



A low-cost measuring investigation of the indoor air quality in a tertiary institution library

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Abstract

Finding out the present indoor air quality (IAQ) conditions in the Federal College of Agriculture, Akure (FECA) library within Nigeria is the aim of the investigation described in this piece. A reading room lacking a cooling system was used for the assessment. Before use, the sensor was collocated with a reference monitor at the National Agency for New Technologies, Energy and Environment (NEEA) reference station in Italy to confirm its accuracy. Temperature, relative humidity (RH), CO₂, PM₁, PM_{2.5}, PM₁₀, NO₂, O₃, and other concentrations were among the many internal thermal conditions found in the library room, according to the results. Temperature (28.4-36.30 °C), RH (47.7-67.80%), PM₁ (0-80 µg/m³), PM_{2.5} (0-103 µg/m³), PM₁₀ (0-106 µg/m³), NO₂ (153-276 ppb), O₃ (24-78 ppb), and CO₂ concentrations ranged from 453 to 6158.1 ppm. The PM levels did not meet the guidelines set forth by the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the World Health Organization (WHO). The results show a relationship between the PM and meteorological conditions. The location's CO₂ and NO₂ have a somewhat negative connection ($r = -0.061$, $p = 0.000$). The major component (PC1) has comparable loadings for PM₁, PM_{2.5}, and PM₁₀, suggesting that all particle sizes contribute equally to variations in indoor air quality. Although it is encouraging to see that the contaminants do not pose a risk to users of libraries, all stakeholders should make sure that every effort is made to minimize their effects on people and library materials.

Keywords: Library, air quality, Sentin Air, pollutants, meteorological parameters, NESREA

Introduction

Readers at universities devote their free hour in the library (Wu *et al.*, 2018) [29]. It may be more challenging to give readers a comfortable indoor thermal setting and good indoor air quality because many educational institutions' libraries lack central air cooling system for heating, cooling, and ventilation owing to their built-up history, which dates back several dozen years. Since fresh air only depends on infiltration from the outside, IAQ will worsen even more during the change in season when windows and doors shut (Li *et al.*, 2015; Shi *et al.*, 2015; Mihucz and Záray, 2016) [16, 25, 20]. As a result, worries about contaminants in the air institution libraries have grown. Volatile organic compounds (VOCs) include organic acids like acetic and formic acid and aldehydes like acetaldehyde and formaldehyde are common indoor contaminants that are also present in libraries (Fenech *et al.*, 2010) [10]. Furthermore, it was found that general libraries in Strasbourg, France, had the greatest indoor concentrations of formaldehyde when

aldehyde was determined in a variety of public locations, including shopping centers, railway stations, airports, libraries, underground parking garages, etc. (Marchand *et al.*, 2006) [19]. Libraries 1 and 2 had indoor formaldehyde values of 55.9 ± 4.9 and $33.7 \pm 2.2 \mu\text{m m}^{-3}$, respectively. There were numerous lines of old books and journals in Library 1 (Kim *et al.*, 2013) [14]. This could be because paper and other cellulose-based materials are known to release a number of volatile organic compounds (VOCs) as they degrade (Radiello, 2009) [24].

IEQ variables associated with library environments have been the subject of many research investigations with differing findings. According to a Nigerian research that evaluated the IEQ of three distinct libraries, all of the facilities exhibited subpar IEQs in comparison to standards like the Chartered Institution of Building Services Engineers (CIBSE) handbook (Akanmu *et al.*, 2021) [3]. A further investigation evaluated the IEQ of library free spaces in a tropical environment. The investigation discovered an

elevated level of dust particles, an absence of illumination in corners, and elevated degrees of noise displeasure (Mahyuddin and Law, 2019) [18]. According to the above results, libraries in tropical regions may require that they upgrade their IEQ metrics. The effects of occupant demographic imbalances on a library's IEQ were examined in a University of Alberta research. The findings showed that in order to lower energy usage, HVAC feedback management systems needed to be expanded (Shum *et al.*, 2022) [26]. In order to guarantee the well-being and ease of library patrons, these investigations emphasize the significance of evaluating and enhancing IEQ elements in library environments, especially with regard to lighting, noise, and air quality. IEQ is crucial for many types of buildings, not just those used for learning. A research conducted in Malaysia assessed office buildings' IEQs to determine how satisfied its tenants were. According to the findings, overcooling (about 24 °C), excessive relative humidity (about 70%), glare, and noise from the surroundings (about 51.9 dB) were identified as the primary causes of discontent. According to the same study, residents' discontent may have an impact on their output (Esfandiari *et al.*, 2021) [9]. A further investigation has indicated the considerable impact of daylight prolonged exposure on mental health and productivity (Hwang *et al.*, 2011; Jin *et al.*, 2017) [12, 13]. Later, this impact was linked to human circadian rhythm (Kotopoulos and Nikolopoulou, 2018) [15].

The current article's goal is to monitor air pollution in the Federal College of Agriculture, Akure (FECA) tertiary institution library activities utilizing cheap technologies. SentinAir, an inexpensive gadget, was used. In order to keep track of the particulate matter (PM₁, PM_{2.5}, and PM₁₀), gas pollutants (CO₂, NO₂, and O₂), and meteorological parameters (temperature and relative humidity (RH)) within the FECA library hall, the monitoring unit "SentinAir" was created at the ENEA-Italian National Agency for New Technologies, Energy and Environment, Research Center of Brindisi, Italy. The purpose of the investigation was to use a low-cost tool to evaluate the indoor air quality of a library at a tertiary institution. The research inquiries that follow are anticipated to be addressed by the study: I. How accurate is the sensor? ii. How polluted are the contamination levels in the library? and iii. Where do the contaminants come from (source)?

Methodology

Study location

The indoor investigation tracking was conducted for a month in the Federal College of Agriculture, Akure (FECA) library (Figure 1), and it lasted for twenty-four hours throughout the dry period. The SentinAir detector was fixed to a structure that was 1.8 meters tall. Employing a low-cost air detector (Model: SentinAir S3) (<https://github.com/domenico-suriano/SentinAir>), the

amounts of carbon dioxide (CO₂), nitrogen dioxide (NO₂), ozone (O₃), and particulate matter (PM₁, PM_{2.5}, and PM₁₀) were measured (Suriano, 2020) [29, 30, 31].

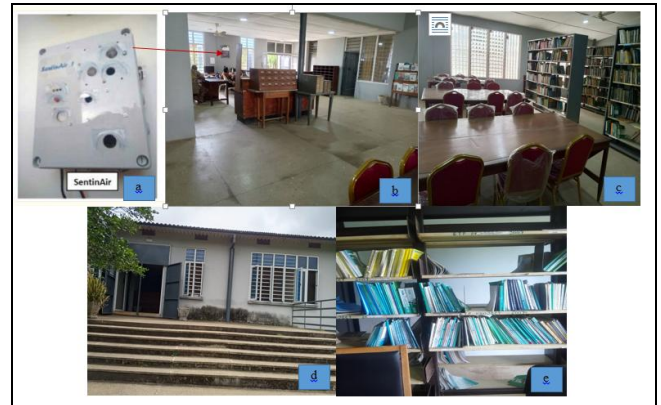


Fig 1: Federal College of Agriculture library, the location of the study showing (a) SentinAir sensor (b) reception office (c) reading room (d) main building showing the entrance (e) books on shelf

Description of sensor

An instrument called SentinAir was created to collect data from a variety of instruments, sensors, or devices (Table 1, Figure 2, and Figure 3). Since the Raspberry 3 B+ board serves as the system's central component, the software described in this guide can be installed on either a Raspberry 3 B+ board or a SentinAir device. SentinAir requires that devices be connected via USB, Ethernet, serial UART, SPI, or I2C interface. Only devices connected to the Raspberry board-the "brain" of SentinAir-through its USB, I2C, Ethernet, and serial UART ports have been used to test the system thus far. With the exception of the web pages that are delivered via the internal web server, the system is based on command line interfaces (Suriano, 2020) [29, 30, 31].



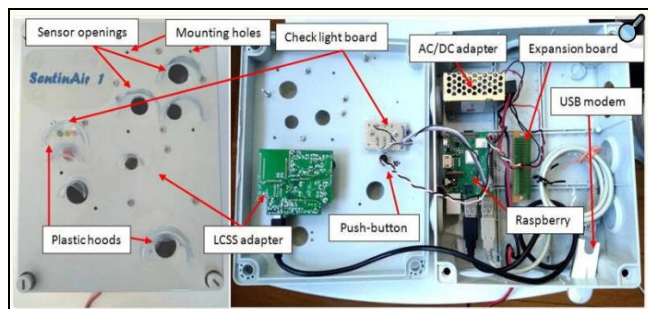
Source: Suriano (2021) [32]

Fig 2: The SentinAir concept and a few of the components that the software is at present using. The SentinAir measures 24.5 cm by 20 cm by 9 cm. Usually, it weighs around 1.5 kilograms. The number of sensors or devices installed inside its enclosure determines this. The reference instruments, Environment VOC72M and 2B405 nm, weigh 12.5 kg and 8.5 kg, respectively.

Table 1: A compilation of the SentinAir system's device drivers that are being developed. Some technical information about each device is further provided in this list. Rather than reporting the accuracy parameter for the environmental devices, the manufacturer presents the degree of noise influencing the measurement's accuracy. Full Scale is what FS stands for. Reading Value is what RV stands for. Not available is denoted by N/A.

Sensor or device	Connection interface	Supplier or manufacturer	Range	Sensitivity	Accuracy
IRC-A1 (CO ₂ sensor)	USB	Alphasense (Alphasense, 2020)	0–5000 ppm	N/A	1% FS
PMS3003 (PM sensor)	TTL serial port	Plantower (2020)	0–500 µg/m ³	N/A	10% RV
Multisensor board (to use sensors having analog outputs)	USB	Tecnosens (2020)	Depends on the attached sensors (see supplementary material)	Depends on the attached sensors (see supplementary material)	Depends on the attached sensors (see supplementary material)
106L GO3 PRO package (CO ₂ and O ₃ monitor)	USB	2B technologies (2020)	0–2000 ppm for CO ₂ ; 0–100 ppm for O ₃	N/A	±(2% FS + 2%RV) for CO ₂ ; greater of 1.5 ppb or 2% of RV for O
405 nm (NO _x monitor)	USB	2B technologies (2020)	0–10 ppm for NO ₂ ; 0–2 ppm for NO	N/a	Greater of 2 ppb or 2% RV
LCSS USB adapter (to use sensors having analog outputs)	USB	Designed and built in our lab	Depends on the attached sensors	Depends on the attached sensors	Depends on the attached sensors
CO12M (CO chemical analyzer)	Ethernet port	Environnement (2020)	0–200 ppm	N/A	0.025 ppm
AF22M (SO ₂ chemical analyzer)	Ethernet port	Environnement (2020)	0–10 ppm	N/A	0.5 ppb
AC32M (NO _x chemical analyzer)	Ethernet port	Environnement (2020)	0–50 ppm	N/A	0.2 ppb
O342M (O ₃ chemical analyzer)	Ethernet port	Environnement (2020)	0–10 ppm	N/A	0.5 ppb
VOC72M (VOC chemical analyzer)	Ethernet port	Environnement (2020)	0–1000 µg/m ³	N/A	0.025 µg/m ³

Source: Suriano (2020) [29, 30, 31]



Source: Suriano (2021) [32]

Fig 3: The assembled hardware's last feature. The top view of the enclosure lid is displayed on the left, while the component's displacement inside the enclosure is displayed on the right.

Calibration

The device itself, its colocation (Figure 3), and all the components and procedures required to build it are described in detail in previous articles and in an online repository (Suriano *et al.*, 2020; Suriano 2021; Suriano, 2022) [29, 30, 31, 32, 33]. Indoor and outdoor trials have been used to test the sensor: such tests have been performed for validating the calibration functions once they were calculated. An evaluation between *RI* evaluations and the outcomes provided by the sensor data, as explained by the Linear Regression (LR) and Multivariate Linear Regression (*MLR*) models, was conducted in order to evaluate the sensor's performance (Suriano, 2020) [29, 30, 31]. The coefficient of determination (*R*²), mean absolute error (*MAE*), root mean squared error (*RMSE*), and normalized

root mean squared error (*nRMSE*), as described by Eqs. 1, 2, 3, 4, and 5, were the metrics used for both the validation and calibration procedures. The readings made by the tool and reference instruments during the validation period were displayed in the Suriano *et al.* (2020) [29, 30, 31] report, which also illustrated the accuracy of the system's observations in relation to the actual gas levels.



Source: Suriano (2020) [29, 30, 31]

Fig 4: The Italian National Agency for New Technologies, Energy, and Environment (ENEA) has a reference station at Research Center of Brindisi, Sustainable Development Department, SS. 7, Appia, km 706, 72100 Brindisi, Italy.

$$R^2 = \frac{(\sum_1^N (m_i - \bar{m})(r_i - \bar{r}))^2}{(\sum_1^N (m_i - \bar{m})^2)(\sum_1^N (r_i - \bar{r})^2)} \tag{1}$$

$$MAE = \frac{1}{N} \sum_{n=1}^N |f(x_i) - r(x_i)| \quad 2$$

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$$SD \sqrt{\frac{1}{N} \sum_{n=1}^N (|f(x_i) - r(x_i) - MAE|)^2} \quad 3$$

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$$RMSE = \sqrt{\frac{1}{N} \sum_{n=1}^N (m_i - r_i)^2} \quad 4$$

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$$nRMSE = \frac{1}{r} \sqrt{\frac{1}{N} \sum_{n=1}^N (m_i - r_i)^2} \quad 5$$

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where N is the number of documentations in the dataset, f(x_i) is the amount of gas value determined by the sensor data at time i, and r(x_i) is the reference value that corresponds to the sensor value x_i at time i. Since NDIR CO₂ sensors typically have high sensitivity and selectivity, Alexandre and Gerboles (2012) [43] state that the effects of interfering gases were not anticipated and, as a result, were not determined. In the equations above, N is the number of records in the dataset, m_i is the model's i-th value, r_i is the reference instrument's reading, \bar{r} is the average of the reference readings, and \bar{m} is the average of the measurements the model provided. The coefficient of determination, or the degree of correlation between AQM and reference data, is a number between 0 and 1 that indicates how well the AQM measurements match the reference values. Good performance is shown by values around 1; poor correlation is indicated by values near 0. Both RMSE and MAE are indicators that reveal the type of error that exists between the reference and the model. Improved outcomes are highlighted by values that are lower. Comparing the accuracy provided by the models for various pollutant gases requires the use of the nRMSE marker. Excellent accuracy is indicated even in this situation by nRMSE values near zero.

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$$R^2 = \frac{(\sum_1^N (m_i - \bar{m})(r_i - \bar{r}))^2}{(\sum_1^N (m_i - \bar{m})^2)(\sum_1^N (r_i - \bar{r})^2)} \quad 1$$

Results and Discussion

Table 2: The basic descriptions of the pollutants and meteorological parameters

	CO ₂ (ppm)	NO ₂ (ppb)	O ₃ (ppb)	PM ₁ (µg/m ³)	PM _{2.5} (µg/m ³)	PM ₁₀ (µg/m ³)	Temp (°C)	RH (%)
Mean	563.71	189.19	72.47	8.33	11.59	12.23	33.49	53.93
Std. Deviation	142.41	7.43	3.42	5.24	7.14	7.77	1.27	2.47
Minimum	453	153	24	0	0	0	28.40	47.70
Maximum	6158.1	276	78	80	103	106	36.30	67.80
A-Squared	788.53	46.68	246.02	120.35	128.19	153.87	39.53	21.36
P-Value	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Q1	518.00	184.00	71.00	5.00	7.00	7.00	32.60	52.30
Q3	577.00	193.00	74.00	10.00	14.00	15.00	34.30	55.70
WHO (2021)	1000	25.00	100.00	25.00	15.00	45.00	36.00	40.00
NESREA (2020)	NA	120.00	100.00	NA	40.00	150.00	20.00	45.00

Comparison of Air Quality Standards

According to the National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2018 (NESREA) National Environmental (Air Quality

Control) Regulations, 2021, Nigerian air quality standards set PM_{2.5} limits at 20 µg/m³ (annual mean) and 40 µg/m³ (24 h mean), not to be exceeded more than once per year, and PM₁₀ limits at 60 µg/m³ (annual mean) and 150 µg/m³ (24 h

mean), respectively. There is a regulatory gap because the legislation contains no precise PM₁ standards. Other accepted standards (Table 2) include temperature (20–35 °C), relative humidity (40–70%), CO₂ (1000 ppm), NO₂ (120 ppb), and O₃ (100 ppb). Hourly and daily levels of PM₁₀ were under NESREA standards throughout the study time frame, demonstrating adherence to national laws. Nevertheless, in order to safeguard the well-being of people, the World Health Organization (WHO, 2016) [37] has amended its standards in 2021, which include PM_{2.5} annual mean of 5 µg/m³ and 24 h mean of 15 µg/m³ and PM₁₀ annual mean of 15 µg/m³ and 24 h mean of 45 µg/m³. Emerging knowledge of health concerns at lower levels of PM is reflected in these revised WHO (2016) [37] standards (WHO, 2021) [38]. Figure 5 shows a maximum concentration of 103 µg/m³, the reported PM_{2.5} 24 hour mean (11.59 µg/m³) indicated possible health risks during peak events. It was below the 2016 WHO guideline limit (25 µg/m³) but frequently exceeded the 2021 guideline limit (15 µg/m³). The 24-hour mean of PM₁₀ (12.23 µg/m³) was below both WHO recommendations; however, hourly maxima (up to 106 µg/m³) indicate short-term exposure hazards, especially during the dry season. The outcomes of this investigation are consistent with those of a study conducted in Brazil by Souza *et al.* (2025) [27]. As of yet, the PM₁ has no standard restriction. There was a good comparison between the results and the version of Arifalo *et al.* (2025) [7] from Ikere-Ekiti, Nigeria.

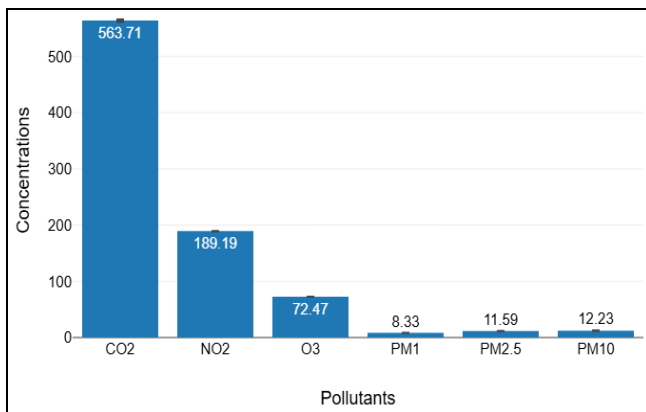


Fig 5: Graphical representation of concentrations of pollutants

Comfort levels (T, RH, CO₂)

Table 3 provides a brief overview of temperature and relative humidity. The average temperature at the site was 33.49 °C, with variations within 28.40 °C and 36.30 °C. The standard deviation demonstrated that there is not much of variation between the minimum and maximum. The mean relative humidity is 53.93%, with a range of 47.70% to 67.80%. The variation is also minimal. The mean temperature in this study is greater than the 20 °C suggested by NESREA but lower than the 36 °C suggested by WHO when compared to the standard limits of both organizations. It implies that the temperature is moderate during the evaluation period.

A reputable source states that the optimal indoor level of moisture is between 30 and 50 percent any figure under 30 percent is considered low. In addition to causing wood to

lose its natural oils, which makes it brittle and unsightly, low humidity can lead to a multitude of undesirable medical issues, such as dry skin and inflamed sinuses. Books, furniture, and other furnishings that require a specific amount of moisture to prevent warping or cracking can also be harmed by low indoor humidity. Amaral (2023) [6] asserts that paper is susceptible to changes in dampness. Books lose condition and readability due to mold, mildew, and paper deterioration caused by high moisture levels. The ideal humidity range, between 30% and 50%, will preserve the library's priceless holdings.

As can be seen in Figure 4, population density appears to have an impact on indoor carbon dioxide levels given the lowest result was reached at the start of the assessments when users were not in the library hall, but the level rose shortly as they gathered for the day's activities. Indoor CO₂ levels fell short of the WHO and Nigerian IAQ requirements that have a 1000 ppm upper limit (WHO, 2021, NESREA, 2021) [38]. When the users began using the library, CO₂ was starting to rise in most of the rooms. When they left in large numbers for other activities, the CO₂ levels began to modestly drop. Wu *et al.* (2018) [29] and Aflaki *et al.* (2023) [1] both followed the same rising trend. Notably, when the overall number of individuals decreased at closure hours, the amount of carbon dioxide (CO₂) increased. This could be because CO₂ accumulated whilst the windows and doors were shut during assessments, and the remaining CO₂ emissions were higher than wind seepage.

Health Impacts

In comparison to Ikere-Ekiti, Nigeria (Arifalo *et al.*, 2025) [7], where PM₁ (11.26 µg/m³), PM_{2.5} (16.66 µg/m³), and PM₁₀ (17.66 µg/m³), FECA library has a lower starting point but higher sporadic peaks, suggesting the necessity for specific actions during biomass combustion and forest fire periods. This study's dependence on a single monitoring facility restricts spatial accuracy, and long-term assessments of health effects are required to evaluate local morbidity. PM_{2.5}'s ability to reach deeply into the lungs and bloodstream is associated with respiratory diseases (e.g., asthma), cardiovascular conditions (e.g., stroke), and a 0.5–1% increase in mortality per 10 µg/m³ increase (Xia *et al.*, 2017; Yang *et al.*, 2020) [40].

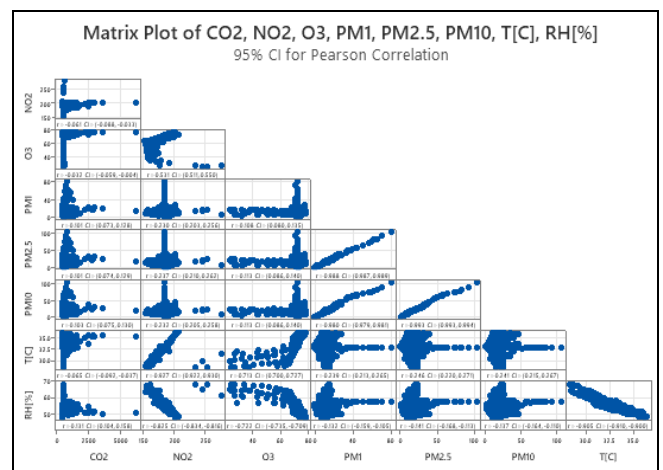


Fig 6: Correlation matrix of pollutants with temperature and RH

Table 3: Correlations coefficient of pollutants with temperature and RH

	CO ₂	NO ₂	O ₃	PM ₁	PM _{2.5}	PM ₁₀	T[°C]
NO ₂	-0.061						
O ₃	-0.032	0.531					
PM ₁	0.101	0.230	0.108				
PM _{2.5}	0.101	0.237	0.113	0.988			
PM ₁₀	0.103	0.232	0.113	0.980	0.993		
T[°C]	-0.065	0.927	0.713	0.239	0.246	0.241	
RH[%]	0.131	-0.825	-0.722	-0.132	-0.141	-0.137	-0.905

Study of correlations involving the monitored pollutants

The magnitude and trend of the linear association among the two factors are quantified by the Pearson correlation coefficient (CC), which has a range of -1 to 1. A CC of -1 indicates a perfect negative linear relationship, a CC of 0 indicates a nonlinear association, and a CC of 1 indicates a perfect positive linear association (aiSource, 2017) [2]. In the present study, $p < 0.001$ is the significant criterion. The CC that our analysis yielded is shown in Figure 6. As shown in Table 3, the location's NO₂ and CO₂ have a modest negative connection ($r = -0.061$, $p = 0.000$). This could mean that the variables that impact NO₂ (such as traffic or combustion) are not inversely connected with those that influence CO₂ (such as ventilation). In a similar vein O₃ and CO₂ have a weakly negative association ($r = -0.032$, 95% CI for (-0.059, -0.004), $p = 0.000$), which indicates an inverse association and could suggest that external factors affecting CO₂ are inversely associate with those that trigger higher O₃ amounts (Xia *et al.*, 2021) [41]. O₃ and NO₂ have a moderately favorable association ($r = 0.531$), which may suggest that the sources or impacting both contaminants are identical. A very significant positive association ($r = 0.988$, 95% CI for (-0.210, 0.262), $p = 0.000$) indicates a practically perfect linear association within PM_{2.5} and PM₁, suggesting a significant association among levels of different fine particulate matter elements, most likely due to identical external influences and behaviors. There is also a very strong positive link between PM_{2.5} and PM₁₀, indicating a virtually perfect linear connection. They are likely released from the same original sources (forest fire, traffic, and natural emissions), undergo identical chemical procedures, and have a perfect linear association, as shown by the very strong positive associations within PM_{2.5} and PM₁, PM₁₀ and PM_{2.5}, and PM₁; the perfect linear connection may also be caused by seasonal and weather-related variables. Given that PM₁, PM_{2.5}, and PM₁₀ have linkages and are heightened indoors in tandem, interior spaces become dangerous and pose chronic dangers when air quality declines. This impacts the local environment in terms of climate, health, and damage to library materials. Temperature: NO₂ ($r=0.927$), temperature: O₃ ($r=0.712$), and temperature: RH ($r=-0.905$) are also found to be strongly correlated in the study, and RH: NO₂ ($r=-0.825$) and RH: O₃ ($r=-0.722$).

According to the positive associations found, higher temperatures increase the amount of PM via encouraging forest fire, dust resuspension, and photochemical reactions. When temperatures rise to 39.9 °C during the dry season, this effect is more noticeable (Ngo *et al.*, 2019) [21]. The negative associations validate the cleansing impact of humidity through particle agglomeration and moist deposition. While high humidity can promote secondary

aerosol production in high volatile organic compound (VOC) circumstances, it also lowers the amount of PM by boosting particle settling rates (Nicholas and Ukoha, 2023) [22]. Due to photochemical activities and resuspension on warm, sunny days, PM_{2.5} shows a positive link with temperature.

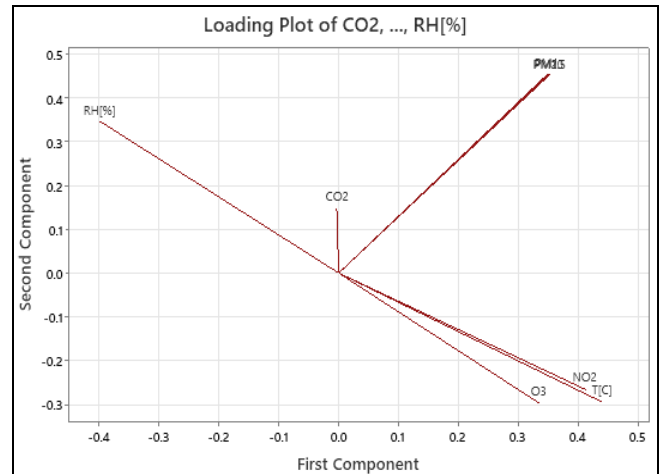


Fig 7: The plot loading of the pollutants with temperature and RH in the library

Plot loading based on a multivariate factor analysis of atmospheric components at the college library is displayed in Figure 7, which was additionally included as an illustration of the data with linkage for specific data of importance. In PC 2, PM₁, PM_{2.5}, and PM₁₀ were above 0.4, suggesting identical interactions and associations from every difference shown from the cluster pairs. As can be observed the plot indicated additional associations among all the atmospheric components investigated with NO₂, O₃, and temperature below (-0.1) from PC 1, while CO₂ and RH seemed above (0.1). The graphic illustrates how temperature and the air pollutants NO₂ and O₃ have a major impact on the PC1. In this case, temperature and NO₂ have significant factor loadings for the location. PM₁, PM_{2.5}, and PM₁₀, on the other hand, exhibit significant positive factor loadings. Additionally, PC2 is impacted by PM particles and the climatic variable RH. Based on the PCA. CO₂, PM₁, PM_{2.5}, PM₁₀ and RH, show significant loadings, indicating that dry conditions, including biomass-burning, and partial combustion through forest fire and indoor fuels, have significant levels of these contaminants (Almsatar, 2020; Mahmud *et al.*, 2023) [4, 17]. O₃ is adversely loaded in PC1, suggesting that it is produced by indicators generated by sunlight, such as NO, NO₂, SO₂, CO, and VOCs. Ikere-Ekiti also showed similar outcomes (Arifalo *et al.*, 2025) [7].

Table 4: PCA of the pollutants in the library

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
CO ₂	-0.003	0.148	-0.985	-0.065	0.064	-0.005	-0.002	-0.000
NO ₂	0.412	-0.265	-0.033	-0.532	-0.445	-0.526	-0.022	-0.001
O ₃	0.333	-0.295	-0.117	0.823	-0.284	-0.175	-0.011	-0.004
PM ₁	0.348	0.453	0.067	0.033	0.011	0.029	-0.772	0.266
PM _{2.5}	0.352	0.452	0.066	0.032	0.025	-0.016	0.155	-0.801
PM ₁₀	0.350	0.452	0.065	0.039	0.023	-0.043	0.614	0.536
T[°C]	0.439	-0.294	-0.049	-0.175	-0.168	0.811	0.043	0.003
RH[%]	-0.399	0.346	-0.004	0.037	-0.829	0.177	0.018	-0.004

The findings of the principal component analysis

The results of the location's principal component analysis (PCA) are provided in Table 4. The main component (PC1) shows identical loadings of PM₁, PM_{2.5}, and PM₁₀, suggesting that these particle sizes add identically to indoor air quality variations. Additionally, consistent loadings for PM₁, PM_{2.5}, and PM₁₀ (0.55, 0.56, and 0.56, respectively) imply that particulates play a major role in explaining the diversity of air quality inside libraries. The PC2 demonstrates high loadings of O₃ (-0.690) and NO₂ (-0.647). It implies that variations in the cleanliness of the air in libraries are influenced by gaseous contaminants in a similar way. It is inferred that the variations in indoor air quality inside the area are influenced by the aggregate impact of NO₂ and O₃ loadings in PC2. The negative loading of CO₂ implies an inverse connection among NO₂ and O₃. Additionally, an elevated CO₂ loading in PC3 indicates that CO₂ impacts significantly to the library's interior air quality variance. The negative loading of CO₂ in PC2, which exhibits an inverse relationship with other factors, suggests that the amount of CO₂ might shift differently than those of NO₂ and O₃. These findings suggest that actions to lower PM in interior settings, such as boosting airflow and cutting back on indoor sources, may have a substantial effect on the overall state of indoor air. The surroundings' NO₂ and O₃ concentrations help to explain fluctuation, emphasizing how important it is to regulate indoor air emissions and airflow. High CO₂ levels in PC3 might potentially be a sign of insufficient airflow.

Conclusions

The Federal College of Agriculture, Akure library's indoor air quality was examined in this study using inexpensive sensors to measure daily contact to the main airborne contaminants (CO₂, NO₂, O₃, PM₁, PM_{2.5}, and PM₁₀) as well as the impact of temperature and relative humidity on the contaminants. For a month, tracking was done continuously for twenty-four hours. A team of researchers from the Italian National Agency for New Technologies, Energy, and the Environment (ENEA) at the ENEA Brindisi Research Centre (Italy) came up with the inexpensive sensor. Prior to the evaluation, the sensor was calibrated and validated. A statistical analysis was performed on the collected data. When users occupy the areas, values for NO₂, O₃, PM₁, PM_{2.5}, and PM₁₀ at the library setting point show intermittently elevated levels and vice versa. The findings indicated correlations across the contaminants, especially among PM and gas pollutants, pointing to identical possible sources. Both natural (forest fire) and man-made (biomass burning) events have an influence on these numbers, and the gases released from these events seep into the library. The library's contamination levels were under NESREA and WHO standards. Because of their interactions and higher indoor levels, PM₁, PM_{2.5}, and PM₁₀ make living spaces dangerous and pose long-term hazards to air quality. In summary, it is encouraging to see that the contaminants do not pose a threat to library users however, all parties involved should make sure that every effort is made to minimize the effects of the contaminants on people and library objects.

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