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Original scientific paper

Assessment of the Indoor Air Quality of Akure, South – West, Nigeria

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Abstract: Air quality has been a major concern throughout the world, Nigeria inclusive. The monitoring of air quality involves indoor and outdoor air quality. In this study, our concern was on indoor air quality. The aim of this study was to assess the air quality of residential homes (17), classrooms (3), hospitals (2), offices (5), Shops (2), and laboratories (5) in Akure, Nigeria in terms of formaldehyde (HCHO), total volatile organic compound (TVOC), Particulate matter ($PM_{1.0}$; $PM_{2.5}$, and PM_{10}). A Multifunction Air Detector was used for the assessment using the manufacturers' procedures and the locations were identified using a Mini GPS. The results revealed as follows: HCHO (0.001-0.030 mg/m^3), TVOC (0.003-362 mg/m^3), $PM_{1.0}$ (004-014 µg/m^3), $PM_{2.5}$ (006-020 µg/m^3), and PM_{10} (006-022 µg/m^3). The results obtained were below the 24 h pollution recommended standards (0.1 mg/m^3- HCHO; TVOC; 10-20 µ/m^3 PM) of EPA and WHO. Statistically, there were correlations within the pollutants and weather. The Indoor air quality (IAQ) depicted the areas as 'good,' and toxicity potential (TP) were below unity. Although the locations looked safe, it is recommended that constant monitoring of the indoors should be ensured and proper ventilation should be provided.

Key words: Indoor, classrooms, residential rooms, air detector, PM, TVOC, EPA.

INTRODUCTION

The concern over indoor air quality worldwide is on the increase due to its attendant problem caused mostly on children, pregnant women and the elderly. Common pollutants indoors are: volatile organic compounds (TVOC), formaldehyde (HCHO), fine particulate matter (PM), ozone (O_3), carbon monoxide (CO), CO_2, and aldehydes caused by indoor emission sources like furniture, paints, combustion appliances, low ventilation within, seasonal variations, meteorological factors, and many other environmental factors (Lee et al., 2018; Walgraeve et al., 2011).

Indoor air pollution is a serious health threat. Studies indicate that the concentrations of air pollutants are sometimes 2-5 times higher in indoor air than outdoor air while in a few cases, indoor air pollutants could be over 100 times higher than outdoors (U.S. Consumer Product Safety Commission (CPSC), 2012). People spend over 90% of their time indoors, for this singular reason; there should be a concern for the assessment, monitoring, and reduction of indoor pollutants.

Indoor air quality (IAQ) and toxicity potential (TP) of pollutants are important in the considerations of air pollutants indoors. The two inform people about the quality of the rooms and potential dangers one might encounter if the pollutants exceed the recommended limits. According to Sonibare et al. (2005), TP is a quantitative toxic equivalency which to express the potential effect of a unit of chemical released into the environment. This is expressed as the ratio of measured ambient pollutants' concentrations to the statutory limit of ambient concentration.

$$\text{Toxicity Potential} = \frac{Mp}{Sp}$$

Mp - the measured pollutant concentration; Sp - the statutory limit set for such pollutant using FMEnv Standard and ASHRAE Standard. TP is useful in determining the harmful effects of the emissions from the source pollutants within the indoors on human health (Ayodele et al., 2016). IAQ refers to the extent to which human requirements are met indoors. The requirements of the people are pleasant and fresh air, which has no negative impact on their health (Fanger, 2006).

Several studies on indoor air quality have been published for example, Wang et al. (2008); Petry et al. (2014), Chen et al. (2016); Shi et al. (2016); Meˇciarová et al. (2017); Lee et al. (2018) many of the interests were on PM, TVOC, formaldehyde, O_3, CO, CO_2, and other aldehydes. Many of their observations were elevated levels of the parameters over the recommended standards. Different source apportionment (Li et al., 2014; Ma et al., 2016), methodologies (Chen et al. (2016); Shi et al. (2016); Meˇciarová et al. (2017); Lee et al. (2018), and instruments (Jiao et al., 2015; Van den Bossche et al., 2016; Zikova et al., 2017; Lee et al., 2018) have been used to determine and identify air pollution parameters. In Nigeria, many studies have not been done on indoor air pollution in Nigeria, but few literates obtained were done in Enugu (Ezezue and Diogu, 2017), Warri (Akpofure, 2015), Ile – Ife (Afolabi et al., 2016), Ido Ekiti (Ayodele et al., 2016), No report has been found for indoor pollution from Akure. On this note, the aim of the study was to assess the HCHO, TVOC, PM_1, $PM_{2.5}$, and PM_{10} in Akure, the relationship between the weather and the pollutants would be determined, the results would be subjected to multivariate analysis, and the potential toxicity of the pollutants would also determined. The results of the study will be an addition to indoor pollution knowledge in Akure, Nigeria, and beyond.

Fig 1. Akure, Ondo State, Nigeria

MATERIALS AND METHODS

Study Area

Akure is the capital city of Ondo State (Fig 1). It is one of the beautiful cities in Nigeria. It is still undergoing rapid industrialization and urbanization over the past decades (Abulude et al., 2018a). Like other cities in other countries of the world, the air quality in Akure has been subjected to high pressure due to the vast economic development and an increase in housing. In different megacities in Nigeria, serious particle pollution, especially $PM_{2.5}$ and PM_{10} pollution have been identified in Akure in recent years (Abulude et al., 2018b).

Table 1. The Description of the locations

S/N	Locations		Description	Date of Sampling
1	7°16’09.36’’N	5°15’14.20’’E	Residential	10/10/2018
2	7°16’09.10’’N	5°15’13.24’’E	Residential	10/10/2018
3	7°16’07.12’’N	5°15’13.50’’E	Residential	10/10/2018
4	7°16’06.20’’N	5°15’12.72’’E	Residential	10/10/2018
5	7°16’06.81’’N	5°15’11.76’’E	Residential	10/10/2018
6	7°16’03.29’’N	5°15’13.40’’E	Residential	11/10/2018
7	7°16’03.27’’N	5°15’14.52’’E	Residential	11/10/2018
8	7°15’59.98’’N	5°15’10.27’’E	Residential	11/10/2018
9	7°16’03.22’’N	5°15’11.52’’E	Residential	11/10/2018
10	7°16’04.78’’N	5°15’14.34’’E	Residential	12/10/2018
11	7°16’07.09’’N	5°15’14.98’’E	Residential	12/10/2018
12	7°15’53.58’’N	5°15’21.20’’E	Residential	12/10/2018
13	7°15’48.84’’N	5°14’21.82’’E	Residential	12/10/2018
14	7°15’49.24’’N	5°14’22.42’’E	Residential	13/10/2018
15	7°15’50.07’’N	5°14’22.83’’E	Residential	13/10/2018
16	7°16’06.02’’N	5°15’13.68’’E	Residential	13/10/2018
17	7°16’08.21’’N	5°15’26.03’’E	Residential	13/10/2018
18	7°15’49.33’’N	5°14’24.28’’E	Shop	13/10/2018
19	7°16’10.14’’N	5°13’38.54’’E	Laboratory	14/10/2018
20	7°16’10.00’’N	5°13’38.30’’E	Laboratory	14/10/2018
21	7°16’09.99’’N	5°13’38.29’’E	Laboratory	14/10/2018
22	7°16’10.01’’N	5°13’38.25’’E	Laboratory	14/10/2018
23	7°15’46.61’’N	5°14’25.56’’E	Laboratory	14/10/2018
24	7°15’46.63’’N	5°14’25.84’’E	Laboratory	14/10/2018
25	7°15’47.76’’N	5°14’23.59’’E	Office	15/10/2018
26	7°15’46.28’’N	5°14’26.29’’E	Office	15/10/2018
27	7°15’46.36’’N	5°14’24.71’’E	Office	15/10/2018
28	7°15’46.40’’N	5°14’24.46’’E	Office	15/10/2018
29	7°15’48.02’’N	5°14’24.48’’E	Office	16/10/2018
30	7°15’47.58’’N	5°14’23.77’’E	Classroom	16/10/2018
31	7°15’47.57’’N	5°14’23.71’’E	Classroom	16/10/2018
32	7°16’10.96’’N	5°13’37.98’’E	Classroom	16/10/2018

PARAMETER MEASUREMENTS

The present measurements were done at 32 indoor locations (Classrooms (3), residential homes (17), laboratories (6), offices (5), and shop (1) – Table 1) in Akure. The current assessment of formaldehyde (HCHO), Total Volatile Organic Compounds (TVOC), $PM_{1.0}$, $PM_{2.5}$, and PM_{10} was performed using a multifunction air detector (Model: WP6910 made-in-China: Detector Description (Table 2). Presently, there are no national-controlling ambient air quality monitoring sites in Akure city, this informed the use of this detector. The mini GPS used for the coordinates of the sites is made-in-China (Model: GPS-006E). The manufacturers' specifications and procedures were strictly followed. During the indoor assessments, the detector device was placed in the center of the room at the height approximately 1.1 m above the ground for 1h. Before the measurements, all the air conditions, fans, other ventilators were switched off, and all windows and doors were shut during the measurement periods. Assessments were carried out in the living rooms because they are the central rooms where members of the families spend time together (Meˇciarová et al., 2017). Also, the $PM_{2.5}/PM_{10}$ was determined. The assessment was performed in seven days (10th – 16th October 2018). The weather report on rainfall, relative humidity (RH), temperature, precipitate, wind speed, and direction was obtained at the Federal University of Technology, Akure, Ondo State.

Table 2. The Detector Description

Display Mode	Power Supply	Pollutant Range	Detection Technology	Concentration
LED	1200mAh*	HCHO	Electrochemistry Sensing Technology	0-1.999mg/m^3
		TVOC	Electrochemistry Sensing Technology	0~9.999 mg/m^3
		$PM_{1.0}$	Adopting Laser Scattering Theory	0~999µg/ m^3
		$PM_{2.5}$	Adopting Laser Scattering Theory	0~999µg/ m^3
		PM_{10}	Adopting Laser Scattering Theory	0~999µg/ m^3

*** Rechargeable lithium** battery, Input: 5.0V/300mA

STATISTICAL ANALYSIS

Results from experimental measurement were statistically evaluated using the Minitab 16 (Minilab Ltd. UK) and Microsoft Office Excel 2007 (Microsoft Corporation Technology Company, Washington, US) software. The wind rose, concentrations of HCHO, TVOC, PM_1, $PM_{2.5,}$ and PM_{10} were obtained using the Microsoft Excel, while basic description, matrix and box plots and dendogram were obtained by Minitab tools.

RESULTS AND DISCUSSION

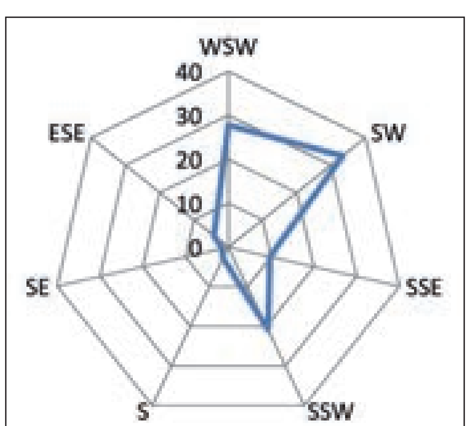


Fig 2. Wind Direction for the month of October, 2018

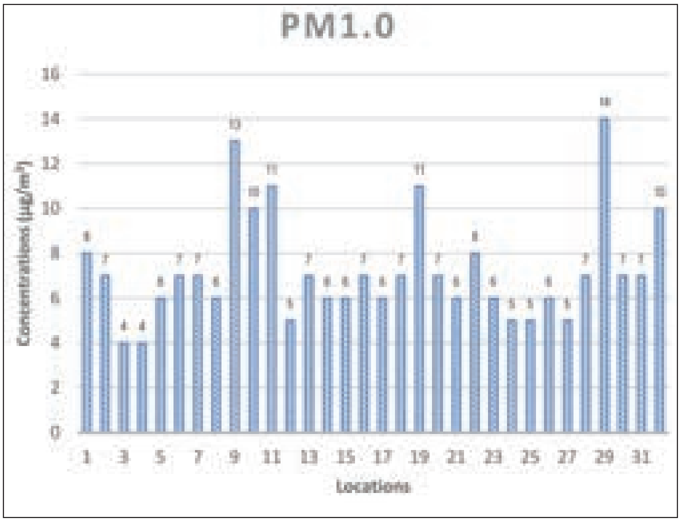
Table 3. Summary of the meteorological data

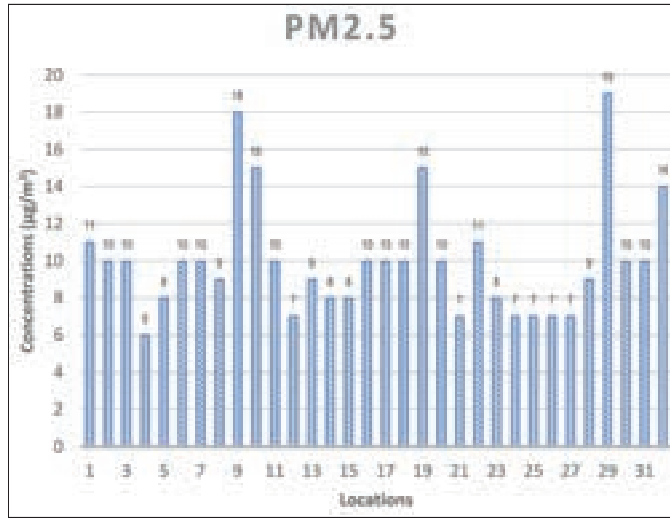
Statistics	Temperature	Wind Speed	Humidity	Precipitate
Range	22.0-33.0 (^{o}C)	1.0-9.0 (m/s)	46.0-99.0 (%)	0.0-36 (mm)
Mean	25.88	5.03	83.94	1.75
Std Error	0.39	0.18	1.92	0.66
Std Deviation	3.34	1.53	16.25	5.59
Coef Variation (%)	12.91	30.41	19.36	319.59
Skewness	0.53	-0.12	-0.83	5.41
Kurtosis	-1.06	0.14	-0.67	29.99

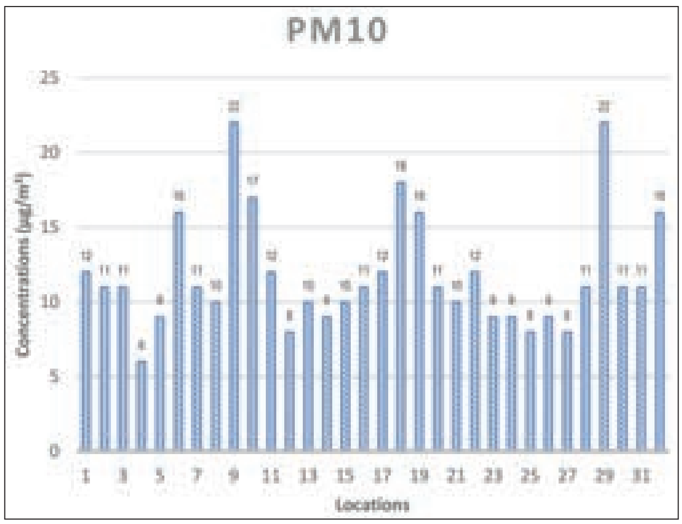
The mean meteorological data for the month of October 2018 were as follows: Temperature (25.88 ^{o}C), wind (5.03m/s), humidity (83.94%), precipitate (1.75mm) (Table 3), and the wind direction for the month was predominantly from WSW, SW, SSE, and SSW (Fig 2). The results obtained in Turkey for precipitate, wind speed, and RH compared with our results (Lokman et al., 2008). There were no significant differences in the data during the seven day assessment as noted by the low percentage in the correlation of variations. The correlation coefficient in Table 4 confirmed the strong positive correlation of PM_1, $PM_{2.5}$, and PM_{10} concentrations with the prevailing temperature (r = 0.889, 0.732, and 0.796 respectively), while there were weak positive correlations between temperature and HCHO and TVOC (r = 0.503 and 0.402 respectively). This means that HCHO, TVOC, and PM concentrations in indoors were intensified with temperature. Temperature has been known to influence pollutants' emissions (HCHO and TVOC) from building materials together with air velocity and humidity (Wolkoff, 1998). Similar trends were also observed for wind and humidity, only precipitate did not have any significant relationship with the pollutants undertaken in this study. It can be deduced that the emitted substances were temperature, wind speed, and humidity dependent. Wind speed is a principal factor in the control of air pollution levels Grivas and Chaloulakou, 2006), wind direction plays a major role in the transport, dilution, and re-suspension of PM_{10} (Harrison et al., 1997; Shahraiyni and Sodoudi, 2016), and temperature is considered as one of the strongest predictors of PM_{10} concentration (Papanastasiou et al., 2007).

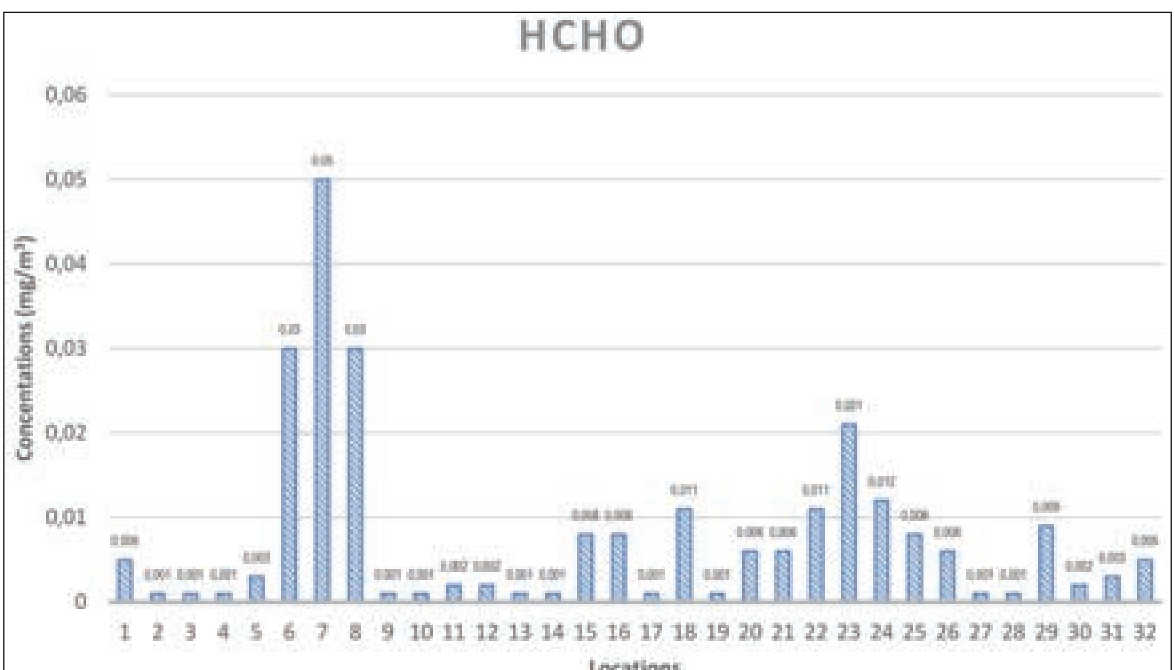
Table 4. Correlation Coefficient of the pollutants and meteorological parameters

	HCHO	TVOC	$PM_{1.0}$	$PM_{2.5}$	PM_{10}	Temp	Wind	Hum	Precip
HCHO	1								
TVOC	0.000	1							
$PM_{1.0}$	**0.649**	**0.722**	1						
$PM_{2.5}$	**0.710**	**0.587**	0.000	1					
PM_{10}	**0.931**	**0.928**	0.000	0.000	1				
Temp	**0.503**	0.402	**0.889**	**0.732**	**0.796**	1			
Wind	**0.900**	**0.781**	**0.682**	0.423	**0.578**	0.000	1		
Hum	**0.997**	**0.818**	**0.876**	**0.856**	**0.876**	0.000	0.001	1	
Precip	0.000	0.000	0.226	0.204	0.229	**0.897**	**0.911**	0.382	1


PM1.0
Concentrations (µg/m³)
Locations


PM2.5
Concentrations (µg/m³)
Locations


PM10
Concentrations (µg/m³)
Locations


HCHO
Concentations (mg/m³)
Locations

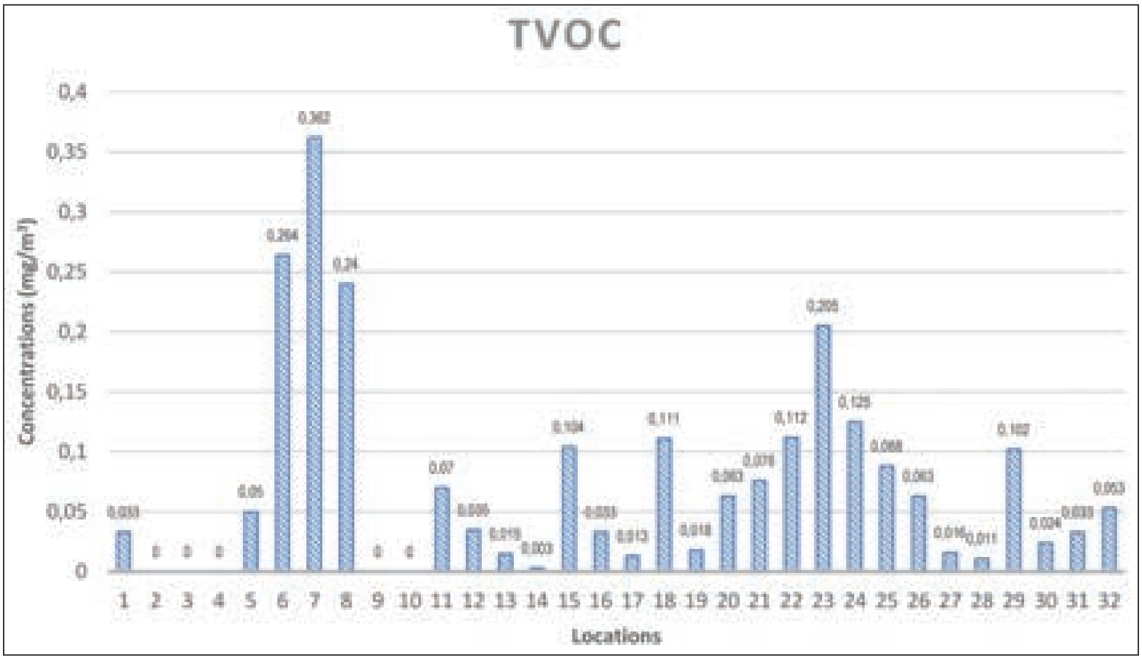


Fig 3. The concentrations of the air pollutants

Table 5. Basic Statistical Description of the Pollutants

Statistics	HCHO	TVOC	$PM_{1.0}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}/PM_{10}$
Range	0.001-0.050	0.001-0.362	4.000-14.000	6.000-19.000	6.000-22.000	0.560-0.940
Mean	008	00.072	7.242	10.030	11.818	0.851
Std Error	0.002	0.015	0.411	0.536	0.661	0.015
Std Deviation	0.011	0.085	2.359	3.077	3.795	0.086
Coef Variation (%)	139.12	119.56	32.57	30.68	32.11	10.12
Skewness	2.61	1.92	1.32	1.45	1.34	-1.99
Kurtosis	7.47	3.72	1.62	2.09	1.56	4.05
TP	0.01-0.5	-	-	0.17-0.54	0.12-0.44	-

TP – Toxicity Potential

Table 6. Comparisons with other studies

References	HCHO	TVOC	$PM_{1.0}$	$PM_{2.5}$	PM_{10}	$PM_{2.5}/PM_{10}$
Munir (2017)	-	-	-	-	-	0.33-0.88
Filonchyk et al.,	-	-	-	25–28	50-70	0.50-0.90
Ho et al. (2003)	-	-	-	42.37-57.38	73.11-83.52	0.53-0.78
Hassanvand et al. (2014)	-	-	10.70-11.00	16.90-19.00	39.70-53.70	-
Lim et al. (2005)	-	-	5.60-13.10	12.80-31.10	27.50-93.90	-
Cai et al. (2015)	0.80-3.90	42-152	255.00-376.00	261.00-383.0	325.00-439.0	-
Xu et al. (2017a)	-	-	-	7.00-356.00	15.00-415.00	0.20-0.90
Evagelopoulous et al. (2006)	-	-	-	19.00	47.00	0.42-0.44
Wang et al. (2014)	-	-	99.00	175.00	0.70-0.80	-
Meˇciarová et al. (2017)	13.50-1712		-	13.10-44.10	87.80	-
Kim et al. (2014)	1.115-1.703		2.82-11.30	2.86-11.40	3.09-11.90	-
Hadei et al. (2018)	17.90					
Huang et al. (2015)	-		-	100	157	0.64
Chen et al. (2014)	-		-	51	76	0.57–0.71
Zhou et al. (2015)	-		-	92	119	0.53–0.86
Our results	0.001-0.050	0.001-0.36	4.00-14.00	6.00-19.00	6.00-22.00	0.56-0.94

Table 7. AQI index scoring system

IQE	Good	Average	Poor	Bad
Humidity	40-50%	50-60%	60-70%	70>H>40%
Temperature	20-24ºC	16-20ºC	24-26ºC	26>T>16ºC
$PM_{2.5}$	0-10µg/m³	10-15µg/m³	15-35µg/m³	>35µg/m³
PM_{10}	0-50µg/m³	50-80µg/m³	80-150µg/m³	>150µg/m³
$PM_{1.0}$				
TVOC	0-200ppb	200-350ppb	350-500ppb	>500ppb
CO_2	350–500ppm	500–1000ppm	1000–5000ppm	>5000ppm
CO	0–3ppm	3–8ppm	8–10ppm	>10 ppm
Indoor air quality	0–10ppm	10–25ppm	25–50 ppm	>50 ppm
Illuminance	300–500lux	200–300lux	100–200lux	<100 lux
Sound levels	0–40dB	40–70dB	70–80dB	>80dB
Scoring impact	0	0.2	0.5	1.0

Source: Tiele et al. (2018)

Figure 3 showed the results of the assessments determined in this study. Also, Table 5 depicted the summary of results for the pollutants. The ranges of the parameters were: 0.001-0.050, 0.001-0.362, 4.000-14.000, 6.000-19.000, 6.000-22.000, and 0.560-0.940, while the mean values were: 0.008, 0.072, 7.242, 10.030, 11.818, and 0.851 (HCHO, TVOC, $PM_{1.0,}$ $PM_{2.5,}$ $PM_{10,}$ and $PM_{2.5}/PM_{10}$) respectively. The only place where the highest value of 0.05 mg/m³ was recorded for formaldehyde happened to be in a residential home and this could be a result of the wallpaper and the new sets of furniture in the living room. It is gratifying to note that the value was below the thresholds of eye irritation (0.1 mg/m³), biting sensation in nose (0.5 mg/m³), danger to life (37.5 mg/m³), and even death (125 mg/m³) (Commission of the European Communities (1990). The means (0.072 mg/m³) and standard deviations (0.085) of TVOC showed significant differences between our indoor results with those of Lee et al. 2018 (Korea - 230.7±1.7 µg/m³); Meˇciarová et al. 2017 (Slovak – 28-2393 µg/m³), Wang et al. 2008 (Taiwan - 1.960 µg/m³), and Park et al. 2010 (Korea - 120 to 328 µg/m3). The reason for the differences could be deduced to the old age of our study sites. The indoor mean values of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ in our study were lower during the weekdays compared to the weekends, the differences were due to the increase in the residents' activities during the weekend due to the holidays. These types of results have been experienced by Goyal and Khare (2010) although they recorded higher concentrations than our results.

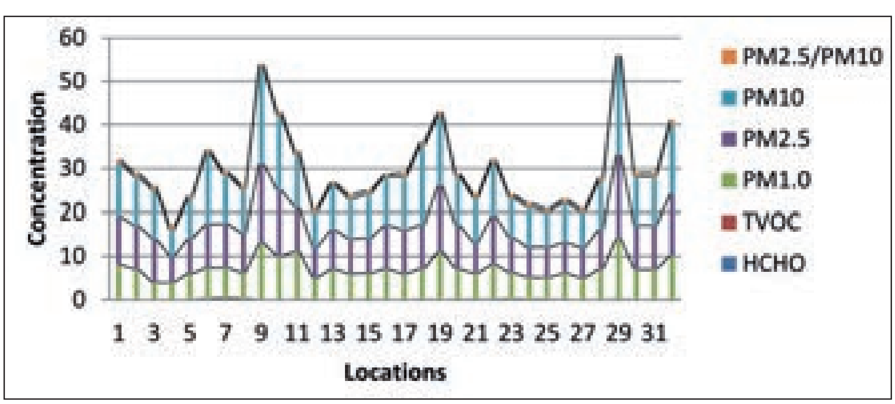


Fig 4 . Concentrations of the parameters in the different locations

The mean concentrations of the particulate matter were: PM_{10} (11.818 μg/m³), $PM_{2.5}$ (10.030 μg/m³), and $PM_{1.0}$ (7.242 μg/m³). Table 6 showed the comparison of our results with the previous studies. The PM_{10} results were lower than those in subway offices (27.5 to 267.9 μg/m³) obtained by Lim et al. (2005). Hassanvand et al. (2014) who carried out the indoor/outdoor relationships of $PM_{10,}$ $PM_{2.5,}$ and PM_1 in a retirement home and dormitory obtained for PM_{10} (7.5-240 mg/m³), $PM_{2.5}$ (4.4-72.3 mg/m³), and PM_1 (3.1-42.0 mg/m³). The summary of these results showed that there were relationships obtained in this study. The Nigerian PM standards are the same as WHO limits (50 and 25 mg/m³) daily average PM_{10} and $PM_{2.5}$ concentrations, respectively. Presently, no standard limit is available for PM_1. It could be deduced from our results that they below the WHO limits. The reason could be due to the low rainfall recorded during the seven day monitoring. The $PM_{2.5}/PM_{10}$ values in this study on the average ranged between 0.50 and 0.90 with an average of 0.851 (Fig 4). Ho et al. (2003) at three monitoring sites in Hong Kong found that the mean $PM_{2.5}/PM_{10}$ ratios were higher in Poly U (0.61) and KT (0.78) than in HT (0.53). In addition, Filonchyk et al. (2016) showed lower ratios of 0.29-0.51. Using the previous studies results it could be observed that the PM indicators are dust storms depicted by high PM_{10} contents and relatively low contents of $PM_{2.5}$ due to the invasion of large particles (Zhang et al., 1998). It should be noted that the $PM_{2.5}/PM_{10}$ ratio may be used as a key measurement to determine the sources of dust. In line with our results, Xu et al. (2017b), obtained above 0.7 of $PM_{2.5}/PM_{10}$ ratios at 19 cities in China, while below 0.5 was recorded at the other cities they studied. The low differences in PM concentrations and the high ratios of $PM_{2.5}/PM_{10}$ obtained in this study showed generally modest PM concentrations, and the possible emission sources include unpaved road and agriculture.

Table 8. Principal Component Analysis of the indoor pollutants

Variable	PC1	PC2	PC3	PC4	PC5
HCHO	-0.102	**-0.698**	-0.025	-0.332	**-0.626**
TVOC	-0.106	-0.698	0.093	**-0.698**	**0.644**
PM_1	**0.568**	-0.062	**0.740**	0.289	-0.206
$PM_{2.5}$	**0.583**	0.060	-0.070	**-0.724**	0.358
PM_{10}	**0.562**	-0.134	**-0.662**	0.451	-1.555
Eigenvalue	2.803	1.962	0.147	0.073	0.015
Proportion	0.561	0.392	0.029	0.015	0.003
Cumulative	56.10	95.53	98.20	99.70	100.0

The principal component analysis (PCA) of the data collected (Minitab 16, Minilab Ltd. UK) showed that the first two principal components accounted for 56% of the variability in the system. Component (PC1) was predominantly associated with $PM_{1,}$ $PM_{2.5,}$ and PM_{10} contents, PC2 was associated mainly with HCHO, and PC5 was associated with TVOC. The implication of this was that there were some mutual correlations. The mutual correlations shown between all principal components are shown in Table 8. Table 4 confirmed the correlations that existed within the parameters. The Pearson correlation factor that existed were HCHO: PM_1 (r=0.63), HCHO: $PM_{2.5}$ (r=0.69), HCHO: PM_{10} (r=0.93) and TVOC: PM_1 (r=0.69), TVOC: $PM_{2.5}$ (r=0.57), and TVOC; PM_{10} (r=0.93). All were strongly correlated. There were strong correlations between the different PM measurements and also between the different aromatic components. TVOC also shows high correlation with many of the individual components, as would be expected this suggested the pollutant sources come from the same source.

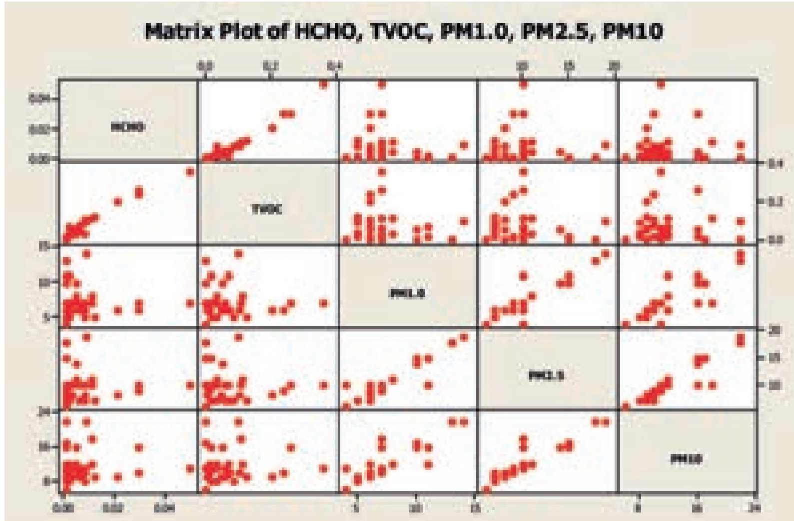


Fig 5. Matrix plot of the pollutants

Matrix plot was also plotted to evaluate the relationship between the measured PM, HCHO, and TVOC from the closed rooms. Matrix Scatterplot has variables that are written in a diagonal line from top left to bottom right (Fig 5). The HCHO, TVOC, $PM_{1.0,}$ $PM_{2.5,}$ and PM_{10} known as the variables were plotted against each other. The boxes on the upper right-hand side of the whole scatterplot were mirror images of the plots on the lower left hand. In the graph, it was shown that there were strong correlations between HCHO, TVOC, $PM_{1.0,}$ $PM_{2.5,}$ and PM_{10}.

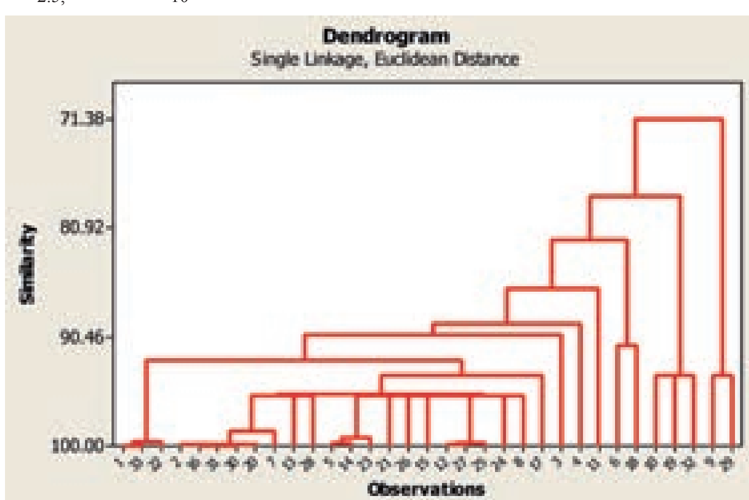


Fig 6. Dendogram of the results

The dendogram plot in Fig 6 showed that the results obtained in the study were highly comparable to the patterns derived by the PCA. They depicted the correlations between the pollutants. The results of multivariate analysis confirmed the different associations among the evaluated parameters, this could be due to PMs formed by secondary aerosol. The $PM_{2.5}$ and PM_{10} skewed to the right, which means they are nonsymmetrical (Fig 5). The reason for the skewing to the right was that there were variations in the values of PM recorded in the study. The boxplot is a visual display that presents five different statistical tools in a study - the minimum, the lower quartile, the median, the upper quartile, and the maximum. It is an indicator of centrality, symmetry, spread and tail length of the population and sample (Abulude et al., 2018a).

Table 7 is the IEQ index scoring system developed by Tiele et al. (2018) the aim was to design a scoring point that can rate the parameter readings of indoor pollutants. In this study, the scoring index was used to score the pollutants assessed in some parts of Akure. The results of the meteorological parameters and the pollutants can be rated as between average and good. Again, the AQI calculator (Airnow, Accessed 2018) was used (concentration to AQI) to determine the air category of PM_{10} and $PM_{2.5}$. The PM_{10} results (AQI) were between 6 (min) and 18 (max) denoting 'Good', the sensitive groups at risk are people with respiratory disease, while $PM_{2.5}$ had AQI = 25 (min) and 55 (max) denoting 'Good and Moderate' respectively, the sensitive groups at risk are people with respiratory or heart disease, the elderly and children.

The TP range was computed for HCHO, $PM_{2.5}$, and PM_{10} using Nigeria's 24-h standard averaging period of FMEnv and ASHRAE Standard Ventilation for Acceptable IAQ (Tables 5). The TP of TVOC and PM_1 were not computed because their FMEnv and ASHRAE standards were provided. The TP were 0.01-0.5 (HCHO), 0.17-0.54 ($PM_{2.5}$), and 0.12-0.44 (PM_{10}). In a TSP study conducted by Sonibare et al. (2005) at an Enamelware Manufacturing Industry, between 0.33 and 7.72 were recorded for the TP. The high concentration obtained in their study could be as a result of the activities (spraying, pickling process, milling etc) that took place when the research was held, but in our study, it was only little vehicular activity that took place.

CONCLUSION

The assessment of pollutants indoor was carried out within seven days in Akure using a multifunctional air detector. The results revealed that Formaldehyde (HCHO) was minimal in all the locations which could have been due to the old age of the buildings and materials therein. In comparison with standard limits its results were far below the limits. TVOC was also detected at very low concentrations. There were significant differences when compared with indoors in Korea. The PM at diameters 1, 2.5, and 10 was low compared to the 24hr indoor limit recommended by WHO. The PM ratios were below unity. The coefficient of correlation and matrix plots depicted strong correlations between PM, HCHO, and TVOC. The report showed that there were significant effects of weather on the pollutants, especially temperature. The PCA revealed associations in the pollutants. The results of the meteorological parameters and the pollutants can be rated as 'average' and 'good'. The sensitive groups at risk are people with respiratory or heart disease, the elderly and children. The TP report showed that the potential of the indoor inhabitants is low, but the probability of human health effects exists due to the activities within and outside the different locations. Finally, it is recommended that constant monitoring of the locations assessed should be enforced.

Conflict of interest statement
The authors certify that they have no conflict of interest concerning the subject matter or materials discussed in the manuscript.

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