Ibadan Planning Journal
December 2024, Vol.10, No. 2, 35-41
Ibadan Planning Journal
journal homepage: http://journals.ui.edu.ng/index.php/ipj/issue/view/7

Perception of Users on Indoor Air Quality of Lecture Theatres Located in the Federal University of Technology, Akure, Nigeria

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Abstract

Satisfaction with odour, indoor temperature, indoor relative humidity, fresh/stuffy air and indoor air speed is widely regarded as universal way of assessing the perception of indoor air quality (IAQ). The aim of this paper was to evaluate the perception of students on the IAQ of lecture theatres within the Federal University of Technology, Akure, Nigeria towards expansion of the database of indoor environmental quality aspects of educational buildings in Nigeria. The two-stage survey was carried out using a structured questionnaire in September 2021 and February 2022. The population of the study was the undergraduate population in the University (17,772) and the sample was 377 students. Results from the rank sum analysis indicated that the prevalence of "dust" has the potential to affect indoor air quality within the research area. Additionally, Satisfaction with breakaway factors of indoor air quality for both dry and wet seasons was less than ASHRAE's benchmark of 80% satisfaction votes for IAQ in the study area. Results of the Spearman rank correlation coefficient analysis between pollution factors and indoor air quality breakaway factors point out that there was an inverse relationship between them, although, it was only significant in the dry season. The design challenge is that architectural projects such as lecture theatres should have the capacity to satisfy the comfort of users in both the dry and wet seasons.

Keywords
Indoor air quality, Lecture theatres, Perception, Satisfaction

Article History
Received 02 September 2024
Accepted 22 October 2024
Published online Dec. 30, 2024

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Declaration of Conflicting Interests
The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

1. Introduction

Industrialization and the growth of cities have been identified as major drivers of indoor and outdoor air pollution in buildings (Flowers, Gray & MacArthur, 2004; Brophy & Lewis, 2011). Some pollutants from road traffic, agricultural practices, industrial production, construction activities and power generation include formaldehyde, ozone, carbon dioxide, carbon monoxide, particulate matter, lead, nitrogen oxide, sulphur dioxide, asbestos fibre and volatile organic compounds amongst others (Bluyssen, 2009). An acceptable indoor air quality is "air in which there are no known contaminants at harmful concentration as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" (American Society of Heating, Refrigeration and Air conditioning Engineers [ASHRAE], 2019).

Using ventilation as a design approach is not new, some of the applications of using the principles of natural ventilation in buildings are that they contribute to improvement in indoor air quality, thermal comfort and cooling of the buildings. Natural ventilation reduces energy consumption by providing alternative to air conditioning (Roulet, 2008; Szokolay, 2008; Dorizas, Assimakopoulos & Santamouris 2015). What is new in this context, is the focus on educational buildings in a developing country within the tropics.

Assessment of perception of indoor air quality in buildings by occupants within educational institutions such as lecture theatres will not only improve data base of buildings in the country, it would also serve as feedback for built environment professionals. The wellbeing, health, comfort and productivity of occupants in buildings generally is a concern to all stake holders including researchers (Department of Education, 2018; Federal Republic of Nigeria [FRN], 2017; Occupational Safety and Health Administration [OSHA], 2011; Nigerian University Commission [NUC], 2004).

This paper examines perception of indoor pollution variables by occupants within lecture theatres in a developing country context.

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The absence of quality data in respect of IAQ of buildings in developing countries generally (World Health Organization (WHO, 2016); Orola (2018) and Akure, Nigeria specifically, is a research gap that needs to be filled in terms of assessing university lecture theatres, towards a better understanding of indoor air quality of educational buildings in Nigeria. Two objectives guided the writing of this paper, firstly, to investigate the influence of indoor air pollution factors on users' satisfaction with indoor air quality in the lecture theatres. Secondly, to evaluate whether gender was a factor in the perception of indoor air quality in the research area.

Since Nigerians spend a considerable number of hours indoors-standard work hours for white collar job in Nigeria is 8am-4pm and average contact period in university lecture theatres is between 7am-7pm in the research area, the quality of the interior space needs to be at the optimum, to improve efficiency of users and to sustain the wellbeing of the university lecture theatre users.

Perception according to Cambridge Dictionary Online (2024) is the "awareness of things through the physical senses", for example, sensory perception like sight, hearing, smell and taste. Perceived indoor air quality is usually expressed in terms of the percentage of building occupants expressing satisfaction with the indoor environment (Hayati, 2017; ASHRAE, 2019). Faulting the use of sensors, Muller *et al* (2008) reported that sensors have not been sensitive enough to imitate the perception of a human being. Furthermore, sensors designed to detect special odours could not be correlated with the assessments made by humans, this is because the pollution mix usually affects the perceived air quality. This is without prejudice to the fact that there are pollutants that the human olfactory system cannot detect, examples include carbon monoxide and radon.

Perception of indoor air quality is usually measured at the ordinal scale (European Collaborative Action, ECA, 1999). A number of protocols have been developed according to Baird (2009). The protocols include The National Australian Built Environment Rating System (NABERS), Building Use Studies (BUS) of the UK and the US-based Centre for Built Environment (CBE) surveys. These protocols usually consider subjective assessments of indoor environments using the following variables, temperature, relative humidity, air quality in different climatic seasons, cleanliness generally, space layout and control of openings.

Perception of indoor air quality by humans is broadly described in two physiological and psychological organs in the human body, olfaction and somesthesia (ECA, 1999; Bluyssen, 2009). Olfaction is often explained as odour identification and classification (Hall, 2011). Paraphrasing Burroughs and Hansen (2011), odours are molecules released by substances which is sensed by chemical receptors located in the upper nasal area connected to the olfactory nerve. This nerve carries the nasal olfaction message to the limbic region of the brain. Further clarifications show that this region also contains the hypothalamus and the pituitary gland. The hypothalamus supports the recognition and emotional functions of the human body, where odour is a major driver of the process. Conversely, the trigeminal nerve endings are sensitive to the irritant aspect of chemicals in the air. Somesthesia (or common chemical sense) is usually stimulated by irritation, for example SOx and NOx chemical series from vehicular transportation and combustion appliances like power generators are not odorous (except Sulphur dioxide and Ammonia) yet they are responsible for irritation such as eyes, nose and throat dryness, facial skin irritation and dryness (Bluyssen, 2009). The common chemical sense is located around the nose, eye and face, it perceives warmth, cold and pain (ECA, 1999)

The comfort of occupants in buildings, have generally been described in terms of aural, thermal, visual and indoor air quality (ASHRAE 55, 2017; ASHRAE 62, 2019; Steskens & Loomans, 2012). To study IAQ effectively, there is an assumption that the other three aspects of comfort, which is aural, thermal and visual should be within comfort range, because any inadequacies from either of the three aforementioned comfort indices can adversely affect the perception of IAQ by building occupants (Burroughs & Hansen, 2011; Orosa, 2012). A seven-point acceptability scale is usually used to evaluate the perception of occupants (Baird, 2015; Kim, 2012). Factors usually considered are level of satisfaction with odour, irritation, temperature, relative humidity and air speed.

2. Materials and Methods

The Federal University of Technology, Akure is located in Akure South Local Government Area of Ondo State. Akure falls within the forest zone with relative humidity as high as 98.1 % during the wet season. In the dry season, average temperature could be as high as 39 °C (Olabode, 2015). A cross-sectional survey of lecture theatre occupants was selected for the study with a closed-ended instrument (Cresswell, 2014). This strategy has been selected because a survey of occupants is useful to assess the perception of users concerning the IAQ of buildings (ECA, 1999; Baird, 2015). The measures are at an ordinal scale (MacRae, 1994). Furthermore, the lecture theatres are not only naturally ventilated, but they were designed by registered professionals in the built environment and the buildings are approved under the Nigerian Universities Commission's regulation for university buildings which comply with minimum building regulations in Nigeria. Lecture theatres are commonly used for lectures and examinations. The research is delimited to the lecture period only. The lecture theatres were Nine (9) in number according to the Federal University of Technology, Akure, Nigeria, University Time Table released for the 2022-2023 academic session. Questionnaires were administered to a simple random sample of students in the Lecture theatres about fifteen minutes to the end of a lecture period. The research population for the survey was undergraduate students in the Federal University of Technology, Akure, Nigeria-17,772 (FUTA, 2021). The calculated sample of 377 was arrived at using Krejcie and Morgan's (1970) calculation method at 95 % confidence level. The sample size, s, for a known population was determined using the following formula described below:

$$s = \frac{x^2 NP(1-P)}{d^2(N-1)+x^2P(1-P)} \quad \ldots\ldots \text{ equation 1}$$

Where s = required sample size

χ^2 = the table value of chi-square for 1 degree of freedom at the desired confidence (3.841)

P = the population proportion (assumed to be 0.5)

d = the degree of accuracy expressed as a proportion (0.05)

N = the population size

3. Results and Discussion

The 377 questionnaires administered were successfully retrieved from participants. There was 100 % response rate, however, only 372 questionnaires were deemed fit for analysis.

3.1 Gender Distribution and Indoor Air Quality in the Dry and Wet seasons

The bar chart in Figure 1, shows the frequency distribution of respondents based on gender for wet and dry seasons. A larger percentage of respondents were male in both the wet and dry seasons (230 and 253 respectively) while there were 109 female respondents for the wet season and 104 female respondents for the dry season. For the purpose of analysis, gender is classified as nominal, where the labelling is of no consequence (Kothari & Garge, 2014).

Additionally, most respondents were within the 16-21 age bracket (up to 79 % in the dry season) and 22-27 years (39 % in the wet season), ages 28 and above share the remaining 1.9 %. This is generally expected, as the entry age to Nigerian Public Universities is 16 years. Respondents in the middle row answered 67 % of the survey, while 33 % was answered by respondents in the row of seats at the edge. This depends largely on the design of the lecture theatres, for example the low-capacity lecture theatres such as 3-1A (240 capacity), Small LT (150 capacity) and 3-1C (240 capacity) have two rows of seats with no central aisle, unlike the larger lecture theatres, 1000 capacity LT, 2-1A LT and 2-1B LT with 500 capacity each, Big LT (448 capacity), 750 capacity Education Tax Fund (ETF) LT. The morning (7:00-11:59 am) and afternoon (12:00-15:59) were noted to have the larger occupation period of 46 % and 51 % respectively. The period of lectures between 16:00 and 19:00 was perceived as the least probable time for lectures with 3 % of the occupation period. During the survey, respondents were majorly seated while taking lectures.

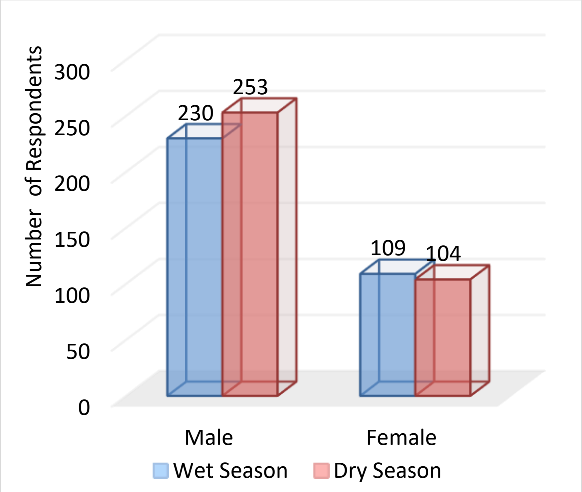

Figure 1: Gender distribution of respondents in the wet season and dry season

A data set can be analysed using the mode. The mode is a positional average and is useful in this premise to eliminate extreme values since the most popular opinion is required (Kothari & Garg, 2014). Modal frequency of both male and female were noted to be in the same category for the IAQ break away factors. The modal frequency for satisfaction with indoor temperature in the dry season reveals that 37.5 % of female occupants voting "very hot" and 37.9 % for the same category of male occupants. In the same vein, the modal frequency for satisfaction with the perception of odour level in the lecture theatres shows 40.4 % of males voting "neither satisfied nor dissatisfied" and 42.3 % voting same category for females. Also, in terms of indoor relative humidity, the frequency analysis reveals that "neither dry nor humid" was the modal frequency with 37.5 % male and 43.5 % female voting in the category. Unswervingly, the frequency analysis makes known that the modal frequency for indoor air speed was "very still air" with the male participants voting 38.5 % and the female participants voting 36.8 %. To close, the modal frequency for indoor irritation levels was "very stuffy" with 48.1 % female students and 41.1 % male students voting in the category.

The same pattern was noted for the wet season, albeit with a slight modification, the breakaway factors were adjudged to be neutral. Frequency analysis of the votes for the perception of relative humidity in the lecture theatres by the occupants shows that 45 % of females voted "neither dry nor humid" and 36.5 % of males voted in the same category. In terms of indoor temperature for the wet season, 39.4 % of female students and 39.1 % of male students voted "neither hot nor cold". The modal frequency for users' perception of airspeed was "neither still nor draft air" with 35.8 % of female occupants and 35.2 % of male occupants voting in the category. Additionally, voting for irritation levels of the indoor air shows that 33.9 % of female occupants voted "neither stuffy nor fresh" category and 31.3 % of male occupants voted for the same classification. Finally, the modal frequency for perception of odour levels indoors reveals that 32.1 % of the female students and 35.7 % of the male students voted "neither satisfied nor dissatisfied" with the indoor air in the research area.

3.2 Comparing Medians of Satisfaction Rating by Male and Female Occupants Using Mann-Whitney U-Test Statistics

The Mann-Whitney U-test is a non-parametric test used to compare two medians. It is considered the non-parametric alternative to the t-test. In this premise, it is used to determine whether the gender of occupants may affect the perception of indoor air quality in the lecture theatres. The test assumes that two independent samples are drawn from the same population (Kothari & Garg, 2014). The null hypothesis stated that the gender does not significantly affect the perception of indoor air quality (IAQ) in the lecture theatres. Also, the decision rule stated was that if p-value < 0.05, the null hypothesis was rejected, otherwise the null hypothesis was upheld.

The results of the test reveal that gender does not significantly affect the perception of indoor air quality by users. This was established because of the p-value (0.899) > 0.05. The null hypothesis was not rejected because the p-value was greater. This substantiated that the perception of either male or female was not different and does not affect the response to the indoor air quality. Similarly, in the dry season, the null hypothesis was not rejected. It was also observed that p-value (0.403) > 0.05 (level of significance). This also informs that during the dry season, gender distribution does not affect the perception of the users of the indoor air quality within the lecture theatres. Thus, the perception of either male or female during both seasons were not significantly different from each other. This reveals that during the research period, there was no significant difference in the perception of male or female users on the indoor air quality of the lecture theatres. This result from this study is consistent with the descriptive statistics in the earlier section of this paper and other works like Yang, Bicerik-Geber and Mino (2013) study, where gender of occupants does not significantly affect responses for two seasons (p value = 0.248, which is greater than 0.05), the study was however carried out in spring and fall seasons.

3.3 Perception of indoor and outdoor pollution variables in the research area

A data set can also be analysed by rank, the rank of a value in a data set is the number that represents its place when the data set is arrange from the least to the highest within the data set (Rumsey, 2007). Perceived pollution factors were analysed using rank sum analysis and mode. Occupants of the lecture theatres rated "dust" as the first amongst outdoor pollution variables in the wet season (rank sum-1055; mode-prevalent). Other outdoor pollution variables analysed are frequency of smell from unsanitary debris/waste dump near the windows (rank sum-947; mode-very rare), perception of moisture or standing water promoting excessive microbial growth (rank sum- 807; mode-very rare), frequency of the use of pesticide in the building (rank sum-782; mode-very rare), perception of the effect of pollen in the building (rank sum-711; mode-very rare), occupants perception of exhaust from nearby road (rank sum-691; mode-very rare), perception of exhaust from power generators (rank sum-670; mode-very rare) and perception of irritants or odours from cooking around the lecture theatres (rank sum-548; mode-very rare), were ranked second, third, fourth, fifth, sixth, seventh and eight respectively within the research area (Table 1).

Table 1: Outdoor pollution variables (Wet Season)

Outdoor pollution sources	Mode	Rank sum	Rank
Dust occurrence	P	1055	1
Smell from unsanitary debris	VR	947	2
Moisture promoting microbial growth	VR	807	3
Use of pesticide in the LT	VR	782	4
Presence of Pollen in the LT	VR	711	5
Exhaust from road	VR	691	6
Exhaust from power generators	VR	670	7
Fumes from cooking	VR	548	8

Note: "VR" means very rare, "R" means rare, "NR nor P" means neither rare nor prevalent, "P" means prevalent, "VP" means very prevalent.

Conversely, in the dry season, occupants of the lecture theatres in the research area also rated “dust” as the first amongst outdoor pollution variables in the dry season (rank sum-1094; mode-prevalent). Other outdoor pollution variables were as rated in the wet season, albeit with different rank sum value. Also, perception of the effect of pollen in the lecture theatres (rank sum-706; mode-very rare) gained the fourth position to frequency of the use of pesticide in the building (rank sum-671; mode-very rare) now in the fifth position (Table 2). Other factors investigated are frequency of smell from unsanitary debris/waste dump near the windows (rank sum-822; mode-very rare), perception of moisture or standing water promoting excessive microbial growth (rank sum-730; mode-very rare), occupants perception of exhaust from nearby road (rank sum-663; mode-very rare), perception of exhaust from power generators (rank sum-655; mode-very rare) and perception of irritants or odours from cooking around the lecture theatres (rank sum-548; mode-very rare), were ranked second, third, sixth, seventh and eight respectively as in the wet season (Table 2).

Table 2: Outdoor pollution variables (dry Season)

Outdoor pollution sources	**Mode**	**Rank sum**	**Rank**
Dust occurrence	P	1094	1
Smell from unsanitary debris	VR	822	2
Moisture promoting microbial growth	VR	730	3
Presence of Pollen in the LT	VR	706	4
Use of pesticide in the LT	VR	671	5
Exhaust from road	VR	663	6
Exhaust from power generators	VR	655	7
Fumes from cooking	VR	548	8

Note: “VR” means very rare, “R” means rare, “NR nor P” means neither rare nor prevalent, “P” means prevalent, “VP” means very prevalent.

Furthermore, frequency of occurrence of indoor pollution variables in the wet season shows that perception of noticeable odour from other occupants (rank sum-985, mode-rare) was rated first. Use of cosmetics by occupants (rank sum-927, mode-neither rare nor prevalent) was rated second by occupants. Other indoor air pollution variables such as occupants perception of frequency of liquid spills in the LT (rank sum-832,), occupants perception of frequency of the use of cleaning material by building managers (rank sum-799), frequency of the use of deodorizers by building managers (rank sum-740), perception of odours or irritants while using office equipment around or inside the LT (rank sum-672) and perception of odour or irritation from smoking by other occupants of the LT (rank sum-468), have modal frequencies of “very rare” (Table 3).

Additionally, frequency of occurrence of indoor pollution variables in the dry season shows that perception of noticeable odour from other occupants (rank sum-945, mode-rare) and use of cosmetics by occupants (rank sum-943, mode-rare) was rated first and second respectively by occupants, as in the wet season. Perception of pollution through smoking by other occupants of the LT (rank sum-446, mode-very rare) was also rated seventh as in the wet season (Table 4).

Table 3: Indoor pollution variables (wet Season)

Indoor pollution sources	Mode	Rank sum	Rank
Odour from other occupants	R	985	1
Use of cosmetics	NR nor P	927	2
Liquid spills	VR	832	3
Cleaning materials	VR	799	4
Use of deodorisers	VR	740	5
Irritation from office equipment	VR	672	6
Smoking by other occupants	VR	468	7

Note: “VR” means very rare, “R” means rare, “NR nor P” means neither rare nor prevalent, “P” means prevalent, “VP” means very prevalent.

Other factors with a modal frequency of “very rare” was the occupant’s perception of frequency of the use of cleaning material by building managers (rank sum-803), occupants’ perception of frequency of liquid spills in the LT (rank sum-799), frequency of the use of deodorizers by building managers (rank sum-693), with ordered positions third, fourth and sixth respectively (Table 4).

Table 4: Indoor pollution variables (dry Season)

Indoor pollution sources	Mode	Rank sum	Rank
Odour from other Occupants	R	945	1
Use of cosmetics	R	943	2
Cleaning materials	VR	803	3
Liquid spills	VR	799	4
Irritation from office equipment	R	738	5
Use of deodourisers	VR	693	6
Smoking by other occupants	VR	446	7

Note: “VR” means very rare, “R” means rare, “NR nor P” means neither rare nor prevalent, “P” means prevalent, “VP” means very prevalent.

3.4 Analysing Indoor Air Quality of the Lecture Theatres using ASHREA’s Benchmark

The survey was analysed according to ASHRAE (2019), where 80 % or a greater percentage of users voting satisfaction with IAQ showed a high acceptability with the IAQ of the lecture theatres. A lesser percentage is below the ASHRAE benchmark. Analysing the seven-point bipolar instrument, satisfaction votes on perception of indoor relative humidity levels in the rainy season shows “fairly dry” with 14.7 % of the votes, “neither dry nor humid” with 39.3 % votes and “fairly humid” with 9.4 % votes. Performance analysis for indoor relative humidity in the wet season reveals that 63.4 % of respondents were satisfied with the indoor relative humidity levels inside the lecture theatres within the research area. Comparably, in the dry season, 55.2 % of the votes corresponds with satisfaction with indoor relative humidity. Subjective assessment of temperature overall reveals that vote for "fairly hot" amounted to 15.9 %, votes for "neither hot nor cold" amounted to 39.2 %, while votes for "fairly cold" was 6.2 % in the wet season. Performance analysis indicates that 61.3 % of users of the lecture theatres were satisfied with indoor temperature overall during use of the lecture theatres in the rainy season. On the other hand, during the dry season, 43.4 % of respondents were satisfied with indoor temperature in the research area.

Analysis of respondents' satisfaction with indoor air speed in the wet season shows that "fairly still" air was voted by 13.9 % of occupants, "neither still nor draft" air was voted by 35.5 % of students and "fairly draft" air was voted by 8.8 % of respondents. The results show that 52.8 % of respondents were satisfied with indoor air speed of the lecture theatres in the wet season. Conversely, during dry season, 44.8 % of respondents were satisfied with indoor air speed.

Votes for "very fresh" air in the research area was 10.3 %, votes for "fresh" was 2.9 % and votes for "fairly fresh" was 7.4 %. Summarily, 20.6 % of respondents voted for satisfaction with freshness of the IAQ during the wet season, with 32.2 % of respondents voting "neither stuffy nor fresh". Contrary wise, satisfaction votes for freshness of indoor air in the dry season corresponds to 12.8 % and 28 % voting "neither stuffy nor fresh". Analysis of satisfaction votes for odour level during the wet season reveals that 6.5 % voted "fairly satisfied", 3.5 % voted "satisfied" and 13 % voted "very satisfied", this indicates that 23 % of respondents report satisfaction with odour level in the lecture theatres during the wet season, with 34.6 % reporting "neither fresh nor stuffy". On the other hand, 23.5 % were satisfied with odour level during the dry season, with 41.8 % voting "neither fresh nor stuffy". Summarily, users' satisfaction with perceived indoor relative humidity, indoor temperature, indoor air speed, freshness and odour levels were below the 80 % ASHRAE (2019) benchmark.

3.5 Correlational Analysis of Pollution Factors and Indoor Air quality.

In the relationship between perception of pollution factors and perception of indoor air quality was assessed using Spearman's coefficient of rank correlation, a non-parametric test used to measure the statistical dependence of variables (Rumsey, 2007). The analysis for the dry season shows that pollution factors had a weak and negative relationship with indoor air quality factors, $r_s = -0.120$, $P < 0.05$. This means that pollution factors and indoor air quality have an inverse relationship. This shows that as the pollution factors increases, the indoor air quality decreases and vice versa. Correlational analysis of pollution factors and indoor air quality factors during the wet season was also carried out. The result demonstrates that there was a weak and negative relationship between the perceived pollution factors and perceived indoor air quality factors as in the dry season ($r_s = -0.095$, $p = 0.079$), however, it was not statistically significant.

Theoretically, the relationship in the dry season is to be expected (ECA, 1999; Bluyssen, 2009; Burroughs & Hansen, 2011), it resonates with other studies. However, in the wet season, the results can be considered to be inconsistent to previous studies, this may be due to other factors beyond the scope of the study.

4. Conclusion and Recommendations

The descriptive statistics shows that the prevalence of "dust" has the potential to affect indoor air quality in the research area. Additionally, use of cosmetics by other occupants was rated "neither rare nor prevalent" in the wet season. Other sources of pollution were considered "rare" or "very rare" within the research area. Satisfaction with breakaway factors of indoor air quality for both dry and wet seasons were less than ASHRAE's benchmark of 80% satisfaction votes for IAQ in the study area. Pollution factors and indoor air quality factors have an inverse relationship within the research area, even though, it was statistically significant in the dry season only. The dry season results were comparable with other results from other climes, while the wet season results were inconsistent with other studies. Additionally, gender does not significantly affect perception of indoor air quality by users in both the wet and dry seasons. The results have provided baseline information needed for managing higher education buildings in south west Nigerian universities. Future research may focus on perception of users in air-conditioned classroom or a lecture theatre designed using advanced natural ventilation technique.

Acknowledgements

The authors appreciate the Tertiary Education Trust Fund (TETFUND) and the Federal University of Technology (FUTA) for the partial grants provided for the study. Additionally, the author appreciates Prof. O. O. Ogunsote and Prof. E. C. Okogbue for their helpful insights.

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