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Original scientific paper

INDOOR AIR QUALITY MONITORING IN AKURE, ONDO STATE, NIGERIA

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ABSTRACT: Using the Canāree A1, a low-cost monitoring device made by Piera System, Canada, variations in Particle Count (PC) and Particulate Matter were observed in a building residence of five rooms in Akure, Nigeria (two living rooms, two bedrooms, and one kitchen) in both January and February 2022. The average $PM_{2.5}$ and PM_{10} levels in all rooms were above the World Health Organization (WHO) guidelines for 2021, which were: $PM_{2.5}$ - Annual (5 µg/m^3), 24 h (15 µg/m^3), and PM_{10} - Annual (15 µg/m^3), 24 h (45 µg/m^3). Rooms A (the first sitting room) and C (the kitchen) were found to have greater PC and PM values than the other rooms. Room A had the greatest $PC_{1.0}$ level, however, $PC_{5.0}$ was also discovered to be high. Based on the volume of activities, PM_{10}, $PM_{5.0}$, and $PM_{2.5}$ were the main air pollutants in Akure. These results indicate considerable effects from both indoor and outdoor activity, two key sources. During the duration of the study, certain residents of the building frequently complained of having a cough, a running nose, and other ailments. These results indicate considerable impacts from both indoor as well as outdoor activities. During the duration of the study, certain residents of the residence often reported having a cough, a running nose, and other ailments.

Keywords: PM10, PM2.5, PC1.0, Indoor, Kitchen, Low-cost sensor.

INTRODUCTION

According to the World Health Organization (WHO, 2021), access to clean air is a fundamental human right. But this seems to be a dream. Many factors make it unclean. Indoor Air pollution (IAP) is one of them. The biggest environmental health risk and a significant contributor to noncommunicable diseases (NCDs) like heart attacks and stroke, air pollution persists to pose a danger to individuals around the globe. Approximately 7 million individuals die prematurely every year as a consequence of outdoor and indoor air pollution, and millions more get sick from breathing it in, according to the WHO. In poor countries, much over half of these casualties take place. Large amounts of particulate matter (PM) of different sizes contribute to air pollution. Examples of particulate matter (airborne liquid or solid particles) include dust, pollen, mold, smoke, metals, bacteria, and viruses (Figure 1). When exposed for a short time or a long time, a few of these particles may be harmful to health. To protect individuals from poor air quality and pandemics like SARS-CoV-2, it is crucial to understand the size of these different types of particulate matter. PM, especially 'fine' PM, can penetrate the lungs and the bloodstream and cause problems with the organs. It causes cardiovascular and respiratory conditions, low moods, and childhood growth retardation (WHO, 2021). SARS-CoV-2, the virus that causes COVID-19, is a very tiny virus. It typically has a diameter between 0.06

and 0.14 microns. Viruses and ultra-fine dust, which range in size from $PM_{0.3}$ to $PM_{0.1}$, include the smallest particles (International Enviroguard, 2021)

Figure 1: Pictorial Diagram showing the diameter of the Particulate Matter

Due to the adverse effects of air pollution on health, the WHO recommended standards for specific pollutants to assist nations in constructing air quality that protects residents. In light of a review of the publications between 1987 and 2005, the 2021 standard was issued as an addendum to the earlier ones. Table 1 contains a list of the PM modifications.

Table 1: Update on the Particulate Guidelines of PM

Pollutant	Average time	2005 Guideline	2021 Guideline
$PM_{2.5}$ (µg/m^3)	Annual	10	5
	24 h	25	15
PM_{10} (µg/m^3)	Annual	20	15
	24 h	50	45

There is a good chance that human actions will have detrimental effects on human health and the environment (Trippetta et al., 2013). Research has shown that there is increased emission of different gaseous pollutants and particulate matter as a result of fast industrialized growth (Jain and Palwa, 2015).

Research has linked the escalating industrialization trend to the causes and sources of air pollution (Jain and Palwa, 2015). In some societies, the combustion of garbage, trash, and other solid waste is still a common trend. In all locations in Auckland, the most prevalent contributors of $PM_{2.5}$ are the burning of biomass and vehicular fumes (Davy et al., 2017; Bulto, 2020). In addition to these, brick kilns, rice and pulse (beans) grinding mills, dust from highways and building sites, dust from chicken farms, and harmful gases from industries are causes of air pollution, according to Huda et al. (2018). The study by Knight et al. (2021) on the Impact of Misting Systems on Local Particulate Matter concluded that misting systems increased PM concentrations. Njoku et al. (2016) and Ibe et al. (2020) list increasing vehicle traffic, biomass fuels, the usage of electricity generators, and leaks from open burning and flare stacks as additional sources of air pollution. Other man-made sources include frying, using pesticides and insecticides, lighting candles, smoking cigarettes, vacuuming, and so on. Volcanic activity, wind-borne dust, suspended soils and dust, sea-salt spray, wildfires, and plant emissions of volatile organic compounds are examples of natural sources (Mackenzie and Turrentine, 2021).

The environment must be checked both inside and out to see if it is below WHO standard limits in order to reduce air pollution. In the past, complex technologies were employed to detect pollution levels, but wearable devices and citizen science projects employing inexpensive technology have rescued the day for individuals with little financial resources (Abulude, 2021). Air sensor networks, including WiFi-distributed networks of sensors, have been devised and developed employing phone apps to collect and make available real-time data on air quality (Jiao et al., 2016). Cell phones are widely used, making them an ideal alternative for monitoring personal exposure (Abulude et al., 2022a). Alternative methods used to measure air quality include mass spectrometry, various low-cost sensor types (which are sometimes combined to form electronic noses), and optical classification. Numerous quantitative networking based on mass spectrometry is typically sensitive and selective, however, despite the considerable effort being made to build portable systems, they are limited in mobility and expensive due to suction technology (Napier et al., 2021).

Nigeria's score of 152nd on the Global Climate Risk Index for Air Quality raises concerns for the country's environmental security (Abulude et al., 2022b). To monitor indoor pollution and its causes, Nigeria, unfortunately, lacks a national program of air quality monitoring stations. In order to do this, a CanreeTM low-cost Intelligent Particulate Sensors (IPS) network was set up in a four-bedroom cottage in Akure, the capital of Ondo State in Nigeria. IPS is precise, straightforward, affordable, and widely used. In contrast to previous inexpensive PM sensors, it detects "extremely fine particles" less than 1.0 microns and reports particle size, and counts in real-time at little power. It could be utilized in a variety of circumstances because it can assess up to seven particle sizes ($PM_{0.1}$, $PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, and PM_{10}). Last but not least, the use of AI/ML algorithms makes it simple to identify sources of pollutants, for example, cooking, vaping, and cigarette smoke. In this region of the world, IPS is being utilized for the first time to track indoor air pollution. The purpose of this research is to present the results of an evaluation of a four-bedroom apartment over the course of one month, including particle counts, particulate matter, and sources of air pollution. As a result, the study's goals were to evaluate the concentrations of PC and PM, to ascertain the sources of PM to each room, to learn the connections between PC and PM, and to highlight the effects of each room's sources on PM.

MATERIALS AND METHODS

Nigeria, a West African nation with 36 states and the Federal Capital Territory, has Abuja as its capital. Africa's most populous nation is Nigeria. According to the World Bank (2020), Lagos is the nation's most significant commercial and industrial hub. Nigeria borders Niger to the north, Chad and Cameroon to the east, the Gulf of Guinea to the south, and Benin to the west. Nigeria's terrain is characterized by plateaus and hills in the middle and lowlands to the north and south. The Niger-Benue basin, Lake Chad basin, and Gulf of Guinea basin are Nigeria's three principal drainage basins. The Niger River inspired the naming of the nation. The two main rivers in the nation are the Niger River and the Benue River. The soil in Nigeria is not as good as soils elsewhere in the world. The Oji River, the Afam, Sapele, and Lagos thermal power plants, as well as the dams at Kainji, Shiroro (Niger State), and Jebba (Kwara State), provide hydroelectricity (firewood and charcoal). All of these support the nation's energy supply (Udo et al., 2021; Abulude et al., 2022b).

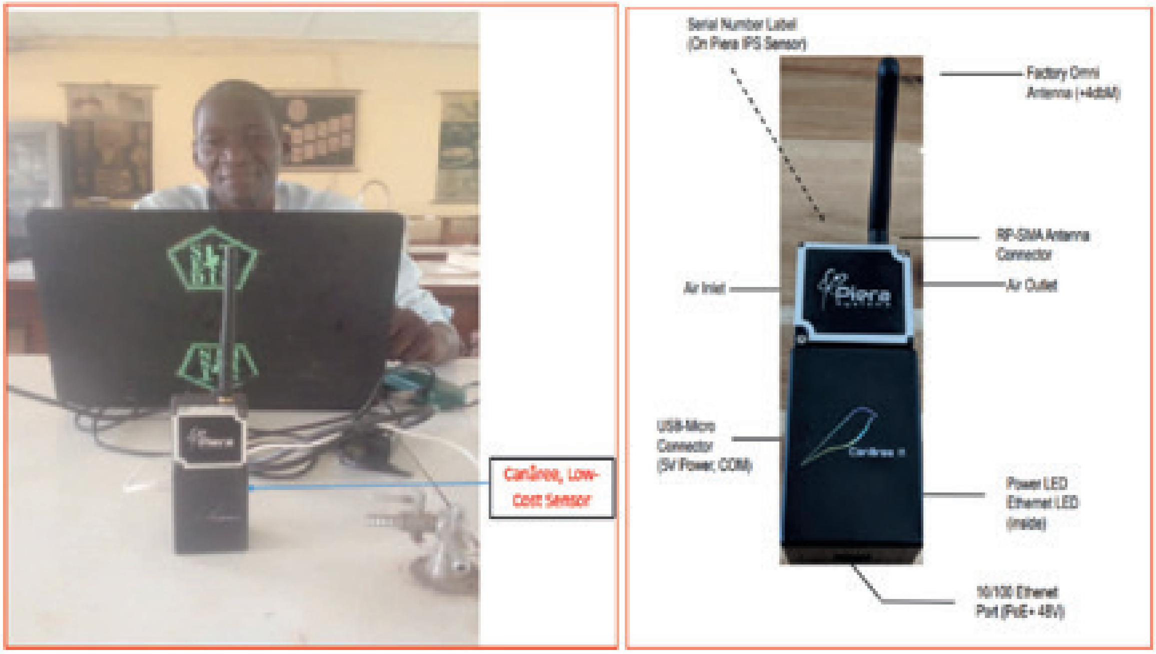
The nation has a tropical climate with distinct rainy and dry seasons according to the region. The southeast is generally warm and muggy, while the southwest and farther interior are dry. October to March, make up the dry season, while the rainy season is from March to September. The center region experiences rainfall totals between 1000 and 1500 mm (40 and 60 inches), exceeding 2000 mm (80 inches) in the south, and exceeding 3000 mm (120 inches) in the far southeast. Depending on the climatic zone, temperatures, which range from 12 to 40 degrees Celsius, vary significantly.

Nigeria is the most populated nation in Africa. Its population totals 211 million, and its total land area is 923,769 km^2. The city of Akure, the capital of Ondo State in southwest Nigeria, was the subject of this study.

The building chosen for the study is a four-bedroom, two-parlor bungalow apartment made of cement that is home to a five-person household. The household makes a middle-class living. The property's floors are tiled consistently. The building's perimeter is made up of unpaved roads and is 100 meters from a busy thoroughfare (8 m). During the entire period, the structure was exposed to outdoor air. A separate room in the building houses the kitchen and pantry (3 x 3 x 3 m^3). The kitchen is usually used for cooking by at least three people.

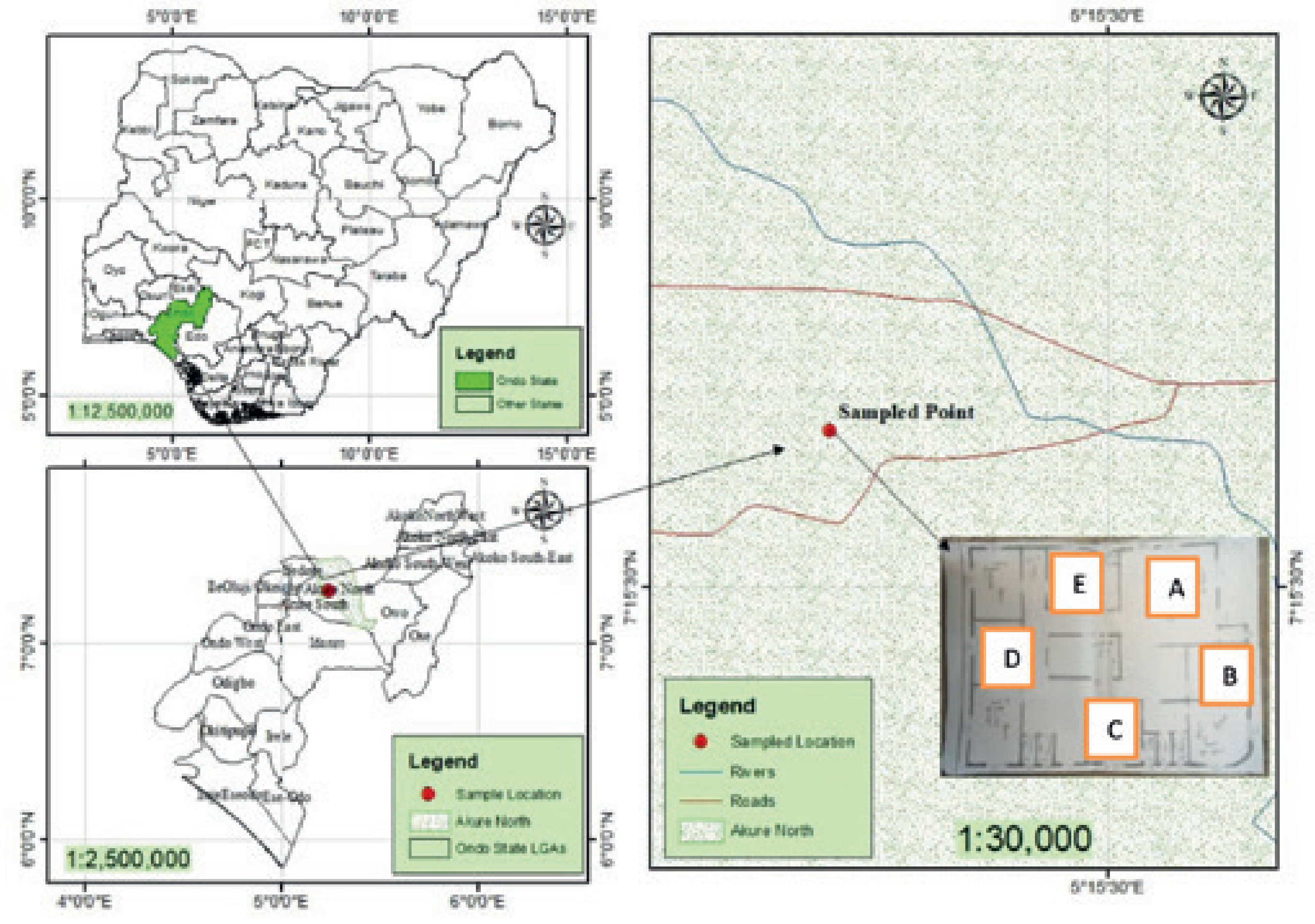
Every single kitchen window and the storeroom has three doors (two for the kitchen and one for the pantry). The windows and doors are typically left open while cooking. No room in the structure has a kitchen heaters system, and there is no air exhaust in the kitchen. Amongst cookware are gas cookers, stoves, and ovens that use gas, kerosene, or electricity. Every day, cooking activities like frying, grilling, boiling, and oven baking take place in the kitchen two to four times. In general, cooking approximately take place within 50 minutes.

The monitoring device (Canāree A1) utilized in this investigation is shown in Figure 2. The measurement took place at Akure, Ondo State, in a four-room house from January 5 to February 2 of 2022. Two living rooms, a kitchen, and two rooms were used for the research (Figure 3). There are various man-made activities that took place indoors, including candle combustion, cooking, sweeping, using insecticides (aerosol and coil), smoking cigarettes, and applying perfume. Within the study area, sweeping, burning of trash dumps and biomass, vehicle, pedestrian, and animal movements are a few examples of outdoor activities (Figure 4).



a) b) **Source:** This Study (2022)

Figure 2: a) Photograph Showing the Low-Cost Sensor during Monitoring of the Indoor Pollution b) Picture of the Sensor depicting the Parts



Source: This Study (2022)

Figure 3: Map Showing Nigeria, Ondo State, and the Sampling Point and the Sketch of the Building with Marked Rooms (A- 1st Living Room, B- 2nd Living Room, C- Kitchen, D- 1st Room, And E- 2nd Room).

When using the equipment, the manufacturer's procedures were meticulously followed. The device was initially set up with wireless networks before coming live. SenseiAQ Software Version 1.2.3 (Download: https://github.com/PieraSystems/SenseiAQ) was used to set up the device and register it with a SenseiAQ Cloud Account.

The USB cable was used to connect the device to the laptop, and then it was powered on. The SenseiAQ Software Version 1.2.3 (https://pierasystems.com/support/) and the Windows 10 installer were downloaded on the computer. The gadget (network) settings were set once the software detected the sensor while it was operating. The WiFi network's name and password were typed in and saved. To register the gadget with SenseiAQ Cloud, an account was made. Using SenseiAQ, the freshly made account was utilized to log into the device remotely (pierasystems.com).

The five sensors were mounted horizontally on a level surface after the previous stages were finished. Every second, the gadget downloaded data for Particle Counts ($PC_{0.1}$–PC_{10}) and Particulate Matter ($PM_{0.1}$–PM_{10}). A local CSV log file was created and used to view the obtained data in SenseiAQ. Hours instead of seconds were used to translate the data for this investigation. With Excel 2013's pie chart and basic description as well as Minitab 2020's t-test and 0.05 level of significance, the data was statistically evaluated.

RESULTS AND DISCUSSION

In the specified living rooms, kitchens, and rooms, the concentrations of Particle Counts ($PC_{0.1}$, $PC_{0.3}$, $PC_{0.5}$, $PC_{1.0}$, $PC_{2.5}$, $PC_{5.0}$, and PC_{10}) and Particulate Matter ($PM_{0.1}$, $PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, $PM_{5.0}$, and PM_{10}) were measured. It was anticipated that indoor air quality would differ because of the different conditions in the home areas. The validity of conducting a comparison examination between the living rooms, kitchen, and rooms is simultaneously supported by occupancy and internal sources of air pollution.

Table 2 displays the indoor PC levels and indoor PM levels recorded at every site (Table 3). The average level ranged from 522473 to 515529, 460491, 479130, and 388548 #/liter, while the minimum indoor levels for PC were 0.0 #/liter in all rooms A–E and the maximum values (#/liter) were 2920856 (A), 1829277 (C), 1489895 (D), 826443 (B), and 702683 (E). The significant changes in the initial and final results were the cause of the high variation in the outcomes in each of the apartments. Skewness values larger than one were found for $PC_{1.0}$, $PC_{2.5}$, and $PC_{5.0}$, indicating that the data sets had distortions or asymmetries that varied from the normal distribution. All of the data from sites A through E showed positively skewed distributions when the mean values were higher than the median.

Table 2: The Basic Description of the Particle Counts in the Different Monitoring Sites inside the Building

Statistics	PC 0.1	PC 0.3	PC 0.5	PC 1.0	PC 2.5	PC 5.0	PC 10
A							
Mean	522473	364491	570438	170866	37044	951	1.978
StDev	328498	24726	359160	422653	87660	1098	1.846
CoefVar	62.87	67.84	62.6	247.36	236.64	115.47	93.29
Skewness	4.64	4.93	3.92	8.36	8.28	4.41	1.76
Kurtosis	31.09	34.16	23.87	75.33	74.27	26.33	4.35
Minimum	209087	139082	186204	22466	5177	178	0.0
1st Quartile	333361	230268	35210	52277	11720	363	1.0
Median	439360	301843	491331	87760	19628	610	1.5
Maximum	2920856	2210458	3033271	3990283	826491	8589	10.0
B							
Mean	479130	273312	332470	110449	25034	932.3	0.97
StDev	166339	96992	131048	72165	16562	561.6	1.62
CoefVar	34.72	35.49	39.42	65.34	66.16	60.24	166.97
Skewness	0.31	0.33	.46	1.19	1.39	1.14	5.70
Kurtosis	-0.98	-0.89	-0.02	2.09	3.74	2.13	43.52
Minimum	215511	119317	124567	23440	3909	236.0	0.00
1st Quartile	339384	193398	225051	52532	12526	490.0	0.00
Median	455705	258214	305889	90961	19174	772.0	1.00
Maximum	826443	507505	791309	417123	103615	3345.0	14.00
C							
Mean	515529	326941	455985	115783	25292	817.1	1.121
StDev	218078	144796	240171	133981	29197	910.3	1.674
CoefVar	42.30	44.29	52.67	115.72	115.44	111.40	149.20

Skewness	2.60	2.56	2.36	5.29	5.30	5.18	2.78
Kurtosis	12.64	12.54	10.94	37.25	37.38	35.92	9.47
Minimum	238127	142923	152435	22002	4735	176.0	0.00
1st Quartile	354018	217284	265803	45369	10186	332.0	0.00
Median	488672	305711	410973	84280	18521	602.0	1.00
Maximum	1829277	1198785	1860805	1152693	251446	7796.0	10.00
D							
Mean	460491	277109	328310	86760	18142	202.5	0.376
StDev	254843	160727	198011	109871	22490	199.4	0.806
CoefVar	55.34	58.00	60.311	126.64	123.7	98.51	214.28
Skewness	2.02	2.06	1.84	3.22	3.17	2.33	4.29
Kurtosis	4.54	4.75	3.83	11.11	11.65	5.83	25.97
Minimum	200928	115035	119499	17448	2680	46.0	0.000
1st Quartile	297762	174747	200306	3129	6408	87.0	0.000
Median	364277	214938	265588	46490	9540	120.0	0.000
Maximum	1489895	931384	1124491	608299	137745	1016.0	6.000
E							
Mean	388548	268424	414200	83952	20648	503.3	16.2
StDev	126451	91513	163982	53046	13299	311.9	162.2
CoefVar	32.54	34.09	399.59	63.19	64.41	61.7	1000.30
Skewness	0.74	0.75	0.72	1.14	1.12	1.14	10.39
Kurtosis	-0.50	-0.50	-0.46	0.33	0.31	0.30	107.99
Minimum	226447	150254	177187	26533	5499	168.0	0.0
1st Quartile	290341	197447	282481	44723	11110	270.3	0.00
Median	357297	246354	378005	65445	16132	403.0	0.0
Maximum	702683	494819	799428	238650	59352	1388.0	1686.0

A- 1st Living Room, B- 2nd Living Room, C- Kitchen, D- 1st Room, and E- 2nd Room.

Table 3: The Basic Description of the Particulate Matter in the Different Monitoring Sites inside the Building

Statistics	PM 0.1	PM 0.3	PM 0.5	PM 1.0	PM 2.5	PM 5.0	PM 10
A							
Mean	0.437	8.66	68.24	-	695	794	797
StDev	0.28	5.85	43.30	-	1537	1642	1642
CoefVar	62.87	67.59	63.46	-	221.16	206.71	206.13
Skewness	4.64	4.92	4.05	-	8.22	8.00	7.99
Kurtosis	31.09	34.02	25.23	-	73.46	70.54	70.46
Minimum	0.18	3.31	22.76	-	109	128	128
1st Quartile	0.28	5.48	42.39	-	239	277	279
Median	0.37	7.18	58.41	-	389	453	455
Maximum	2.44	52.31	369.10	-	14497	15394	15395

B							
Mean	0.40	6.57	41.29	133.58	460.5	557.9	559.2
StDev	0.14	2.33	15.95	75.75	290.9	349.1	349.8
CoefVar	34.72	35.44	38.62	56.17	63.18	62.58	62.56
Skewness	0.31	0.33	0.41	1.01	1.29	1.27	1.27
Kurtosis	-0.98	-0.90	-0.24	1.51	3.11	2.95	2.96
Minimum	0.18	2.87	15.88	35.47	87.1	111.8	112.1
1st Quartile	0.28	4.65	27.80	72.22	232.8	279.0	279.8
Median	0.38	6.21	37.98	115.01	390.1	470.8	472.1
Maximum	0.69	12.14	94.78	443.32	176.5	2145.9	2151.8
C							
Mean	0.43	7.81	55.43	153.3	482.7	567.9	569.4
StDev	0.18	3.45	28.47	139.5	519.6	614.5	615.3
CoefVar	42.30	44.18	51.36	91.10	107.65	108.21	108.04
Skewness	2.60	2.57	2.39	4.63	5.15	5.16	5.14
Kurtosis	12.64	12.55	11.22	30.68	35.87	35.92	35.79
Minimum	0.20	3.42	19.34	37.7	9.6	118.1	118.4
1st Quartile	0.30	5.20	32.96	71.2	201.4	236.9	237.5
Median	0.41	7.31	50.37	121.0	363.1	425.3	427.4
Maximum	1.53	28.57	222.92	1186.1	4469.9	5283.9	5286.5
D							
Mean	0.39	6.64	40.93	113.4	350.3	371.5	372.2
StDev	0.21	3.84	24.49	115.3	408.0	428.5	428.6
CoefVar	55.35	57.85	59.84	101.62	116.49	115.36	115.16
Skewness	2.02	2.06	1.88	2.95	3.08	3.04	3.04
Kurtosis	4.54	4.74	3.97	9.51	10.79	10.49	10.47
Minimum	0.17	2.77	15.25	30.0	65.2	70.1	70.3
1st Quartile	0.25	4.19	25.17	51.3	135.8	144.7	145.2
Median	0.31	5.15	32.8	68.3	197.0	208.8	209.7
Maximum	1.25	22.26	139.70	648.0	2446.9	2552.9	2553.5
E							
Mean	0.32	6.38	49.64	124.83	390.6	442.0	443.1
StDev	0.11	2.17	19.29	92.44	240.5	269.2	270.0
CoefVar	32.53	34.01	38.86	74.06	61.59	60.92	60.94
Skewness	0.74	0.75	0.72	4.58	1.16	1.09	1.09
Kurtosis	-0.51	-0.50	-0.47	32.61	0.60	0.22	0.22
Minimum	0.19	3.58	22.08	44.67	117.7	135.3	135.6
1st Quartile	0.24	4.70	34.30	72.00	216.6	244.9	245.5
Median	0.30	5.86	45.50	100.45	311.5	353.8	354.7
Maximum	0.59	11.75	95.24	838.85	118.3	1200.2	1206.3

PM$_{10}$, which ranged in diameter from 0.1 to 10 µg/m^3, had the greatest concentration of all the particulate matter. Sites A, C, D, B, and E had minimum and maximum (g/m3) values of 128 and 15395 (mean

= 797) and 118.4, 5286.5 (mean = 569.4), 70.3, 2553.5 (mean = 372), 112.1, 2151.8 (mean = 559.2), and 135.6, 1206.3 (mean = 443.1), accordingly. The findings showed that the PM ranges had significant standard deviations. While a low standard deviation meant that the data points were closely clustered around the mean, a high standard deviation meant that the data points were distant from the mean. All measurements revealed a significant degree of kurtosis. It must be observed that the data has heavier tails than a normal distribution (more in the tails) if the kurtosis is larger than 3; conversely, the data has lighter tails than a normal distribution (less in the tails) if the kurtosis is less than 3. (less in the tails). According to the general principle for kurtosis, the dispersion is too peaked if the value is higher than +1. Similar to this, an excessively flat distribution is indicated by a kurtosis of less than -1. Skewness and/or kurtosis in non-normal distributions are above these limits (Hair et al., 2016).

The sites with the highest PM and PC values were the living room (Site A) and the kitchen (Site C), depicted in Figure 4. The reasons for the high PM and PC values were: Firstly, the living room was nearer to a dirt road, secondly, the windows and entry door have all been frequently left closed, implying low ventilation; thirdly, smoke from the kitchen during cooking moved into the living room through the passage within the building; the forth, cigarette smoking and vaping; and lastly, smoke from outside. The cooking, frying, baking, and grilling that's been done in the kitchen resulted in exceptionally high PM and PC levels. Additional sources of pollution in other rooms included cigarette smoking (Site B), pesticide and mosquito coils (Site D), and fragrance and candle burning (Site E). In general, the interior air quality might have been impacted by the cooking and outside activities. The results back up Tran et al. (2020)'s assertion that several pollution sources can be found in both indoor and outdoor settings, whereas others come from outside settings. Indoor air quality in residential neighborhoods or buildings is primarily influenced by three factors: (i) outdoor air quality, (ii) human activities in structures, and (iii) building and construction supplies, furnishings, and equipment (Mar et al., 2018; Peng et al., 2017). IAP is harmful to health whether exposed for a short time or a long time, according to WHO (2017). It's understandable why some of the people living in this building were sneezing, coughing, and had runny noses.

Source: This Study (2022)

Figure 4: Sources of Indoor Air Pollution from Indoor and Outdoor of the Building

For facility economy and human comfort, indoor air quality (IAQ) is essential. Since studies have connected poor interior air quality to enhanced COVID-19 transmission, the building's residents were at risk for COVID-19 because the particle counts and mass indoors were high in this study (Watson, 2021).

Table 4 displayed the PC and PM assessments of the rooms. Particle counts in Rooms A and C were greater than in the other rooms. The room with the least PC was Room E. The high PC indicated an increase in the particles produced by nearby man-made activities. Environmental pollution also had an effect on the higher PC. The results show that the PC values decrease as the particle count diameter increases. The high PC in the different rooms may be caused by stagnant air (lack of wind and air mixing), when particles are not removed by the wind, or when breezes carry dirty air in from outside sources. The t-test findings showed that there was no statistically significant difference between the PC results' means among the five rooms ($p > 0.05$). All of the rooms showed the similar patterns, with the exception of room D, which had low readings from $PM_{0.5}$ to PM_{10} compared to the others. The events that took place during the monitoring could be reason for this state. The results reported by Tittarelli et al. (2008) for the particle counts (13517 (minimum) - 507529 (maximum) at a location in Lingotto station, a residential area in Turin, were significantly lower than the PC mean values observed here. The discrepancies between the two places might be attributed to the temperature, population in the buildings, weather parameters, and circulation of the two places.

Table 4: Comparisons of the Mean Results of Rooms (A-E) Within the Building

Parameter	A (n=92)	B (n=99)	C (n=99)	D (n=93)	E (n=108)
PC 0.1	522473	479130	515529	460491	388548
PC 0.3	364491	273312	326941	277109	268424
PC 0.5	570438	332470	455985	328310	414200
PC 1.0	170866	110449	115783	86760	83952
PC 2.5	37044	25034	25292	18142	20648
PC 5.0	951	932.3	817.1	202.5	503.3
PC 10	1.978	0.970	1.121	0.3763	16.2
PM 0.1	0.4366	0.4.003	0.4308	0.3847	0.3246
PM 0.3	8.660	6.566	7.807	6.636	6.380
PM 0.5	68.24	41.29	55.43	40.93	49.64
PM 1.0	-	133.58	153.2	113.4	124.83
PM 2.5	695	460.5	482.7	350.3	390.6
PM 5.0	794	557.9	567.9	371.5	442.0
PM 10	797	559.2	569.4	372.2	443.1

The impacts of locations to each of the observed PCs as identified during tracking are shown in Figure 5(a-e). In every site, the sequence of impact was the same: $PC_{0.1} > PC_{0.3} > PC_{0.2} > PC_{0.5} > PC_{1.0}$. Rooms A, B, C, and D had the highest levels of $PC_{0.1}$, $PC_{0.3}$, and $PC_{0.2}$, respectively. The impacts of each location to the overall quantity in the surroundings are shown in Figure 6(a-e). The PC and PM values were influenced by the indoor activities that took place during the measurement times. The most abundant particles were PM_{10} and PM_5, which made up of rooms B (32%), C (31%), D (31%), and E (30%). These results are in line with those made by Al-Awadhi (2014) in Kuwait, who found that PM10 was the main contributor of air pollution, and Motesaddi et al. (2017) in Tehran, also made a similar discovery. In-room A, PM_5, and $PM_{2.5}$ had higher percentage, each contributing 34% to the air quality determination, followed by $PM_{1.0}$, which accounted for 29%. This might be caused by interior ventilation issues, crowding, and indoor air pollution infiltration.

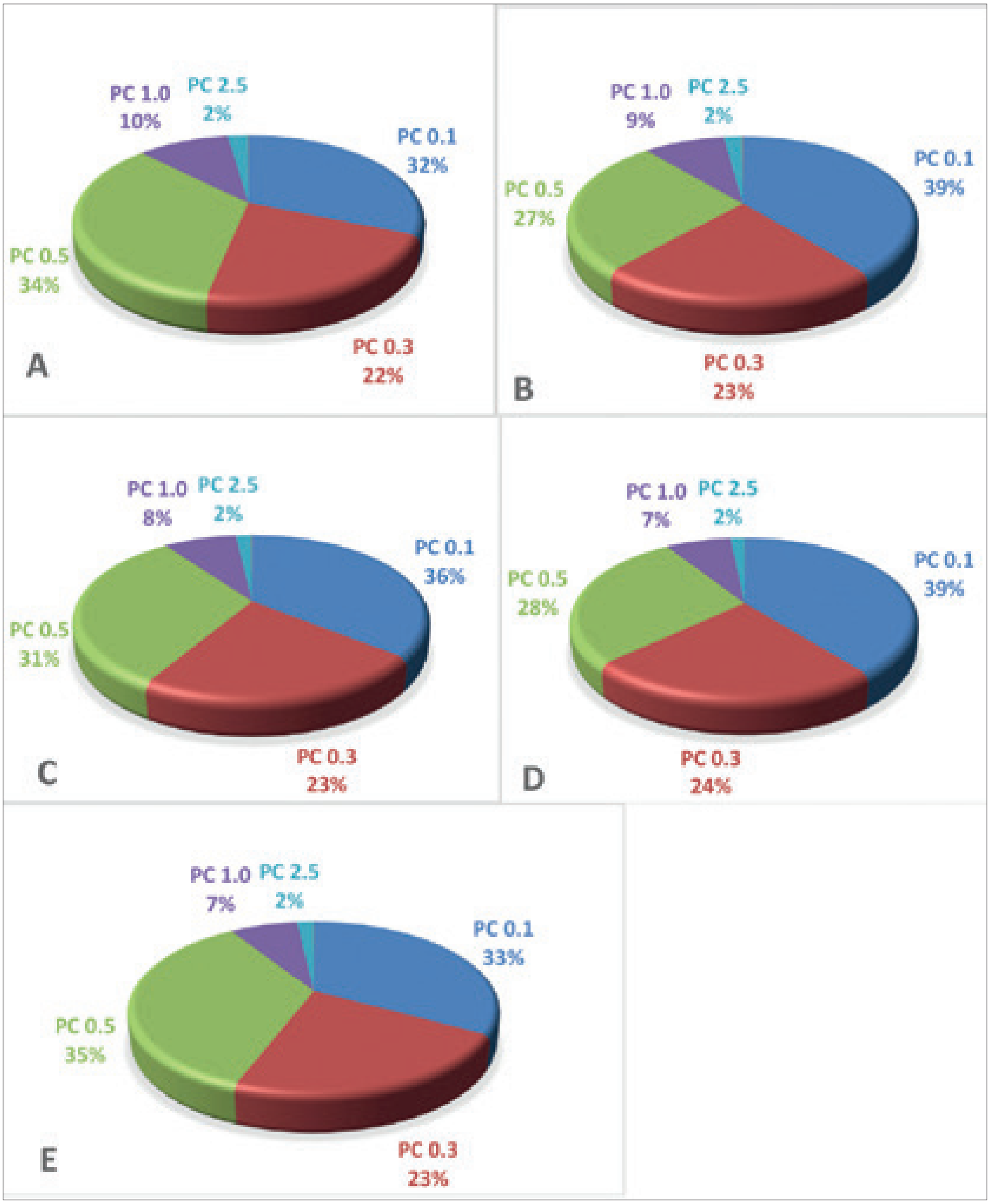


Figure 5: The Contributions of Particle Count to Each of the Rooms in the Building

The time series of PC and PM were plotted using the data that were gathered for this investigation. The average PC and PM concentrations are shown in Figure 7(a-e), and they generally follow a pattern of greater PC_{10} and PM_{10} concentrations in rooms A and C and lower values in room E. On the other hand, $PC_{0.5}$ concentrations were higher in Room E. If the atmosphere were more active, the pollutant dispersion processes would aid the emitted pollutants, explaining the lower PM_{10} concentration in room D. The time of monitoring and, most likely, weather conditions were the causes of the discrepancies found in this study. There are three fundamental elements of time series data: seasonality, trend, and residuals (Gerbing, 2016).

Understanding a time series' behavior requires deconstructing it. The time series' seasonality is consistent with seasonal swings in pollution levels. Seasonality has always had a defined and well-established period, typically several months (twelve). The trend component shows whether a pollutant's concentration is rising or falling over time and illustrates the time series' general long-term tendency. The part of the data that cannot be assigned to seasonality or trend is known as the residual or error component of a time series (Munir and Mayfield, 2021).

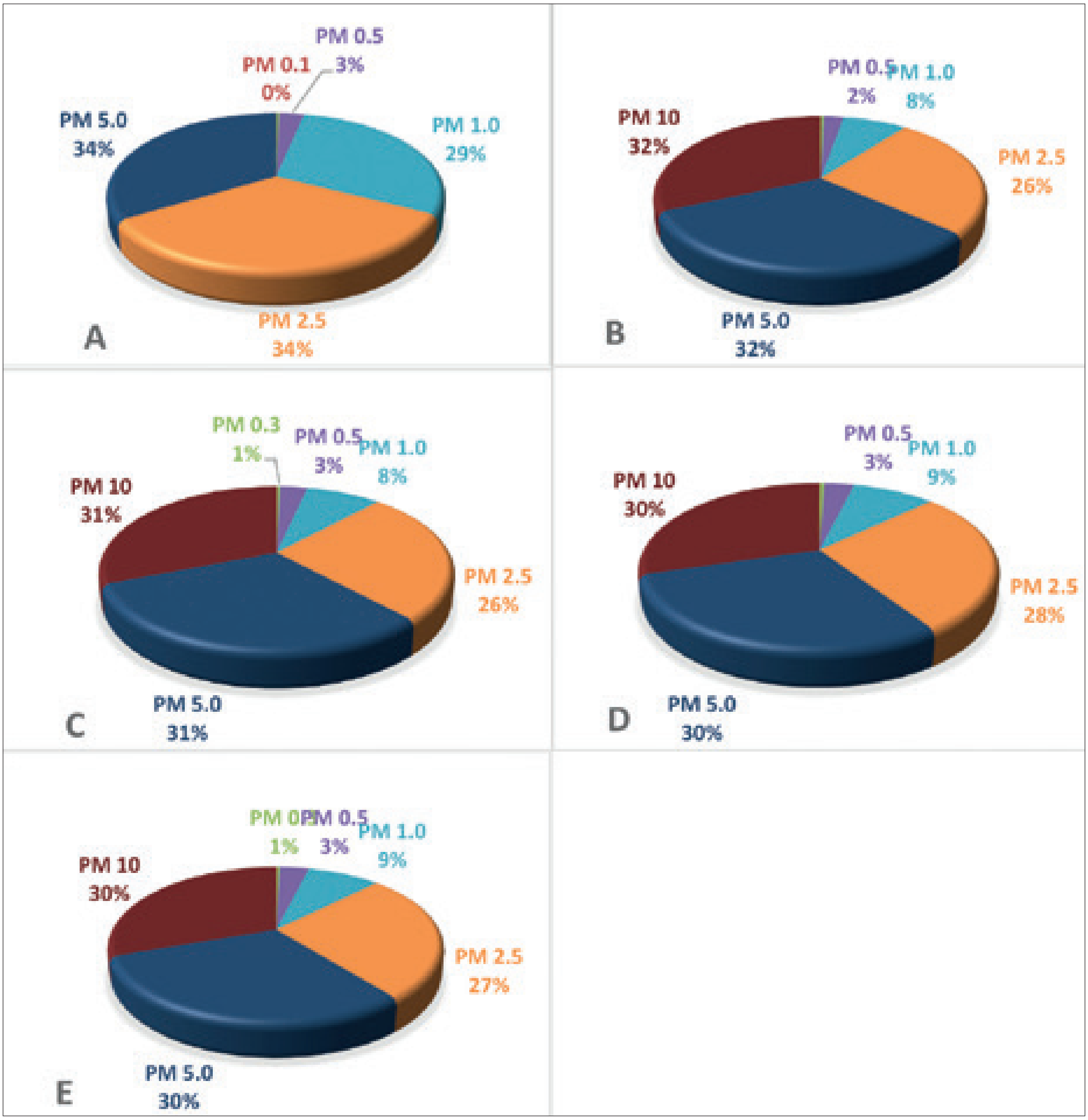
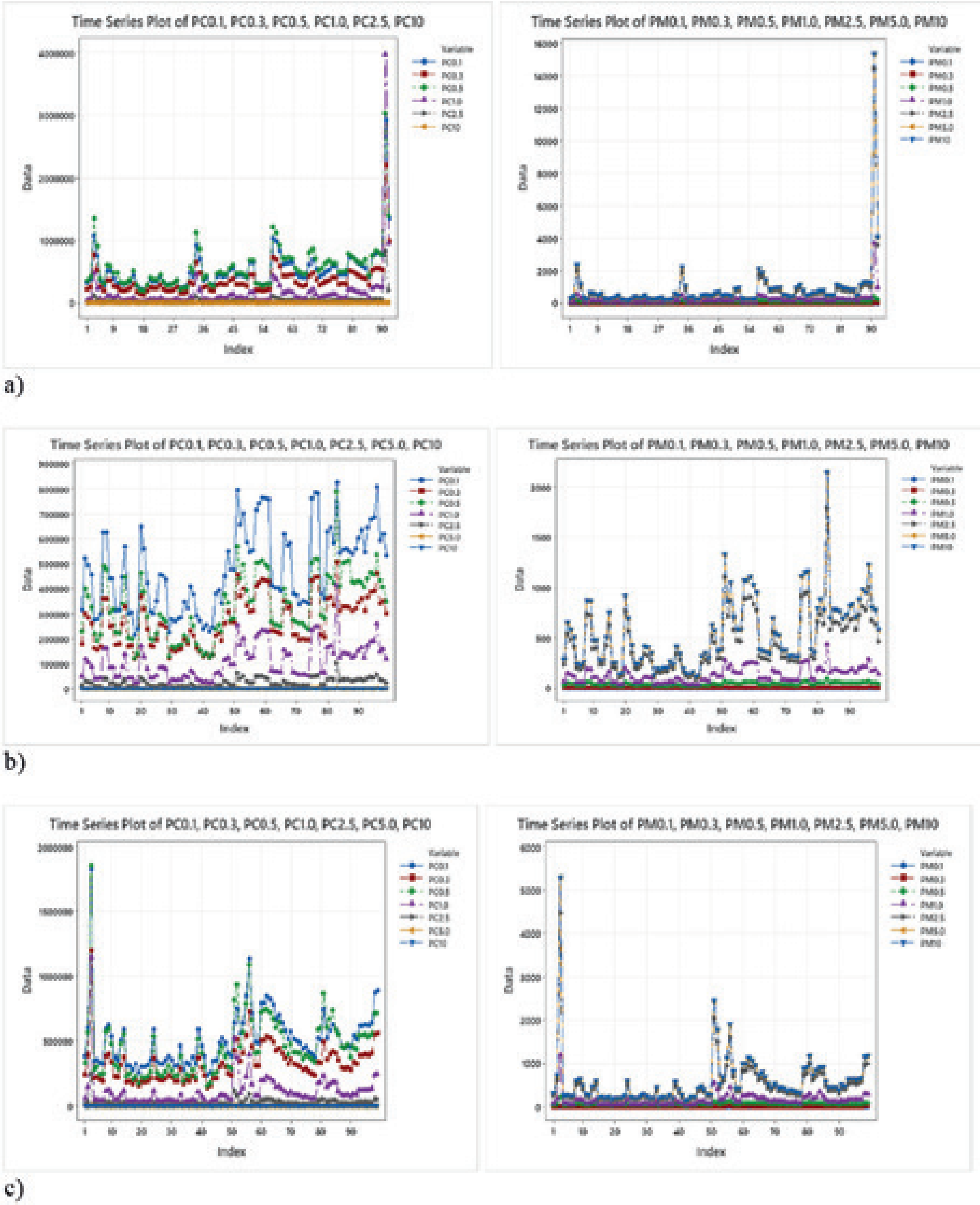


Figure 6: The Contributions of Particulate Matter to Each of the Rooms in the Building


Time Series Plot of PC0.1, PC0.3, PC0.5, PC1.0, PC2.5, PC10
Data
Index
Variable
PC0.1
PC0.3
PC0.5
PC1.0
PC2.5
PC10
Time Series Plot of PM0.1, PM0.3, PM0.5, PM1.0, PM2.5, PM5.0, PM10
Variable
PM0.1
PM0.3
PM0.5
PM1.0
PM2.5
PM5.0
PM10
Time Series Plot of PC0.1, PC0.3, PC0.5, PC1.0, PC2.5, PC5.0, PC10
PC5.0
Time Series Plot of PM0.1, PM0.3, PM0.5, PM1.0, PM2.5, PM5.0, PM10
Time Series Plot of PC0.1, PC0.3, PC0.5, PC1.0, PC2.5, PC5.0, PC10
Time Series Plot of PM0.1, PM0.3, PM0.5, PM1.0, PM2.5, PM5.0, PM10

a)

b)

c)

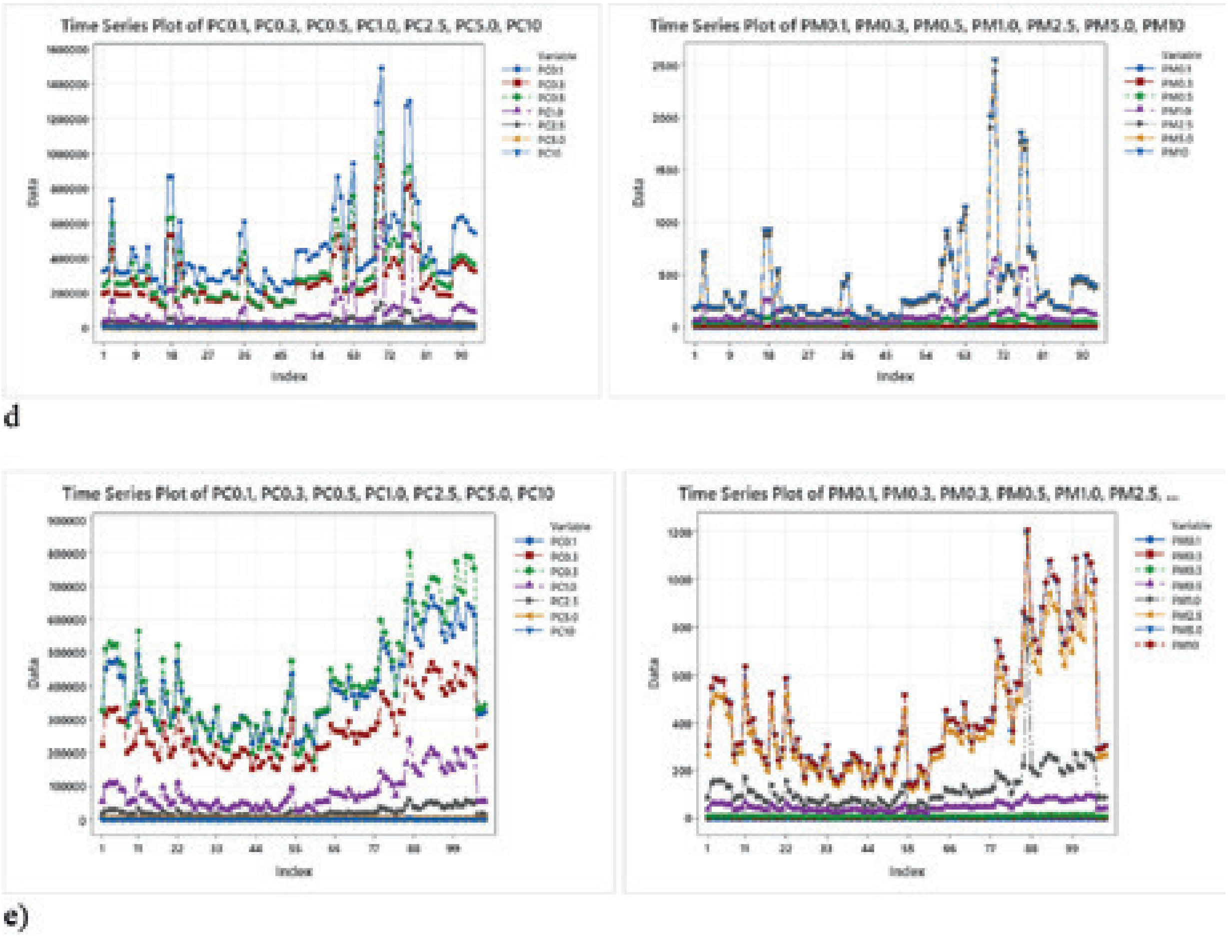


Figure 7 (a - e): The Time Series Plot Showing the Results of PC and PM in the Indoor Monitoring Location

CONCLUSION

In summary, PC and PM levels were high and surpassed WHO benchmark levels for different diameters (0.1, 0.3, 0.5, 1.0, 2.5, 5.0, and 10). One of the key advantages of Canāree, the low-cost particle counter model employed in this research, is its ability to identify particles with diameters as small as 0.3 µm, indicating an adequate evaluation of total particle number and a feasible evaluation of mass over the monitoring periods. The indoor air pollutant was notable for causing poor IAQ and, as a result, causing negative health consequences such as coughing, sneezing, and runny nose. The residents are prone to COVID-19 even though there were no incidences reported during the study. There were two primary sources of pollution in the building: i. human-induced activities in the building rooms, like combustion in the kitchen and candle burning, cleaning, smoking, using insecticide and mosquito coils, using perfume, and using specific materials and products when using electronic machines; and (ii) vehicular movements from outside sources, burning of waste and biomass, sweeping, and other factors. High amounts of this pollutant were discovered in the rooms, and prolonged exposure and poor ventilation can have detrimental effects on one's health. Implementing techniques and approaches for pollution control and reduction is necessary to lessen the effects of IAP in this apartment complex.

DECLARATIONS

Ethical Approval

The Ondo State Health Research Ethics Committee of the Ministry of Health gave the study approval with the given numbers NHREC/18/08/2016 and OSHREC 29/11/2021/403.

Consent to Publish

Not Applicable

Authors Contributions

Francis, Conceptualization and wrote the original draft; Vincent, Jay, Raj – All provided the sensors; Akinyinka, Yemisi, Kikelomo, Ademola, Lateef, writing, reviewed, and editing. All authors read and approved the final manuscript**.**

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Competing Interests

None

Availability of data and materials

On request, information are available.

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