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Indoor Air Measurements with a Low-Cost Air Quality Sensor: A Preliminary Report †

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Abstract: The goal of the project was to monitor $PM_{0.1}$ to PM_{10} levels in one of the four rooms in a four-bed building for a period of one month using a low-cost in accordance with the manufacturer's instructions. The data collected during this period was statistically analyzed using Minitab software. The mean PM (μg/m³) values obtained when compared with the available World Health Organisation (WHO) standards, $PM_{2.5}$ and PM_{10} were found to be above the 24-hour limits, indicating a potential danger to the environment and individuals.

Keywords: PM0.1; Sensor technology; Indoor; Communities; WHO

1. Introduction

By supplying reliable and inexpensive energy (Goal 7) in communities and cities that are sustainable (Goal 11), the United Nations Sustainable Development Goals [1] aim to improve the quality of life (Goal 3). Improving indoor air quality (IAQ) fits perfectly with these objectives. Lower indoor air pollution (IAP) is particularly crucial for attaining gender balance (Goal 5) and reducing poverty (Goal 10), as emissions from burning solid fuels like coal as well as wood when heating have a significant negative impact on women in developing nations and put them at a higher risk for IAP-related disorders. The risk that contaminants from the inside can reach the lungs rises by an order of 1,000 [2, 3] because research shows that air contaminants indoors are always greater than that outside because of constrained regions [4].

Several illnesses may serve as helpful warning signs of poor IAQ, particularly if symptoms develop after an individual relocates into a fresh house, remodels or redecorates their present residence, or uses chemical treatments on their property. Finding probable causes of contamination of indoor air is another technique to determine whether your home now has indoor air quality issues or is at risk of developing them. Examining your way of life and daily activities can be an additional indicator in determining the probability that your home has poor IQA. Lastly, check for indications that your home's airflow may be having issues. Due of the price, a cheap sensor will be helpful for detecting contaminants indoors. Research have been conducted indoors in locations with a variety of pollution sources [5, 6], but few or no investigations have been conducted in locations where people smoke cigarettes. If one is being examined, it is not inappropriate.

Hence, this research presents the initial results of an IQA surveillance study conducted in a building where cigarette is smoked often. The study presents information gathered about $PM_{0.1}$ to PM_{10}. This study adds to our understanding of the function of inexpensive sensors in determining indoor air quality.

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2. Materials and Methods

The Canāree A1 surveillance equipment utilized in this investigation is shown in Figure 1. This portable Air Quality Monitor (AQM) detects air quality in real-time. It makes use of the Bosch BME688 (I5 versions) and the Intelligent Particle Sensor series 7100. Canree can categorize sources of air pollution for interior applications such as smoke (tobacco, wildfire), vaping, cooking, dust, and toxic gas detection using data from the sensors and special algorithms to recognize various particulate sources. The sensing component of the Canree A1 sensor can measure pressure, temperature, relative humidity, CO_2, BVOC, and airborne particles ($PM_{0.1}$ to PM_{10}) [7]. This investigation is an initial overview of a one-month investigation into IQA evaluation in Akure, Nigeria's Ondo State. One of the four bedrooms in a four-bed residence is used in the investigation for measuring $PM_{0.1}$ to PM_{10} values. The manufacturer's recommendations were followed when Canāree A1 was deployed on January 5, 2023, and it continues recording information today [7]. There are several human-made events present in the apartment that was the subject of the study, including cigarette smoking, to name a few. Within the study area, vacuuming, biomass combustion and garbage landfills, as well as vehicular, pedestrian, and animal movements, are a few instances of outdoor activities.

Every second, the range of particulate matter ($PM_{0.1}$–PM_{10}) is downloaded. In SenseiAQ, the acquired data is evaluated and then recorded to a local CSV log file. Excel 2013 was used to statistically evaluate the results for the study, translate the data from seconds to hours, and create pie charts, and loading plots.

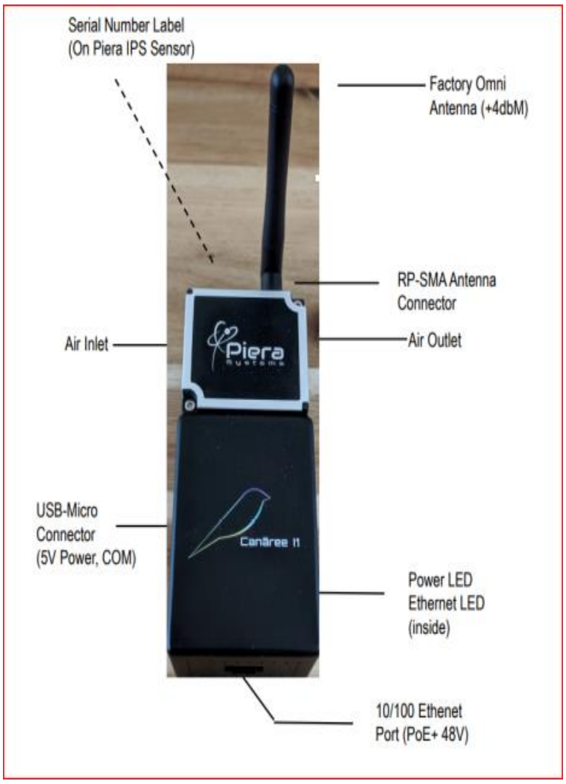

Figure 1. Low cost sensor (Canāree A1).

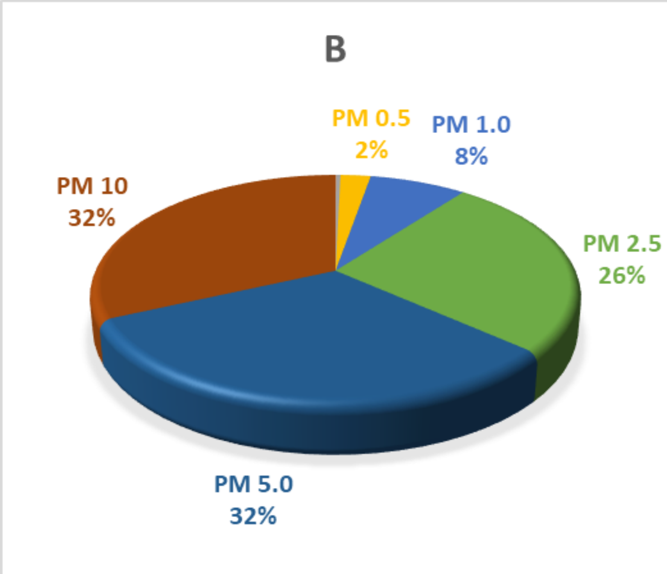

Figure 2. Chart of the contributions of PM levels.

3. Results and Discussion

Table 1. Anderson-Darling Normality Test Results.

	$PM_{0.1}$	$PM_{0.3}$	$PM_{0.5}$	$PM_{1.0}$	$PM_{2.5}$	$PM_{5.0}$	$PM_{10.0}$
P-value	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
A-Square	1.31	1.26	1.24	1.91	2.24	2.18	2.18
Mean	0.40	6.57	41.29	133.58	460.51	557.89	559.24
Std	0.14	2.33	15.95	75.75	290.94	349.13	349.84
Variance	0.019	5.42	254.31	5738.71	84645.83	121893.85	122388.73
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	2.96	2.96
N	99	99	99	99	99	99	99
Minimum	0.18	2.87	15.88	35.47	87.13	111.85	112.14
Q1	0.28	4.65	27.80	72.22	232.83	279.00	279.77
Median	0.38	6.21	37.98	115.01	390.15	470.84	472.13
Maximum	0.69	12.14	94.78	443.32	1796.55	2145.91	2151.80
Q3	0.51	8.33	54.88	181.42	685.27	783.01	785.65
95% Confidence Interval (mean)	0.43	7.03	44.47	148.69	518.54	627.53	629.01
95% Confidence Interval (median)	0.46	7.49	45.29	150.99	478.92	579.43	581.04
95% Confidence Interval (Std)	0.16	2.71	18.54	88.07	338.25	405.91	406.74

The minimum and maximum (μg/m³) values of 0.18-0.69 (0.4±0.14), 2.87-12.14 (2.33±6.57), 15.88-94.78 (41.29±15.95), 35.47-443.32 (133.5±875.75), 87.13-1796.55 (460.51±290.94), 111.85-2145.91 (557.89±349.13), and 112.94-279.77 (559.24±349.84) of 0.1, 0.3, 0.5, 1.0, 2.5, 5.0, and 10 respectively. The mean values of $PM_{2.5}$ and PM_{10} are far above the 24 h and annual ($PM_{2.5}$ - 15 and 5 μg/m³) and (PM_{10} – 45 and 15 μg/m³) recommended WHO [8] limits respectively. The findings showed that the PM ranges had significant standard deviations. While a low standard deviation meant that the data sets were tightly grouped about the mean, a high standard deviation meant that the data sets were distant from the mean. Every observation revealed a significant amount of kurtosis. It noted that if the kurtosis are -0.24-3.11. If the kurtosis is greater than 3, the dataset has shorter tails than a normal distribution (less in the tails), and vice versa. If the kurtosis is lower than 3, the dataset has more weight in the tails than a normal distribution (more in the tails).

According to the general rule for kurtosis, the distribution is too peaked if the value is higher than +1. Identical to this, an excessively flat distribution is indicated by a kurtosis of less than -1. These ceilings are exceeded by nonnormal distributions' skewness and/or kurtosis [9]. Cigarettes smoking in the room and pollutants brought in from outdoor activities are to blame for the high levels of $PM_{2.5}$ (26%), $PM_{5.0}$ (32%), and PM_{10} (32%) shown in Figure 1. The results back up Tran et al. [10]'s assertion that certain pollutants origins can be observed in indoor as well as outdoor environments.

Table 2. Descriptive Statistics of Run.

Test

Null hypothesis H_0: The order of the data is random
Alternative hypothesis H_1: The order of the data is not random

	Number of Runs		
Variable	**Observed**	**Expected**	**P-Value**
PM0.1	18	50.25	0.000
PM0.3	18	50.09	0.000
PM0.5	18	50.37	0.000
PM1.0	18	50.09	0.000
PM2.5	18	49.65	0.000
PM5.0	18	49.89	0.000
PM10	18	49.89	0.000

			Number of Observations	
Variable	**N**	**K**	**≤ K**	**> K**
PM0.1	99	0.400	53	46
PM0.3	99	6.566	54	45
PM0.5	99	41.294	52	47
PM1.0	99	133.576	54	45
PM2.5	99	460.508	56	43
PM5.0	99	557.893	55	44
PM10	99	559.238	55	44

K = sample mean

The Runs test, a method of statistical analysis, is shown in Table 2 and examines if a series of data inside a certain distribution were obtained through a random process or not [11]. It is used to check the data's randomness in this investigation. The data acquired are subject to randomness (≤ K), which is inferred from the table (H_0 is chosen as the hypothesis).

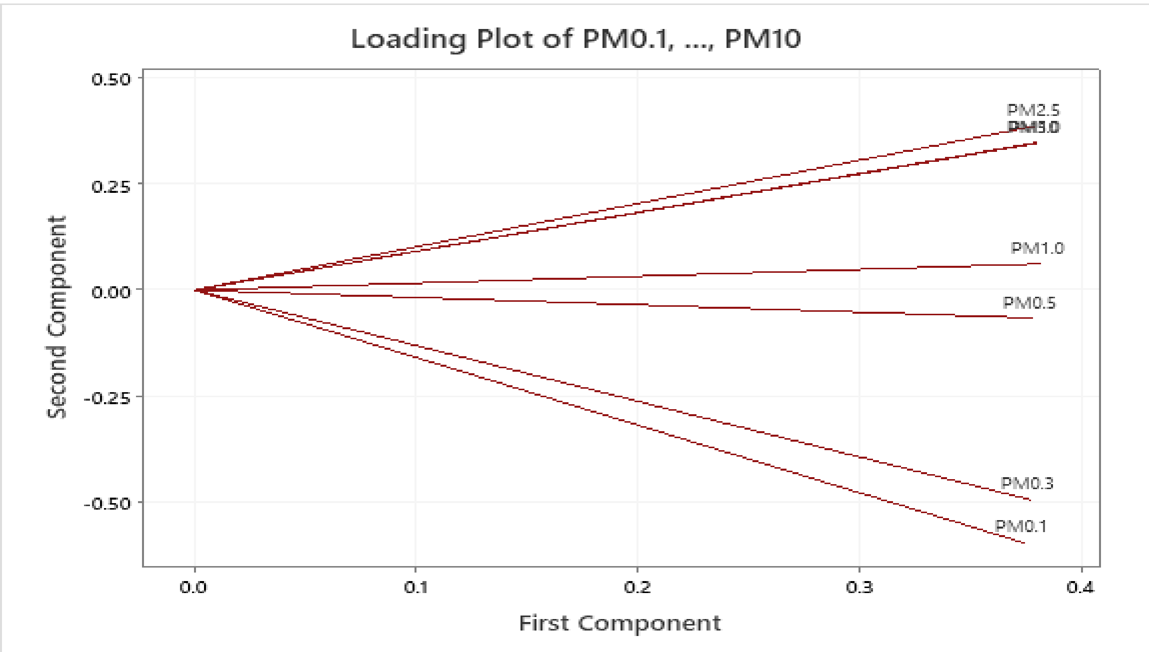

Figure 3. The loading plot of the particulate matter studied.

The PM loadings are shown in Figure 3. In the data set of the pollutants at the study room, the principal components (PC) 1, 2, and 3 successively accounted for $PM_{1.0}$ and $PM_{0.5}$ (87.74%), $PM_{0.3}$ and $PM_{0.1}$ (12.25%), $PM_{2.5}$ and $PM_{5.0}$ (3.01%) variability (Fig. 3). The loading plot's first two components, cigarette smoke and outdoor penetration of pollution contact, respectively, were used to clarify the variation. The variance was only partially explained by other components with eigenvalues greater than 1.

4. Conclusion

In the present investigation, a low-cost sensor was used to monitor the $PM_{0.1}$-PM_{10} levels in a room of a four bedroom apartment in Akure, Nigeria, over the course of one month. Cigarette smoking in the room and pollutants brought in from outside activities are to blame for the high levels of $PM_{2.5}$, $PM_{5.0}$, and PM_{10}. Additionally, the results demonstrate that $PM_{2.5}$ and PM_{10} levels were considerably higher than WHO 2021 values. Guidelines were lacking, therefore it was impossible to compare the data to that of others ($PM_{0.1}$, $PM_{0.3}$, $PM_{0.5}$, $PM_{1.0}$, and $PM_{5.0}$). The variation in the variance shows the substantial differences in the results' levels throughout the course of the monitoring period and the randomness of the PM levels throughout the data. Future study calls for extensive intervention studies, involving cost-benefit assessment, medical impact, and tracking of IAP levels. Considering into account the spatial distribution of smoke exposure in the environment, this study is anticipated to assist decision-makers in their evaluation of environmental health-policy initiatives related to exposure to cigarette smoking in this subtropical region.

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