerns in a given region. Moreover, the air quality index provides useful awareness of the associated hazards of breathing polluted air and the impending effects that may be experienced for a few hours or days of exposure (Wambebe, and Duan, 2020). Air quality is considered better at lower AQI values. Table 1 lists the air quality indices and AQI pollutant concentration specific ranges for the $PM_{2.5}$ and PM_{10} concentrations (Wambebe, and Duan, 2020; USEPA, 2018; Longinus *et al.*, 2016).

Table 1 represents the six major characteristic classifications of the AQI. The AQI comprises the air pollution level, AQI range, health concern level and AQI daily colour code. Air quality Level 1, with an AQI ranging from 0–50 and an AQI daily colour code of "green", represents good and healthy air with relatively minor or no health-related effects. Air quality Level 2, with an AQI ranging from 51–100 and an AQI daily colour code of "yellow", represents an acceptable level of air pollution with associated moderate health concerns for some specific individuals who are highly sensitive to air pollution, although these sets of individuals are often limited in number. An AQI of 101–150 and an AQI daily colour code of "orange" indicate unhealthy air for sensitive groups of individuals who are suffering from certain illnesses, such as heart disease and lung disease, and vulnerable groups, such as elderly people and children. Such sensitive groups of individuals are always more vulnerable to the impending dangers of air pollution even when other people may be unaffected. An AQI of 151–200 and an AQI daily colour code of "red" indicate unhealthy air with major health concerns to certain groups of people, while vulnerable and sensitive people may face more severe health complications when they inhale air. An air quality level of 5 with an AQI ranging from 201–300 and an AQI daily colour code of "purple" suggest a very severe health implication that may call for urgent health attention not only for sensitive groups but also for the general population. An AQI of 300 or above and an AQI daily colour code of "maroon" indicate a very hazardous health concern. Air pollution at Level 6 triggers an emergency warning of health conditions, and the entire exposed population is more likely to be affected (Wambebe, and Duan, 2020; USEPA, 2018).

RESULTS AND DISCUSSION

Results

The results of the monthly mean and AQI of the outdoor and indoor $PM_{2.5}$ and PM_{10} concentration distributions obtained for the Primary School Ogoja road and Onuebonyi Inyimagu Primary School, Abakaliki are presented in Tables 2 and 3, respectively. In this study, data monitoring and collection were carried out within nine (9) months (i.e., from December 2022 to August 2023) and represented three weather conditions (Harmattan, dry and rainy) within the study areas.

Table 2 Monthly mean and air quality index distributions of $PM_{2.5}$ and PM_{10} for Primary School Ogoja road, Abakaliki

Month	$PM_{2.5}$ (μg/m³)				PM_{10} (μg/m³)			
	Outdoor		Indoor		Outdoor		Indoor	
	$\bar{x}$±SD	AQI	$\bar{x}$±SD	AQI	$\bar{x}$±SD	AQI	$\bar{x}$±SD	AQI
Dec.	53.94±11.70	360	40.96±9.83	273	34.27±2.83	76	26.88±2.49	60
Jan.	47.16±11.90	314	32.87±10.11	219	68.43±2.08	152	25.20±2.55	56
Feb.	40.38±12.11	269	22.79±10.43	152	27.00±2.65	60	23.53±2.61	52
March	47.99±10.61	320	35.00±9.29	233	17.29±5.28	38	16.89±2.16	38
April	41.94±10.81	280	42.26±9.03	282	26.47±2.43	59	13.64±2.37	30
May	52.05±10.44	360	27.74±9.58	185	17.10±2.55	38	10.39±2.57	23
June	40.41±10.43	269	25.72±8.53	171	9.89±1.74	22	11.77±1.96	26
July	33.36±10.68	222	17.41±8.90	116	10.49±1.72	23	10.53±1.92	23
Aug.	47.46±10.20	316	34.03±8.19	227	24.20±2.28	54	13.01±2.00	29

Key: $\bar{x} = mean, SD = Standard\ deviation, AOI = Air\ quality\ index$

Table 3 Monthly mean and air quality index distributions of $PM_{2.5}$ and PM_{10} for the Onuebonyi Inyimagu Primary School, Abakaliki

Month	**$PM_{2.5}$ (µg/m^3)**				**PM_{10} (µg/m^3)**			
	Outdoor		**Indoor**		**Outdoor**		**Indoor**	
	$\bar{x}$±SD	**AQI**	**$\bar{x}$±SD**	**AQI**	**$\bar{x}$±SD**	**AQI**	**$\bar{x}$±SD**	**AQI**
Dec.	34.03±8.19	227	18.83±4.56	126	21.09±2.93	141	22.59±3.06	151
Jan.	25.72±8.53	171	14.55±4.34	97	12.21±5.30	81	21.84±3.05	146
Feb.	17.41±8.90	116	16.52±3.32	110	27.15±5.83	181	21.12±3.04	141
March	24.97±4.93	166	18.99±4.43	127	23.18±2.87	155	32.24±6.85	215
April	27.72±4.85	185	22.31±4.32	149	19.03±4.57	127	25.39±5.40	169
May	22.23±5.02	148	15.67±4.56	104	22.00±6.81	147	18.54±5.97	124
June	18.99±4.43	127	12.00±369	80	7.68±2.57	51	8.33±2.78	56
July	15.67±4.56	104	8.09±3.88	54	7.35±1.03	49	7.56±2.77	50
Aug.	33.31±4.32	222	15.92±3.51	106	24.20±2.58	161	9.09±2.79	61

Key: $\bar{x} = mean, SD = Standard\ deviation, AOI = Air\ quality\ index$

DISCUSSION

Analysis of the outdoor/indoor $PM_{2.5}$ and PM_{10} mean distributions

As was observed from the results (Tables 2 and 3), the outdoor/indoor mean distributions of $PM_{2.5}$ and PM_{10} concentrations in the study areas were greater during Harmattan weather conditions (December–February) and dry weather conditions (March–May), often referred to as the dry season, than during rainy weather conditions (June–August), which are mostly referred to as the rainy season. However, the outdoor/indoor mean distributions of the $PM_{2.5}$ concentration were found to be far greater in primary school Ogoja road and Abakaliki for all the months, with maximum and minimum mean values of 53.94 µg/m^3/40.96 µg/m^3 and 33.36 µg/m^3/17.41 µg/m^3, respectively, recorded in December and July, respectively, than in Onuebonyi Inyimagu Primary School, Abakaliki with maximum and minimum mean values of $PM_{2.5}$ concentration distributions of 34.03 µg/m^3/22.31 µg/m^3 and 15.67 µg/m^3/8.09 µg/m^3, respectively, recorded in December and April and in July. This signifies that outdoor/indoor $PM_{2.5}$ levels are greater on the Primary School Ogoja Road, Abakaliki, than on the Onuebonyi Inyimagu Primary School, Abakaliki. Therefore, there is a greater presence of air pollution sources located close to the Primary School Ogoja Road than close to the Onuebonyi Inyimagu Primary School, Abakaliki. Moreover, the results at these two locations indicated a greater increase in the mean and air quality indices of $PM_{2.5}$ and PM_{10} during Harmattan and dry weather conditions than during rainy weather conditions. This observation may be linked to the proximity of the school to the Ebonyi State Rice Mill Industry, Abakaili, which houses more than 300 milling diesel generators, and also the Ebonyi State Mechanical Village (Site), which is believed to contribute a greater percentage of particulate matter emissions in the state.

The results also revealed that the outdoor/indoor PM_{10} mean concentration distributions on Primary School Ogoja Road, Abakaliki, were equally greater than the values obtained on the Onuebonyi Inyimagu Primary School, Abakaliki, for the months of the study. This may be connected to the difference in the environmental disposition and location of the two schools. In the Primary School Ogoja Road, Abakaliki where the ground floor of the school's environment and some classes are dusty with open windows in most classes is bound to aid indoor air pollution from PM, especially during Harmattan and dry weather conditions, which are often driven by excessive north-trade wind movement. This could also be necessitated by the location of the school near the PM generation sources, which may be a contributory factor to the increase in PM concentration in the area. In contrast, in the Onuebonyi Inyimagu Primary School, Abakaliki, the ground floor of the school environment is cemented and has good working windows that can normally be locked up during massive wind movement to avoid infiltration of the classes with dust; moreover, the location of the school farther from PM-generating sources may play a role in the low concentration distribution recorded in the area.

In this study, the concentrations of $PM_{2.5}$ and PM_{10} emissions were significantly greater during the dry season (Harmattan and dry weather conditions) than during the rainy season (rainy weather conditions) in the two areas of study. This may be attributed to increase is natural activities such as dryness of the environment by the Sun due to hot weather which can hasten excessive dust, north trade wind movement, etc., and human activity such as increase in bush burning, vehicular emission, sweeping of class rooms and environment, etc., that undoubtedly led to air pollution in the area. This implies that the air quality during this period may have had a negative effect on some schoolchildren, while sensitive and vulnerable groups are most likely to experience more serious health issues.

Analysis of outdoor/indoor $PM_{2.5}$ and PM_{10} AQI and risk factors

From this study, it is obvious that on Primary School Ogoja Road, Abakaliki, the outdoor and indoor AQIs for $PM_{2.5}$ obtained within the months of December, January, March, May and August fall within level 6, level 5, level 4, level 3, and level 2 of the updated WHO (2021) global air quality guideline for PM and thus signify hazardous, very unhealthy, unhealthy, unhealthy for sensitive groups and moderate health concerns, respectively, if inhaled by schoolchildren. Sequentially, schoolchildren in the area may be faced with a series of dangerous health-related complications for those months if they are exposed to the outdoor/indoor environment in the area. This may be attributed to air pollution due to the emissions from the operations of diesel engines used at the Ebonyi State Rice Mill Industry, which is located close to the school and runs for approximately 10 hours a day and six days a week. However, in Onuebonyi Inyimagu Primary School, Abakaliki, the outdoor and indoor AQI for $PM_{2.5}$ obtained within the months of December, January, March, May and August, respectively; fall within level 5, level 4, level 3, and level 2 of the updated WHO (2021) global air quality guideline for PM; and consequently indicate very unhealthy, unhealthy, unhealthy for sensitive groups and moderate health concerns if inhaled by schoolchildren. This may be direct consequence of vehicular emissions and other PM emission-related sources at the school.

The implication of this finding is that schoolchildren at the Primary School Ogoja Road, Abakaliki, faced more complicated health-related challenges emerging from air pollution caused by $PM_{2.5}$, which spurred an increase in the AQI for almost all the months within the period of study compared with schoolchildren at the Onuebonyi Inyimagu Primary School, Abakaliki. This is because the $PM_{2.5}$ AQI value surged to the highest level (level 6), which can trigger an emergency warning of critical health conditions for children and the entire exposed population for the period of study in the area. However, for every indication, the outdoor and indoor AQI for $PM_{2.5}$ in all the months, as obtained in the two areas of study, are above the WHO (2021) global guidelines for healthy air quality. In contrast, there were evidently few months when the outdoor and indoor AQI of PM_{10} assumed values (0–50) that are considered good and relatively consistent within the WHO global guidelines for healthy air quality; these values are mostly found during the rainy season and thus suggest a reduction in the activities of such factor(s) that can enhance high levels of particulate matter air pollution in the areas of study. According to Wambebe and Duan (2020); Lala *et al.* (2019), as human activities such as construction increase, the burning of land grasses, which are more peculiar during the dry season, may also be the cause of higher $PM_{2.5}$ and PM_{10} concentrations in any given location and thus may be the cause of the increase in concentration observed in the areas of study. Air quality at level 5 is very unhealthy for everyone and severe for the sensitive groups. When exposed, unhealthy air can reach deep into the lungs and bloodstream, thereby causing increased respiratory problems, asthma, heart disease, lung disease and premature death (Wambebe, and Duan, 2020). According to the research carried out by Ristovski *et al.* (2011); Ayres *et al*. (2008), constant exposure to $PM_{2.5}$ leads to impending respiratory and health risks, such as chronic obstructive pulmonary disease, asthma, and lung cancer, compared to $PM_{10.}$

According to a study carried out by Mortimer *et al.* (2002) on the effect of $PM_{2.5}$ on children, exposure to fine particulate matter ($PM_{2.5}$) can possibly trigger asthma and other health-related respiratory issues in children and in the general population. Fine particulate matter ($PM_{2.5}$) can easily meander through the alveoli of the lung and pass effortlessly into the bloodstream if it is soluble in water; otherwise, it is retained in the lungs (Breysse *et al*., 2010).

CONCLUSION

In this study, the health effects of exposure of children to indoor and outdoor air pollution from particulate matter ($PM_{2.5}$ and PM_{10}) emissions at schools (Primary School Ogoja Road and Onuebonyi Inyimagu Primary School) in Abakaliki were investigated. From the results, it was observed that in some months, the mean concentration of ambient air pollution due to particulate matter ($PM_{2.5}$ and PM_{10}) was far greater than that of the updated WHO (2021) global guideline for air quality monitoring for particulate matter during the period of study in these two areas. This was more prevalent on the Primary School Ogoja Road than on the Onuebonyi Inyimagu Primary School and more specifically during Harmattan and dry weather conditions. This finding implies that schoolchildren within these areas are more susceptible to direct health-related issues from air pollution due to $PM_{2.5}$ and PM_{10} during the period of study. However, the results also showed that the PM_{10} mean concentration distribution in some months, especially during the rainy season, fell within the range recommended by the WHO (2021) global updated guidelines for air quality for particulate matter emissions. Similarly, the results of the Air Quality Index (AQI) monitored signified that children in the two schools for the period of study were highly exposed to a dangerous health related effects due to $PM_{2.5}$ and PM_{10} air pollution and hence, several health challenges such as head ache, bizarre catarrh, cough, etc., were constantly witnessed and complained of by the children during the period of study in some months. Finally, it can be deduced from the results that the health effects of outdoor and indoor PM_{10} air pollution on schoolchildren may be lower on the Primary School Ogoja Road, Abakaliki, than on the health effects of PM_{10} on the Onuebonyi Inyimagu Primary School, Abakaliki, especially during the rainy season. Therefore, the present study concluded that the government and regulatory bodies should enact laws prohibiting intending school owners from building schools near particulate matter-generating sources and all other air pollutant sources to reduce health-related complications and enhance air quality standards. Additionally, school owners, both the government and the private schools should maintain a clean environment devoid of excessive dust emissions to ensure healthy air quality.

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