



EXPERIMENTAL INVESTIGATION OF OUTDOOR AIR QUALITY AT A TERTIARY INSTITUTION GATE

¹Asani, M. A., ²Idi, M. D. and ³Oke, I. A.

¹Department of Urban and Regional Planning, Ladoké Akintola University Technology, Ogbomosho, Nigeria

²Land, Air and Water Consulting Engineers, B105 Ramat Shopping Complex, Maiduguri, Borno State, Nigeria

³Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

E-mail Addresses: maasani@lautech.edu.ng; okeia@hotmail.com or okeia@oauife.edu.ng

Telephone Number: +234-08065476509, 08032323276

Asani M. A., Idi M. D. and Oke I. A. (2022): Experimental Investigation of Outdoor Air Quality at a Tertiary Institution Gate. *Journal of Engineering and Engineering Technology* /16(2), 58-72

Submission Date- 29-06-21

Accepted Date- 30-08-22

Abstract

Air pollution is the reduction in the outdoor or indoor environment quality by any physical, biological or chemical agents above the ambient level that can modify the natural characteristics of the atmosphere. Air pollution can cause long-term and short-term health effects. In this paper air quality of an institutional environment was evaluated and presented based on selected air pollutants, air quality indices (AQI), hazard ratio and lifetime cancer risk. Air quality measurements were conducted at Obafemi Awolowo University Road 1 gate for three months. The Air quality indices were computed using standard methods and procedures. The study revealed that mean, skewness and kurtosis of temperature, relative humidity, total organic compounds (TVOC), Carbon dioxide (CO₂) and HCHO were temperature (34.2, 34.3°C; 0.6 and 0.6; -0.4 and -0.4); relative humidity (35.46 and 39.23 %; 1.52 and 1.54; and 1.67 and 1.73), TVOC (0.753 ppm and 0.660 ppm; 1.501 and 1.541; and 1.331 and 1.116), CO₂ (926.77 ppm and 803.77 ppm; -0.70 and -0.63; -1.27, and -1.22) and HCHO (0.051 ppm and 0.048 ppm; 1.123 and 1.51; and 0.504 and 1.69), respectively. AQI for CO₂, TVOC and HCHO were between 135 and 336, 16.72 and 173.02, 12.37, and 2191.42, respectively. Life cancer risk for CO₂, TVOC and HCHO were between 2.42×10^{-3} and 6.02×10^{-3} , 2.36×10^{-6} and 9.06×10^{-5} , 2.63×10^{-8} and 2.36×10^{-6} respectively.

It was concluded that AQI in-term of CO₂ was high (poor and polluted) but fair for TVOC and HCHO. There is a need to reduce CO₂ concentration as an increase in CO concentration has been associated with cardiovascular diseases, high blood pressure and chronic kidney disease.

Keywords: Carbon dioxide, formaldehyde, outdoor air quality, total volatile organic compounds, air quality indices and lifetime cancer risk

Introduction

Atmospheric pollution results from natural causes as well as from man's activities and the results of increasing environmental pollution due to the anthropogenic activities of man are of great concern worldwide (Yaru, 2021). Air pollution is both an indoor and outdoor universal environmental problem that has effects mostly on the health of the urban population (Gorai and Goyal, 2015). Over the past few years, epidemiological research has established adverse health effects of air pollution due to higher concentrations than ambient concentrations of these air pollutants (Gorai and Goyal, 2015; Baris *et al.*, 2019). Research has indicated that repeated exposures to these ambient air pollutants over a protracted period of time increase the risk of being susceptible to airborne diseases, such as (cardiovascular disease, respiratory disease, and lung cancer (Gorai and Goyal, 2015; Baris *et al.*, 2019).

Air pollution has been dependably linked to considerable burdens of ill-health in developed and developing countries (Gorai *et al.*, 2014a, 2014b; Bruce *et al.*, 2000; Smith *et al.*, 2000). Air pollution is becoming a topic of intense research at all levels because of the increased level of anthropogenic activities and climatic changes (Njoku *et al.*, 2016). It has been reported that air pollution in the urban centre has increased rapidly due to high population-density, such as increased numbers of motor vehicles, use of fuels with poor environmental performance, poorly maintained transportation systems and above all, ineffective environmental regulations and policies (Komolafe *et al.*, 2014). Air pollution is believed to have killed more people worldwide than AIDS, malaria, breast cancer, or tuberculosis (WHO, 2014). Airborne particulate matters are, especially detrimental to health (Beelen *et al.*, 2013), and have previously been estimated to cause between 3 and 7 million deaths every year, primarily by creating or worsening cardio-

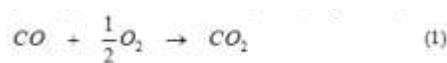
respiratory disease (Hoek *et al.*, 2013; Baris *et al.*, 2019). Air pollutants sources include electric power plants, industrial facilities, automobiles, biomass burning, and fossil fuels used in homes and factories for heating. Air pollutants can be in the form of solid particles, liquid droplets, or gases (Njoku *et al.*, 2016). Globally, many cities and institutions are continuously assessing air quality using monitoring networks designed to measure and record air pollutant concentrations at several points deemed to represent the exposure of the population to these pollutants (Njoku *et al.*, 2016). The World Health Organization (WHO) estimates that 25 % of all deaths in the developing world can be directly attributed to environmental factors (Gorai and Goyal, 2015). The problem of air pollution and its corresponding adverse health impacts have been aggravated due to increasing industrial and other developmental activities. The monitoring concentrations of air pollutants in the residential, institutional commercial, and industrial areas are used for the calculation of air quality index (AQI) or air pollution index (API), which are indications of air quality levels. These air quality indices were so varied that it was necessary to develop a system to classify indices according to four Criteria (Ott and Thorn, 1975; 1976) as follows: a number of variables; calculation method; calculation mode; and descriptor categories reported with the index (Ott and Thorn, 1976).

Several types of research have been conducted on assessing air quality in traffic-dense areas, industrial zones, classrooms, in academic environments of institutions (primary, secondary and tertiary) in a selected part of Nigeria, but there seems to be a paucity of information on monitoring considering the contribution of pollutants from vehicular traffic and other activities at the entrance of tertiary institutions. Hence, the objective of this study is to present the air quality monitoring data of selected gaseous pollutants (Carbon – dioxide (CO₂), total volatile organic compounds, Formaldehyde) and environmental parameters (temperature, relative humidity) at the

Obafemi Awolowo University entrance (gate) and to highlight the ecological and health associated problems. It is equally hoped that the AQI rating for ambient air quality will generate data for further research on air quality control and management.

Materials and Method

Measurement of air quality was undertaken at Obafemi Awolowo University, Ile – Ife, Nigeria Road 1 (known as Aderemi Adesoji Road) gate (Figure 1, located at 7° 30' 16" N, 4° 31' 32" E with an elevation of 261 m) between March and May 2021 on weekdays (Monday to Friday) and weekends (Saturday and Sunday), for approximately (limited by visibility and safety factors) 12 hours per day (6:30 a.m. to 6:30 p.m.). Road 1 gate is a section of busy Ife-Ibadan or Ife-Ede Road. The intensities of vehicular movement and other commercial activities are very high. These activities give room for the emission of gases and air pollution. Temperature and relative humidity were measured using 556- HTC-1 for temperature and relative humidity. Air quality detector JSM-131SC was used for the measurement of Carbon – dioxide (CO₂), total volatile organic compounds (TVOC), Carbon – monoxide (as CO₂, Equation 1) and Formaldehyde (HCHO).



Effects of time and season of the air pollutant level were evaluated statistically using analysis of variance (ANOVA). Descriptive statistical analysis (mean, standard error, median, standard deviation, kurtosis, skewness, minimum and maximum) was used to express the results. Kurtosis and skewness were determined to establish the concentration distribution of the air pollutants during the selected period.

Skewness is a measure of symmetry or, more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the centre point. The Skewness for a normal distribution is zero, and any symmetric data should have skewness near zero.



Figure 1: Aerial View Obafemi Awolowo University and Road 1 gate (Goggle map, 2021)

Negative values for the skewness indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right. The literature reported that Skewness greater than zero (Right skewed distribution - most values are concentrated on left of the mean, with extreme values to the right). When Skewness is less than zero (Left skewed distribution - most values are concentrated on the right of the mean, with extreme values to the left) and when Skewness is equal to zero (mean = median, the distribution is symmetrical around the mean). Skewness was computed as follows (Equation 2):

$$\gamma = \frac{\sum_{i=1}^N (Y - \bar{Y})^3}{N\delta^3} \quad (2)$$

Where; γ is the skewness, δ is the standard deviation,

Y is the year rainfall; $\bar{Y}$ is the mean rainfall and N is the number of samples.

Kurtosis (β) is a measure of data peakedness or flatness relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution. The literature stated that when Kurtosis is greater than 3, it is leptokurtic distribution, sharper than a normal distribution, with values concentrated around the mean and thicker tails. This means a high probability of extreme values. When Kurtosis is less than 3, it is a platykurtic distribution, flatter than a normal distribution with a wider peak. The probability for extreme values is less than for a normal distribution, and the values are wider spread around the mean. When Kurtosis is equal to 3, it is then a mesokurtic distribution (normal distribution). It was computed as follows (Equation 3):

$$\beta = \frac{\sum_{i=1}^N (Y - \bar{Y})^4}{N\delta^4} \quad (3)$$

Air quality levels were computed using standard air quality indices (Oak Ridge Air Quality Index (ORAQI), Air Quality Index (AQI), hazard ratio and total hazard ratio, lifetime cancer risk and the global lifetime cancer risk).

Air Quality Index (AQI): Air Quality Index (AQI) is used for describing ambient air quality. The indices for each of the pollutants were derived using the mathematical formula as follows (Njoku *et al.*, 2016, Equation 4):

$$AQI = 100 \left(\frac{C_i}{C_s} \right) \quad (4)$$

Where; AQI is the air quality index, C_s is the pollutant standard concentration and C_i is the pollutant concentration reading from the device.

Lifetime cancer risk and the global Lifetime cancer risk: Lifetime cancer risk and the global Lifetime cancer risk attributed to inhalation exposures of the air pollutant were computed as follows (Tracey *et al.*, 2000, Wisit *et al.*, 2017, Gianluigi *et al.*, 2013, Equation 5):

$$LCR_i = C_i \times UR_i \quad (5)$$

Relationship between ppm and concentration can be express as follows (WHO, 2017; Yaru, 2021):

$$\text{ppm} = \frac{24.45 \times \text{Concentration}(\text{mg m}^{-3})}{\text{Molecular Mass}}$$

Where; LCR_i is the Lifetime cancer risk of air pollutant I , and UR_i is the unit risk of air pollutant I (Equation 6).

$$LCR_{\text{tg}} = \sum_{i=1}^N (C_i \times UR_i) \quad (6)$$

Where; LCR_{ig} is the global lifetime cancer risk of air pollutants

The Integrated Risk Information System (IRIS) is an Environmental Protection Agency (US EPA) database of human health effects that may result from exposure to various substances found in the environment suggested a unit risk of $2.9 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ of HCHO concentration and $3.0 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ of TVOCs and CO_2 concentrations (Wisit *et al.*, 2017, WHO, 2017).

Hazard ratio (HR) and total hazard ratio (THR):

Hazard ratio (HR) and total hazard ratio (THR) attributed to inhalation exposures of the air pollutants were computed as follows (Gianluigi *et al.*, 2013, Equations 7 and 8):

$$HR_i = \frac{C_i}{C_r} \quad (7)$$

$$THR = \sum_{i=1}^N HR_i \quad (8)$$

Oak Ridge Air Quality Index (ORAQI) is one of the equations for the nonlinear (Type A) index, which is express as follows (Ott and Thorn, 1976, Tiwari, 2015, Fezari *et al.*, 2015, Equation 9):

$$ORAQI = \left(5.7 \sum_{i=1}^N HR_i \right)^{1.37} \quad (9)$$

It is well stated that air quality index (AQI) is a rating scale for outdoor air. The lower the AQI value the better the air quality. AQI rating A stand for Very good (0 -15), B for Good (16 -31), C for Moderate (32 – 49), D for Poor (50 – 99) and E for Very poor (100 and over) (Njoku *et al.*, 2016)

Results and Discussion

Results and discussion from the study are presented as follows:

a. Temperature: Table 1a presents a statistical

summary of temperature (weekdays and weekends) during the study. The study revealed that the minimum, maximum and mean of the temperatures (weekdays and weekends) were (31.4, 31.5°C), (38.1, 38.2°C) and (34.2, 34.3°C). In addition, Kurtosis, Skewness, Median and Standard Deviation are presented in Table 1. Table 2 presents an ANOVA of the temperature. The table shows the effects of time, days and weekends on temperature. The table revealed that there is a significant difference between the temperature within the time ($F_{12, 12} = 11519.92$; $p = 1.97 \times 10^{-22}$, less than 0.05) and within the weekend and days ($F_{1, 12} = 129.6771$; $p = 8.65 \times 10^{-8}$, less than 0.05). The table revealed that temperatures were higher during the weekend than during the weekday. These results may be attributed to social and religious activities at the Gate (take-off and stopping or returning points for social and religious activities during the weekend using common buses). These results agree with the literature Leal-Junior *et al.* (2018) and Gupta and Patel (2017) on significant differences in the temperature in relation to climate.

b. Relative humidity: The degree of saturation, may be expressed as the relative humidity of the air, which is the ratio of the actual water vapour pressure of the air to that at saturation for the same temperature. Table 1a presents a statistical summary of the relative humidity during the study. The study revealed that the minimum, maximum and mean values of the relative humidity were 27.00 % and 30.81 %, 58.00 and 60.74 %, and 35.46 % and 39.23 %, (weekdays and weekends) respectively. These results revealed that the environment was dry and of moderate temperature. The relationship of temperature and relative humidity is as presented in the Relative Humidity table (Irgum, 1983; Dymond, 2007; Pinto *et al.*, 2015; Zhao *et al.*, 2014; Da Cunba, 2015; Hird and Bolton, 2016; Murmu and

Mishra, 2016 and Shin *et al.*, 2017; Figure 2), there are some disagreements between the values on the Table and instrumental readings. This indicated that there is a need to calibrate the equipment for higher levels of accuracy. Table 3 presents an ANOVA of the relative humidity. The table shows the effects of time, weekdays and weekends on relative humidity. The table revealed that there is a significant difference between the relative humidity within the time ($F_{12,12} = 1173.234$; $p = 1.76 \times 10^{-16}$, less than 0.05) and within the weekend and days ($F_{1,12} = 626.39$; $p = 1.00 \times 10^{-11}$, less than 0.05).

Table 1a: A statistical summary of temperature and Relative Humidity (weekdays and weekends) during the study

Time of the Day	Temperature (°C)		Relative humidity (%)	
	Weekdays	Weekends	Weekdays	Weekends
6.30 am	31.4	31.5	41.0	44.1
7.30 am	32.6	32.7	29.0	32.3
8.30 am	34.2	34.3	29.0	32.4
9.30 am	33.6	33.7	30.0	33.4
10.30 am	35.6	35.7	29.0	32.6
11.30 am	35.8	35.9	31.0	34.6
12.30 pm	37.6	37.7	28.0	31.8
13.30 pm	38.1	38.2	27.0	30.8
14.30 pm	34.6	34.7	36.0	39.5
15.30 pm	34.1	34.3	51.0	54.4
16.30 pm	33.1	33.3	37.0	40.3
17.30 pm	32.4	32.6	58.0	61.2
18.30 pm	31.8	32.0	35.0	38.2
Mean	34.2	34.3	35.46	39.23
Median	34.1	34.3	31.00	35.28
Standard Deviation	2.1	2.1	9.51	9.09
Kurtosis	-0.4	-0.4	1.67	1.73
Skewness	0.6	0.6	1.52	1.54
Minimum	31.4	31.5	27.00	30.81
Maximum	38.1	38.2	58.00	60.74

Table 2: ANOVA for Temperature

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F crit
Time	104.8313	12	8.735938	11519.92	1.97×10^{-22}	2.686637
Days	0.098338	1	0.098338	129.6771	8.65×10^{-08}	4.747225
Error	0.0091	12	0.000758			
Total	104.9387	25				

a. Carbon dioxide: Outdoor pollutant properties of CO and CO₂ at a global scale are well documented, but in outdoor environments, CO₂ cannot be considered a pollutant, but represents an important proxy indicator of air quality. Table 1b presents the statistical summary of relative humidity during the study. The study revealed that the minimum values, the maximum values and the mean of CO₂ were 592 ppm and 449 ppm, 1199 ppm and 1044 ppm, and 926.77 ppm and 803.77 ppm for weekdays and weekend, respectively. Table 4 presents ANOVA of the CO and CO₂. The table shows the effects of time, days and weekends on these pollutants. The table revealed that there is a significant difference between the pollution level of these pollutants within the time ($F_{12,12} = 121.47$; $p = 1.32 \times 10^{-10}$, less than 0.05) and within the weekend and days ($F_{1,12} = 129.6771$; $p = 8.65 \times 10^{-8}$, less than 0.05). Previous studies revealed that indoor to the outdoor ratio of these pollutants is greater than one in most of the classrooms, indicating the internal source prominent, with a low level of outdoor intrusions; levels of 600–1000 ppm is normally registered in the literature, indicative of inadequate ventilation rates (Apte *et al.*, 2000, Yaru, 2021), with peaks of 4,000 ppm (Daisey *et al.*, 2003; Clements-Croome, 2006). Exposure to these pollutants is associated with asthma (Mi *et al.* 2006) and values of 1,000 ppm are associated with a 10–20 % increase in student presence in schools (Shendell *et al.*, 2004), thus indicating CO₂ concentrations is a primary variable in the health risk assessment of people in school (Rudnick and Milton, 2003). Baris *et al.*, (2019) reported that an increase in CO and CO₂ concentration as air pollutant is associated with an increased risk of chronic kidney disease, estimated glomerular filtration rate decline and end-stage renal disease. Table 5 presents the standard air quality index of CO and CO₂. The results revealed that AQI was in the range of 135 to 336, HR and OAQI were between 1.35 and 3.36, while LCR was between 2.42×10^{-3} and 6.04×10^{-3} . Figure 3 presents the relationship between the concentration of CO, CO₂ and time. The figure revealed that there was a non-linear relationship. These results indicate that the quality of air in the environment was moderate and exposure to this environment for a long time is dangerous to asthmatic patients. The health messages are that there is no need to modify your usual outdoor activities (general

population), but people with heart or breathing problems, and experience symptoms, should consider reducing physical exertion outdoors or rescheduling activities to times when the index is lower.

Formaldehyde (HCHO): HCHO is defined as a human carcinogen on the basis of a sufficient evidence of carcinogenicity from studies in animals and humans and of supporting data on mechanisms of carcinogenesis. Table 1 presents statistical summary of HCHO during the study. The study revealed that minimum, maximum and mean of HCHO were 0.001 ppm and 0.007 ppm, 0.177 ppm and 0.183 ppm, and 0.051 and 0.048 ppm for weekdays and weekend, respectively. The kurtosis and skewness were 0.50 and 1.69, and 1.23 and 1.51 for weekdays and weekends, respectively. Table 6 presents the ANOVA of the HCHO. The table shows the effects of time, days and weekends on these pollutants. The table revealed that there is a significant difference between the pollution level of these pollutants within the time ($F_{12,12} = 146.81$; $p = 5.74 \times 10^{-19}$, less than 0.05) and within the weekend and days there was no significant difference but the days had effects on the pollution level in respect of HCHO ($F_{1,12} = 1.114$; $p = 0.312$, which greater than 0.05). Table 7 presents the standard air quality index of HCHO. The results revealed that AQI was in the range of 0.001 to 2.26, HR and OAQI were between 0.00 and 0.02, while LCR was between 3.56×10^{-9} and 6.51×10^{-7} . These results indicate that the quality of air in the environment was moderately good and exposure to this environment for a long time is not dangerous to asthmatic patients. The health messages are that there is no need to modify your usual outdoor activities (general population) and people with heart or breathing problems, and experience symptoms, should not consider reducing physical exertion outdoors or rescheduling activities as the index is lower in respect to HCHO. In recent years, scientific papers published during the last 10 years reported experimental results obtained from the investigation of HCHO and other carbonyl compounds in school buildings (Gianluigi *et al.*, 2014, Sofuoglu *et al.* 2010; 2011; Yamashita *et al.* 2012; Pegas *et al.* 2010; 2011a and b; 2012). Pegas *et al.* (2011a) measured indoor and outdoor concentrations of HCHO and other carbonyls in 14 elementary schools in Lisbon, Portugal. In all the investigated environments, indoor aldehydes' levels

were higher than those observed outdoors. Pegas *et al.* (2011b) carried out a further measuring campaign in school buildings in order to evaluate seasonal variation in indoor and outdoor levels. Most of the assessed carbonyls occurred at input-to-output ratios above unity in all the seasons, and this evidence showed the

influence of indoor sources and building conditions on indoor air quality. However, it was observed that carbonyls' levels were higher during the warm months. Sofuoğlu *et al.* (2011) reported HCHO levels measured in primary school classrooms and kindergartens in Turkey.

Table 1b: Statistical summary of the air quality parameters measured

Time of the Day	Carbon Dioxide (ppm)		TVOC (ppm)		HCHO (ppm)	
	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
6.30 am	1096	1033	0.586	0.4764	0.183	0.17714
7.30 am	1117	1044	1.945	1.8333	0.132	0.11255
8.30 am	1119	1036	0.638	0.5261	0.001	0.00738
9.30 am	1092	999	0.572	0.4628	0.001	0.00672
10.30 am	875	772	0.59	0.5025	0.052	0.0461
11.30 am	1000	887	0.941	0.841	0.001	0.01041
12.30 pm	738	615	0.478	0.4042	0.056	0.05122
13.30 pm	1012	879	0.981	0.8798	0.002	0.01181
14.30 pm	592	449	0.313	0.2538	0.017	0.01387
15.30 pm	620	467	0.25	0.188	0.015	0.0125
16.30 pm	1009	846	0.296	0.1951	0.052	0.04904
17.30 pm	1115	942	1.905	1.7935	0.126	0.10695
18.30 pm	663	480	0.294	0.2277	0.026	0.02306
Mean	926.77	803.77	0.753	0.660	0.051077	0.048365
Median	1009.00	879.00	0.586	0.476	0.026	0.02306
Standard Deviation	203.71	226.67	0.568	0.556	0.059592	0.052802
Kurtosis	-1.27	-1.22	1.331	1.416	0.50481	1.694224
Skewness	-0.70	-0.63	1.501	1.541	1.232926	1.507243
Minimum	592.00	449.00	0.250	0.188	0.001	0.00672
Maximum	1119.00	1044.00	1.945	1.833	0.183	0.17714

Table 3: ANOVA for Relative humidity

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F crit
Time	2074.728	12	172.894	1173.234	1.76×10^{-16}	2.686637
Days	92.30847	1	92.30847	626.3918	1.00×10^{-11}	4.747225
Error	1.768385	12	0.147365			
Total	2168.805	25				

Table 4: ANOVA for Carbon Dioxide

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F crit
Time	1105393	12	92116.05	121.4717	1.32×10^{-10}	2.686637
Days	98338.5	1	98338.5	129.6771	8.65×10^{-8}	4.747225
Error	9100	12	758.3333			
Total	1212831	25				

Table 5: Standard air quality index for CO and CO₂

Time of the Day	AQI		HR		OAQI		LCR	
	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend
6.30 am	329	310	3.29	3.10	3.29	3.10	5.92 x10 ⁻³	5.58 x10 ⁻³
7.30 am	335	314	3.35	3.14	3.35	3.14	6.03 x10 ⁻³	5.64 x10 ⁻³
8.30 am	336	311	3.36	3.11	3.36	3.11	6.04 x10 ⁻³	5.59 x10 ⁻³
9.30 am	328	300	3.28	3.00	3.28	3.00	5.90 x10 ⁻³	5.39 x10 ⁻³
10.30 am	263	232	2.63	2.32	2.63	2.32	4.72 x10 ⁻³	4.17 x10 ⁻³
11.30 am	300	266	3.00	2.66	3.00	2.66	5.40 x10 ⁻³	4.79 x10 ⁻³
12.30 pm	222	185	2.22	1.85	2.22	1.85	3.98 x10 ⁻³	3.32 x10 ⁻³
13.30 pm	304	264	3.04	2.64	3.04	2.64	5.46 x10 ⁻³	4.75 x10 ⁻³
14.30 pm	178	135	1.78	1.35	1.78	1.35	3.20 x10 ⁻³	2.42 x10 ⁻³
15.30 pm	186	140	1.86	1.40	1.86	1.40	3.35 x10 ⁻³	2.52 x10 ⁻³
16.30 pm	303	254	3.03	2.54	3.03	2.54	5.45 x10 ⁻³	4.57 x10 ⁻³
17.30 pm	335	283	3.35	2.83	3.35	2.83	6.02 x10 ⁻³	5.09 x10 ⁻³
18.30 pm	199	144	1.99	1.44	1.99	1.44	3.58 x10 ⁻³	2.59 x10 ⁻³
Total			36.18	31.38	36.18	31.38	0.07	0.06
OAQI					1481.34	1218.80		

Experimental data revealed that HCHO was one of the most abundant indoor pollutants and that concentrations were related to both spatial and seasonal variability. Similar HCHO levels between urban and suburban schools, but different HCHO levels between two urban schools can be explained by the relative strength of the indoor HCHO sources compared with the outdoor ones. The HCHO concentrations measured in classrooms were in the literature range (10–400 µg/m³) although the results are high if compared with data related to schools in Sweden (Smedje *et al.* 1997a, 1997b; 2011) China (Lee *et al.* 2004) and Australia (Zhang *et al.*, 2006; Zhang and Zhu, 2012; Zhu *et al.*, 2010). Furthermore, HCHO levels in classrooms were lower than the concentrations measured in homes and offices (Mentese and Gullu 2006; Vaizoglu *et al.*, 2003) but similar to those in libraries (Righi *et al.*, 2002; Hanoune *et al.*, 2006). Regarding kindergartens, HCHO levels were higher than those measured in classrooms and the difference in urban and suburban concentrations was not significant. It can be asserted that there were consistent sources of HCHO inside

kindergartens because neither seasonal nor spatial differences were significant. The overall average of the concentrations measured in this study (85 µg/m³) was clearly higher than the Dutch kindergartens (from 6 to 11 µg/m³) (Kotzias 2005) and in the range of the Danish and Korean kindergartens (Yang *et al.* 2009). Figure 4 shows the relationship between CO₂, HCHO and time. All these results revealed that HCHO is not a major outdoor air pollutant but rather an indoor air pollutant that must be taken care of.

a. Volatile organic compounds (VOC): Total volatile organic compounds are widely present in school environments as they are emitted from multiple both internal and outdoor sources. Among the VOC, the high priority pollutants that are regulated in indoor environments and that significantly affect human's health are Benzene, Naphthalene, Formaldehyde, Toluene, Xylenes, Styrene, Limonene, Alpha-pinene and Dichloromethane. Benzene, Toluene, Xylenes and Styrene can be emitted from solvent-based paints and consumer products (Kotzias, 2005; Canha *et al.*, 2012; Gianluigi *et al.*, 2014).

Table 6: ANOVA for HCHO

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F crit
Time	0.075556	12	0.006296	146.814	4.3 x10 ⁻¹¹	2.686637
Days	4.78 x10 ⁻⁵	1	4.78 x10 ⁻⁵	1.114352	0.311928	4.747225
Error	0.000515	12	4.29 x10 ⁻⁵			
Total	0.076119	25				

Table 7: Standard air quality index for HCHO

Time of the Day	AQI		HR		OAQI		LCR	
	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend
6.30 am	2.26	2.19	0.02	0.02	0.02	0.02	6.51×10^{-7}	6.30×10^{-7}
7.30 am	1.63	1.39	0.02	0.01	0.02	0.01	4.70×10^{-7}	4.00×10^{-7}
8.30 am	0.01	0.09	0.00	0.00	0.00	0.00	3.56×10^{-9}	2.63×10^{-8}
9.30 am	0.01	0.08	0.00	0.00	0.00	0.00	3.56×10^{-9}	2.39×10^{-8}
10.30 am	0.64	0.57	0.01	0.01	0.01	0.01	1.85×10^{-7}	1.64×10^{-7}
11.30 am	0.01	0.13	0.00	0.00	0.00	0.00	3.56×10^{-8}	3.70×10^{-8}
12.30 pm	0.69	0.63	0.01	0.01	0.01	0.01	1.99×10^{-7}	1.82×10^{-7}
13.30 pm	0.02	0.15	0.00	0.00	0.00	0.00	7.12×10^{-9}	4.20×10^{-8}
14.30 pm	0.21	0.17	0.00	0.00	0.00	0.00	6.05×10^{-8}	4.94×10^{-8}
15.30 pm	0.19	0.15	0.00	0.00	0.00	0.00	5.34×10^{-8}	4.45×10^{-8}
16.30 pm	0.64	0.61	0.01	0.01	0.01	0.01	1.85×10^{-7}	1.74×10^{-7}
17.30 pm	1.56	1.32	0.02	0.01	0.02	0.01	4.48×10^{-7}	3.81×10^{-7}
18.30 pm	0.32	0.29	0.00	0.00	0.00	0.00	9.25×10^{-8}	8.21×10^{-8}
Total			0.08	0.08	0.08	0.08	2.36×10^{-6}	2.24×10^{-6}
OAQI					0.35	0.33	6.51×10^{-7}	6.30×10^{-7}

Dichloromethane is found in adhesives, spray paints, while the presence of Limonene and Alpha-pinene is more related to the emission from cleaning products (aerosol and liquid) (Priscilla *et al.* 2010 ; Canha *et al.*, 2012; Gianluigi *et al.*, 2014). Polymeric materials that are used for construction, decoration and furnishing of schools are high VOC emitters due to their composition and large surface areas. Moreover, wood-based products used for construction of writing desks and cabinets are important sources of these pollutants in these environments. Some TVOCs are associated with a variety of serious health effects (Shendell *et al.* 2004 ; Canha *et al.*, 2012; Gianluigi *et al.*, 2014) and symptoms such as asthma and allergic reactions (Sofuoglu *et al.* 2011). Several studies reported a strong association between mucous membrane irritation, central nervous system symptoms and total exposure to VOC; these symptoms are similar to those that are frequently attributed as a cause of sick-building syndrome (Canha *et al.*, 2012; Gianluigi *et al.*, 2014). In case of extreme concentrations, some VOC may result in impaired neurobehavioral function (Burton 1997). Exposure to high concentrations of several VOCs commonly found in indoor air is associated with cancers in laboratory animals (Jones 1999 ; Canha *et al.*, 2012; Gianluigi *et al.*, 2014). Table 1 presents a statistical summary of TVOC during the study. The study revealed that the minimum, maximum and mean of HCHO were 0.250 ppm and 0.188 ppm, 1.833 ppm and 1.945 ppm, and 0.660 and 0.753 ppm for weekdays and weekends, respectively. The kurtosis and skewness were 1.331 and 1.416, and 1.501 and 1.541 for weekdays and weekends, respectively. Table 8 presents the ANOVA of the TVOC. The table shows the effects of time, days and weekends on these pollutants.

The table revealed that there is a significant difference between the pollution level of these pollutants within the time ($F_{12,12} = 3048.039$; $p = 5.74 \times 10^{-19}$, less than 0.05) and within the weekend and days there was no significant difference but the days had effects on the pollution level in respect of TVOC ($F_{1,12} = 269.072$; $p = 1.39 \times 10^{-9}$, less than 0.05). Table 9 presents the standard air quality index of HCHO. The results revealed that AQI was in the range of 0.001 to 2.26, HR and OAQI were between 0.00 and 0.02, while LCR was between 3.56×10^{-9} and 6.51×10^{-7} . These results indicate that the quality of air in the environment was moderately good and exposure to this environment for a long time is not dangerous to asthmatic patients. The health messages are that there is no need to modify your usual outdoor activities (general population) and people with heart or breathing problems, and experience symptoms, should not consider reducing physical exertion outdoors or rescheduling activities as the index is lower with respect to TVOC. Volatile organic compounds monitoring campaigns conducted in different school environments of several cities (Michigan, Catania, Athens, Arnhem and Nijmegen, Brussels, Milan, Thessaloniki, Nicosia) highlighted that indoor sources, micrometeorological parameters and building conditions might have negative effects on indoor air quality (Pegas *et al.* 2010, 2012). Moreover, it was found that increasing ventilation rates and using low-emission materials improve indoor air quality (Pegas *et al.* 2010). Godwin and Batterman 2007, monitoring VOC concentrations over one workweek in 64 elementary and middle school classrooms in Michigan, found that most VOC had low concentrations (mean of individual species $4.5 \mu\text{g}/\text{m}^3$) also if they were higher than outdoor air concentrations

(mean of individual species $0.51 \mu\text{g}/\text{m}^3$) higher indoor levels of many VOC were registered in two studies involving 14 elementary schools in Lisbon, Portugal (Pegas *et al.*, 2010; 2012). Almost all identified VOC (up to 40 compounds) showed Input to Output ratios higher than one. The same results were found by Kotzias (2005) in schools and kindergartens of several cities in Southern and Central Europe: the sum of indoor concentrations ranged from a few micrograms (0.8) to $281 \mu\text{g}/\text{m}^3$, while outdoor levels ranged from 7 to $153 \mu\text{g}/\text{m}^3$. VOC concentrations two to four times higher than the outdoor concentrations were detected in kindergartens and schools of Arnhem and Nijmegen and in Izmir (Turkey) (Shendell *et al.*, 2004; Sofuoglu

et al., 2011; Stranger *et al.*, 2008). Among monitored VOC, benzene, toluene, ethylbenzene and xylenes were the most abundant compounds with Input to Output ratios exceeding unity. A huge increase in indoor VOC concentrations was also observed when artworks or science activities were undertaken concurrently or just prior to the measurements (Shendell *et al.* 2004; Godwin and Batterman 2007; Pegas *et al.*, 2010). In particular, Pegas *et al.* (2010) found that there was an increase in VOC concentrations reaching 13 ppm, when glue and paints were used in pupil's art class. Figure 5 shows a relationship between TVOC, HCHO and the time of the day.

Table 8: ANOVA for TVOCs

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F crit
Time	7.589105	12	0.632425	3048.039	5.74×10^{-19}	2.686637
Days	0.055829	1	0.055829	269.0716	1.39×10^{-9}	4.747225
Error	0.00249	12	0.000207			
Total	7.647423	25				

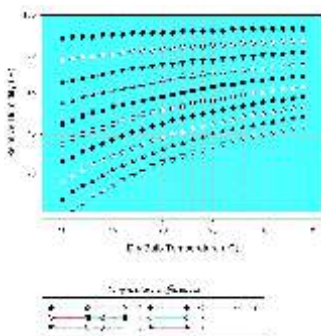


Figure 2a: Relationship between Temperature and Relative Humidity

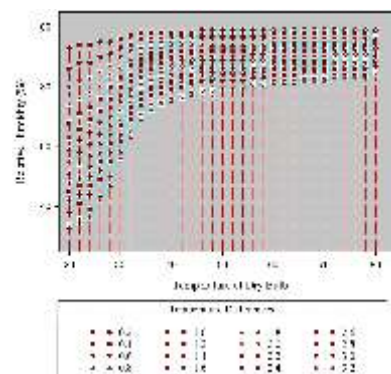


Figure 2b: Relationship between Temperature and Relative Humidity (0.2 to 3.2 Temperature difference)

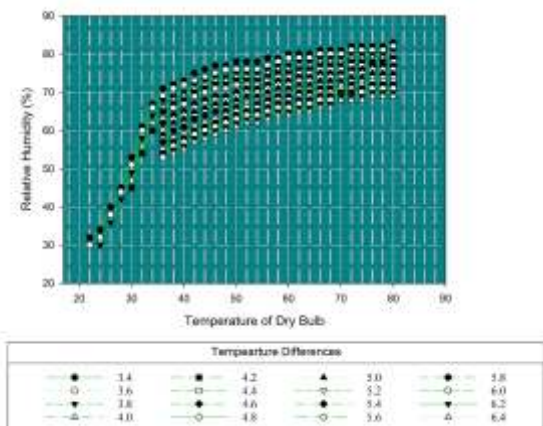


Figure 2c: Relationship between Temperature and Relative Humidity (3.4 to 6.4 Temperature difference)

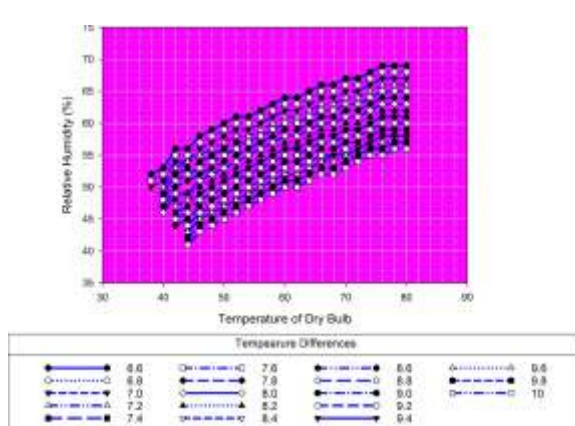


Figure 2d: Relationship between Temperature and Relative Humidity (6.6 to 10.0 Temperature difference)

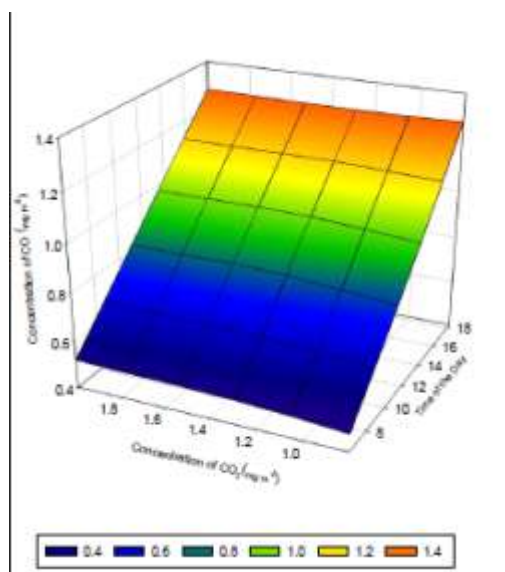


Figure 3: Relationship between time, CO₂ and CO

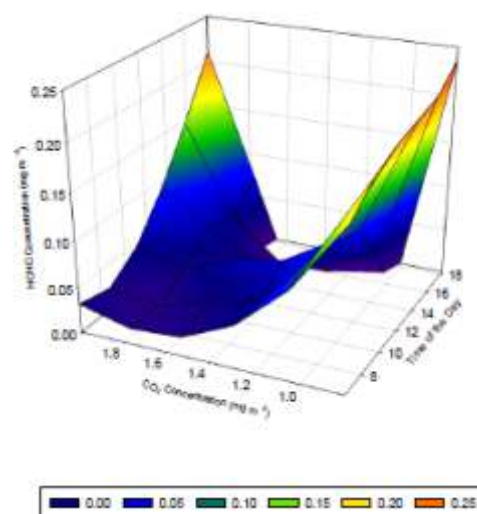


Figure 4: Relationship between time, CO₂ and HCHO

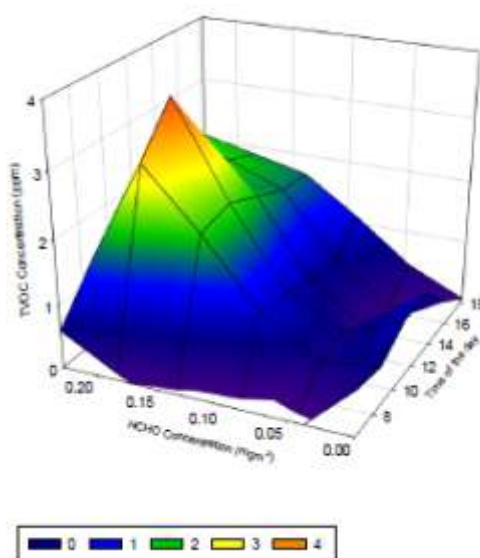


Figure 5: Relationship between time, HCHO and TVOC Concentrations

Table 9: Standard air quality index for TVOC

Time of the Day	AQI		HR		OAQI		LCR	
	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend	Weekdays	Weekend
6.30 am	52.13	42.38	0.52	0.42	0.52	0.42	5.42×10^{-6}	4.41×10^{-6}
7.30 am	173.02	163.08	1.73	1.63	1.73	1.63	1.80×10^{-5}	1.70×10^{-5}
8.30 am	56.75	46.80	0.57	0.47	0.57	0.47	5.90×10^{-6}	4.87×10^{-6}
9.30 am	50.88	41.17	0.51	0.41	0.51	0.41	5.29×10^{-6}	4.28×10^{-6}
10.30 am	52.48	44.70	0.52	0.45	0.52	0.45	5.46×10^{-6}	4.65×10^{-6}
11.30 am	83.71	74.81	0.84	0.75	0.84	0.75	8.71×10^{-6}	7.78×10^{-6}
12.30 pm	42.52	35.96	0.43	0.36	0.43	0.36	4.42×10^{-6}	3.74×10^{-6}
13.30 pm	87.27	78.26	0.87	0.78	0.87	0.78	9.08×10^{-6}	8.14×10^{-6}
14.30 pm	27.84	22.58	0.28	0.23	0.28	0.23	2.90×10^{-6}	2.35×10^{-6}
15.30 pm	22.24	16.72	0.22	0.17	0.22	0.17	2.31×10^{-6}	1.74×10^{-6}
16.30 pm	26.33	17.36	0.26	0.17	0.26	0.17	2.74×10^{-6}	1.80×10^{-6}
17.30 pm	169.46	159.54	1.69	1.60	1.69	1.60	1.76×10^{-5}	1.66×10^{-5}
18.30 pm	26.15	20.26	0.26	0.20	0.26	0.20	2.72×10^{-6}	2.11×10^{-6}
Total			8.71	7.64	8.71	7.64	9.06×10^{-5}	7.94×10^{-5}
OAQI					210.49	175.83		

Conclusion

It can be concluded that

- AQI in-term of CO₂ was poor (polluted) but fair for TVOC and HCHO;
- There is the need to reduce CO₂ concentration as an increase in CO concentration has been associated with cardiovascular diseases, high blood pressure and chronic kidney disease

ACKNOWLEDGEMENT

The authors wish to acknowledge SODIPO ADENIYI AYOKUNLE and ITEDJERE OGHENEYISUEN EMMANUEL of the Department of Civil Engineering Obafemi Awolowo University, Ile-Ife (Nigeria) for their roles in the data collection and field study.

REFERENCES

- Apte, M.G, Fisk, W.J, and Daisey, J.M (2000) Associations Between Indoor (CO₂) Concentrations and Sick Building Syndrome Symptoms in US Office Buildings: an analysis of the 1994–1996 BASE Study Data (LBNL 44385). *Indoor Air* 10:246–257.
- Baris, A., Rengin, E. A. , Asiye, K., Adrian, C., Alberto, O. and Mehmet, K. (2019). Air Pollution and Kidney Disease: review of current evidence. *Clinical Kidney Journal*, 12 (1), 19–32.
- Beelen, R., Raaschou-Nielsen, O., Stafoggia, M., Andersen, Z.J. and Weinmayr, G. (2013). Effects of Long-term Exposure to Air Pollution on Natural-cause Mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet* 383 (9919): 785-795.
- Bruce, N., Perez-Padilla, R., and Albalak, R. (2000) Indoor Air Pollution in Developing Countries: A Major Environmental and Public Health Challenge. *Bulletin of World Health Organisation* 78(9), 1078-1092
- Burton, B. T. (1997) Volatile Organic Compounds. In: Bardana, E.J, Montanaro, A. (eds) *Indoor Air Pollution and Health*. Marcel Dekker, New York, pp 127–153
- Canha, N., Martinho, M., Almeida-Silva, M., Freitas, M.D.C., Almeida, S.M., Pegas, P., Alves, C., Pio, C., Trancoso, M.A., Sousa, R., Mouro, F. and Conteiros, T. (2012) 'Indoor Air Quality in Primary Schools', *International Journal. Environment and Pollution*, 50 (1/2/3/4), 396–410.
- Clements-Croome, D. (2006) Ventilation Rates in Schools. *Build Environ* 43(3):362–367
- Da Cunha, A. R. (2015). Evaluation of Measurement Errors of Temperature and Relative Humidity from HOBO Data Logger Under Different Conditions of Exposure to Solar Radiation. *Environmental Monitoring and Assessment*, 187(5), 1-11

- Daisey, J.M, Angell, W.J, and Apte, M.G. (2003) Indoor Air Quality, Ventilation and Health Symptoms in Schools: An Analysis of Existing Information. *Indoor Air* 13:53–64
- Dymond, E. E. (2007). Table of Relative Humidity. *Quarterly Journal of the Royal Meteorological Society*, 7(37), 1–3.
- Fezari, M., Hattab, R. and Al-Dahoud, A. (2015) Oak Ridge Air Quality Index Computation: A Way for Monitoring Pollutions in Annaba City. The International Arab Conference on Information Technology (ACIT'2015), Isra University, 1-12
- Gianluigi de G. Paolo, R. D, Annamaria, D. L., Alessia, D. G., Pasquale, G., Maria, T., Annalisa, M., Antonio, M, Jolanda, P. and Francesca, P. (2014). Indoor air quality in schools. *Environ Chem Lett*. 1-16
- Gianluigi de G., Genoveffa, F., Annalisa, M., Antonio, M. and Godwin C, Batterman S (2007) Indoor Air Quality in Michigan Schools. *Indoor Air* 17:109–121
- Gorai, A.K., Kanchan, Upadhyay, A., and Goyal, P. (2014a) Design of Fuzzy Synthetic Evaluation Model For Air Quality Assessment. *Environment Systems and Decisions* 34, 456-469.
- Gorai, A.K., Tuluri, F., and Tchounwou, P.B. (2014b) A GIS Based Approach for Assessing the Association between Air Pollution and Asthma in New York State, USA. *International Journal Environmental Research and Public Health* .11(5), 4845-4869.
- Gorai, K.A.K and Goyal, P. (2015). A Review on Air Quality Indexing System. *Asian Journal of Atmospheric Environment* (9-2), 101-113.
- Gupta, P. K., and Patel, R. N. (2017). A Teaching-Learning Tool For Elementary Psychrometric Processes On Psychrometric Chart Using MATLAB. *Computer Applications in Engineering Education*, 25(3), 458–467
- Hanoune, B., LeBris, T., Allou, L, Marchand, C., and Calve, L. S. (2006) Formaldehyde Measurements in Libraries: Comparison Between Infrared Diode Laser Spectroscopy and A DNPH-Derivatization Method. *Atmosphere Environment* 40:5768–5775
- Hird, R., and Bolton, M. D. (2016). Measurement of Relative Humidity to Monitor Salt Migration in Unsaturated Porous Media. *Transport in Porous Media*, 112(3), 749–763.
- Hoek, G., Krishnan, R.M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B., and Kaufman, J.D. (2013). Long-term Air Pollution Exposure and Cardiorespiratory Mortality: A Review. *Environmental Health*, 12: 43 - 45.
- Irgum, K. (1983). Instrument For Relative Humidity Measurement. *Analytical Chemistry*, 55(7), 1186–1187.
- James, W. L., Winnie, K., Ralph, J. D., James, J. S. and Constantinos, S (2012) Characterization of Organic, Metal and Trace Element PM_{2.5} Species and Derivation of Freeway-Based Emission Rates in Los Angeles, CA. *Science of the Total Environment* 435–436, 159–166
- Jones, A.P. (1999) Indoor Air Quality and Health. *Atmospheric Environment*. 33(28):4535–4564
- Komolafe, A.A., Adegboyega, S.A., Anifowose, A.Y.B., Akinluyi, F.O., and Awoniran, D.R. (2014). Air Pollution and Climate Change in Lagos, Nigeria: Needs for Proactive Approaches to Risk Management and Adaptation. *American Journal of Environmental Sciences*, 10 (4): 412-423.
- Kotzias, D (2005) Indoor Air and Human Exposure Assessment—Needs and Approaches. *Exposure Toxicology Pathology*. 57:5–7
- Leal-Junior, A., Frizzera-Neto, A., Marques, C., and Pontes, M. (2018). Measurement of Temperature and Relative Humidity with Polymer Optical Fiber Sensors Based on the Induced Stress-Optic Effect. *Sensors*, 18(3), 916: 1 – 12.
- Lee, K., Parkhurst, W.J., Xue, J, Ozkaynak, A., Neuberg, D., and Spengler, J.D (2004) Outdoor/Indoor/Personal Ozone Exposures of Children in Nashville, Tennessee. *Air Waste Management Association* 54:352–359
- Maria, T.. (2013) Indoor and Outdoor Monitoring of Volatile Organic Compounds in School Buildings: Indicators Based on Health Risk Assessment to Single out Critical Issues. *International. Journal. Environment Resources. Public Health*, 10, 6273-6291.
- Mentese, S, and Gullu, G. (2006) Variations and Sources of Formaldehyde Levels in Residential Indoor Air in Ankara, Turkey. *Indoor Built Environment* 15:273–281
- Mi, Y.H, Norback, D, Tao, J, Mi, Y.L, and Ferm, M. (2006) Current Asthma and Respiratory Symptoms among Pupils in Shanghai, China: Influence of Building Ventilation, Nitrogen Dioxide, Ozone, and Formaldehyde in Classrooms. *Indoor Air* 16(6):454–464.
- Murmu, S. B., and Mishra, H. N. (2016). Measurement and Modelling the Effect of Temperature, Relative Humidity and Storage Duration on the Transpiration Rate of Three Banana Cultivars. *Scientia Horticulturae*, 209, 124–131.
- Njoku, K.; Longinus, R., Tosin, J. Akinola, M.; Olatunde, A, Adeola A., and Jolaoso, A. O. (2016). Ambient Air Quality Monitoring in Metropolitan City. *J. Appl. Sci. Environ. Manage*. 20(1), 178 – 185.
- Owoade, O.K., Fawole, O.G., Olise, F.S., Ogundele, L.T., Olaniyi, H.B., Almeida, M.S., Ho, M., and Hopke, P.K. (2013). Characterization and Source Identification of Airborne Particulate Loadings at Receptor Site Classes of Lagos Mega-City, Nigeria. *Journal of the Air and Waste Management Association*, 63:9: 1026-1035.

- Pegas P.N, Alves, C.A, Evtugina, M.G, Nunes, T, Cerqueira, M, Franchi, M, Pio, C.A, Almeida, S.M, and Freitas, M.C (2011a) Indoor Air Quality in Elementary Schools of Lisbon In Spring. *Environ Geochem Health* 33(5):455–468
- Pegas P.N, Alves, C.A, Evtugina, M.G, Nunes, T, Cerqueira, M, Franchi, M, Pio, C.A, Almeida, S.M, Verde, S.C, and Freitas, M. C. (2011b) Seasonal Evaluation of Outdoor/Indoor Air Quality in Primary Schools in Lisbon. *Journal Environment Monitoring*. 13(3):657–667
- Pegas, P. N, Nunes, T, Alves, C. A, Silva, J. R, Vieira, S.L.A, Caseiro, A., and Pio, C.A (2012) Indoor and outdoor characterisation of organic and inorganic compounds in city centre and suburban elementary schools of Aveiro, Portugal. *Atmos Environ* 55:80–89
- Pegas PN, Evtugina MG, Alves CA, Nunes T, Cerqueira M, Franchi M, Pio C, Almeida SM, Freitas M (2010) Outdoor/Indoor Air Quality in Primary Schools in Lisbon: a preliminary study. *Quim Nova* 33(5):1145–1149
- Pinto, J. A. V., Schorr, M. R. W., Thewes, F. R., Ceconi, D. L., Both, V., Brackmann, A., and Fronza, D. (2015). Relative Humidity During Cold Storage on Postharvest Quality of “Niagara Rosada” Table Grapes. *Ciência Rural*, 45(3), 386–391.
- Priscilla, N., Pegas, M., Evtugina, G., Alves, C. A, Nunes, T., Cerqueira, M., Franchi, M., and Pio, C. (2010) Outdoor/Indoor Air Quality in Primary Schools in Lisbon: A Preliminary Study. *Quim Nova* 33(5):1145–1149
- Righi, E., Aggazzotti, G., Fantuzzi, G., and Ciccacese, P.G (2002) Air Quality and Well-Being Perception in Subjects Attending University Libraries in Modena (Italy). *Science Total Environment*. 286:41–50
- Rudnick, S., and Milton, D.K (2003) Risk of Indoor Airborne Infection Transmission Estimated from Carbon Dioxide Concentration. *Indoor Air* 13:237–245
- Shendell, D.G, Prill, R, Fisk, W.J, Apte, M.G, Blake, D., and Faulkner, D. (2004) Associations between Classroom CO₂ Concentrations and Student Attendance in Washington and Idaho. *Indoor Air* 14:333–341
- Shin, M., Patton, R., Mahar, T., Ireland, A., Swan, P., and Chow, C. M. (2017). Calibration and Validation Processes for Relative Humidity Measurement by a Hygrochron Button. *Physiology and Behaviour*, 179, 208–212.
- Smedje, G, Mattsson, M, and Walinder, R., (2011) Comparing Mixing and Displacement Ventilation in Classrooms: Pupils' Perception and Health. *Indoor Air* 21:454–461.
- Smedje, G., Norback, D., and Edling, C. (1997a) Asthma among Secondary School Children in Relation to the School Environment. *Clin Exp Allergy* 27(11):1270–1278.
- Smedje, G., Norback, D., and Edling, C. (1997b) Subjective Indoor Air Quality in Schools in Relation to Exposure. *Indoor Air* 7:143–150
- Smith, K.R., Samet, J.M., Romieu, I., and Bruce, N. (2000) Indoor Air Pollution in Developing Countries and Acute Lower Respiratory Infections in Children. *Thorax* 55(6), 518–532.
- Sofuoglu, A., Kiymet, N., Kavcar, P., and Sofuoglu, S.C. (2010) Polycyclic and Nitro Musks in Indoor Air: A Primary School Classroom and A Women's Sport Center. *Indoor Air* 20:515–522.
- Sofuoglu, S.C., Aslan, G., and Inal, F. (2011) An assessment of Indoor Air Concentrations and Health Risks of Volatile Organic Compounds in Three Primary Schools. *International Journal Hygiene Environment Health* 214:38–46.
- Thom, G.C., and Ott, W.R. (1976) A Proposed Uniform Air Pollution Index. *Atmospheric Environment* 10, 261–264.
- Thorn, C. C. and Ott, W. R. (1975), Air Pollution Index Systems in the United States and Canada. *Journal of the Air Pollution Control Association*, 26(5), 460–470.
- Tiwari, P. (2015). Computational Methods of Air Quality Indices: A Literature Review. *IOSR Journal of Environmental Science, Toxicology and Food Technology*. 1(5), 46–49
- Vaizoglu, S.A, Aycan, S., Deveci, M.A., Acer, T., Bulut, B., Bayraktar, U. D., Akyollu, B., Celik, M., Arslan, U., Akpınar, F., Baris, Z., Arslan, S., Deniz, A., Didem, E. E., and Güler, C. (2003) Determining Domestic Formaldehyde Levels in Ankara, Turkey. *Indoor Built Environment* 12:329–335.
- WHO (2017). Evolution of WHO Air Quality Guidelines: Past, Present And Future. Copenhagen: WHO Regional Office for Europe.
- Yamashita, S., Kume, K., Horiike, T., Honma, N., Masahiro, F., and Amagai, T. (2012) Emission Sources and Their Contribution to Indoor Air Pollution by Carbonyl Compounds in a School and A Residential Building in Shizuoka, Japan. *Indoor Built Environment* 21(3):392–402
- Yang, W., Sohn, J., Kim, J., Son, B., and Park, J., (2009) Indoor Air Quality Investigation According to Age of the School Buildings in Korea. *Journal Environment Management* 90:348–354
- Yaru, S. S (2021). Pollution Of Vehicular Emission Analysis at Federal University Of Technology Akure North Gate. *Journal of Engineering and Engineering Technology . FUTAJEET*, 15(1), 29–37.
- Zhang, G., Spickett, J., Rumchev, K., Lee, A.H., and Stick, S., (2006) Indoor Environmental Quality in A 'Low Allergen' School and Three Standard Primary Schools in Western Australia. *Indoor Air* 16:74–80
- Zhang, Q., and Zhu, Y., (2012) Characterizing Ultrafine Particles and Other Air Pollutants at

- Five Schools in South Texas. *Indoor Air* 22:33–42.
- Zhao, Y., Li, A., Gao, R., Tao, P., and Shen, J. (2014). Measurement of Temperature, Relative Humidity and Concentrations of CO, CO₂ And TVOC During Cooking Typical Chinese Dishes. *Energy and Buildings*, 69, 544–561.
- Zhu C.S, Cao J.J, Tsai C.J, Shen Z.X, Ho K.F, and Liu S.X (2010) The indoor and outdoor carbonaceous pollution during winter and summer in rural areas of Shaanxi, China. *Aerosol Air Qual Res* 10:550–558.