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An Analytical Study of the Variables that Influence the Indoor Environmental Quality of Northeast Nigerian Churches

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Abstract

Today, Christianity in Nigeria has increased in churches in large cities to the point where Nigeria now has the highest number of churches per capita globally. As good as that is, the concern of this paper was whether building professionals consider indoor environmental indices performance about worshippers' comfort and well-being. This paper aimed to compare the indoor environmental performance of church buildings to develop design guidelines for improved environmental indices performance of churches in North-East Nigeria. Ten church buildings were purposefully chosen, and the effects of temperature, CO, CO_2, RH, PMs, HCHO, TVOCs, Radon, Sound, Ventilation, Moisture, Dewpoint, and Lighting were investigated using a questionnaire, observation, and indoor environmental detectors. A case study evaluation was used to evaluate this pragmatic approach. The paper found that seven out of fourteen parameters had low performance on church members in North-East Nigeria. The paper recommends that information about the danger of these indices be made public. Creating a design guideline to improve worshippers' comfort and well-being became necessary.

Keywords: Indoor Environment; Church Buildings; Performance; Northeast: Nigeria.

Introduction

Globally, Christianity has expanded into so many different denominations and beliefs that it is nearly difficult to deny its influence on worship buildings. According to Akintaro (2014) Nigeria has the most churches per capita globally. Mainline churches, such as Catholics and Evangelicals, as well as new-generation churches, such as Pentecostals and independent churches, are growing on a daily basis (Tessus, 2014). As a result, demand for church auditoriums for Christian worship has surged (Adesanya, 2011). Buildings such as halls, classrooms, factories, hotels, abandoned cinema buildings, studios, and houses are virtually daily converted to churches with little or no regard for the comfort and well-being of church members. Despite the fact that these structures may be modified and utilised for Christian worship, it is of the utmost concern that the quality of indoor environmental performance of those converted to church buildings falls short of the required comfort and well-being of worshippers. Meanwhile, Zubairu (2018) has argued the need for building professionals to design to meet users' needs of comfort and well-being. Around the world, a number of researchers (Turcanu *et al.*, 2019; Monica, 2018; and Hussain *et al.* 2021) have conducted comparative investigations on various factors affecting various congregations in various assemblies. Their findings have resulted in enhanced church indoor environmental performance. Most congregations in Nigeria have not examined or given proper thought to the health and well-being of their worshippers in the architecture of their worship buildings. This has resulted in gaps in existing church-building research. This assertion confirms the opinions of Lilly-Tariah *et al.* (2017), who stated that the current performance of indoor indices in Nigerian churches is unclear and that no well-established modelling framework exists to capture this performance.

Review of Literature

Indoor air pollution is responsible for 32,000 cancer cases, 50% of cold and flu cases, and harms worshippers' comfort, health, and ability to work normally (US EPA, 2011). In the internal dimensions of Catatuia Monastery and Polish churches, Turcanu *et al.* (2019) and Monica (2018) discovered insufficient indices. According to Lilly-Tariah *et al.* (2017), these indoor amenities are lacking in Nigerian churches. Ruffolo *et al.* (2015) discovered that the topographical latitude of a church influences air quality. Hussain *et al.* (2021) evaluated five interior environmental quality indices in Faisalabad churches. According to the Indoor Air Quality Association (2017) and Godish (2016), indoor discomfort is linked to climate and building pollutants. Many contaminants exist in indoor church air, some in such low amounts that they are deemed harmless to the occupants, while others might exist in high percentages (Klepeis *et al.*, 2001; Weschler, 2009). These pollutants are often divided into three types: biological, chemical, and particle (US EPA, 2011). Due to the impossibility of describing all known interior contaminants in this study, only a few of the most common pollutants in church indoor air are mentioned. Odour is a bio effluent produced by occupation, cooking, bathroom activities and waste that is prominent among the contaminants in churches' internal environments. Odour is unpleasant, yet it usually has no harmful influence on health. Body odour is produced through sweat and sebum excretion through the skin, as well as the digestive system. Yaglou *et al.* (1936) tested people in a ventilated test chamber almost 80 years ago, and the results are still used today. A minimum fresh air rate of 3 1 s-1 per person is required to neutralise body smell (ASHRAE,1966) and the ventilation rates required to reduce pollution from buildings and their contents, as well as any HVAC system that may contribute to indoor pollution. This is in addition to the ventilation rates required to decrease pollution from buildings, their contents, and any HVAC systems.

Another pollutant in indoor spaces is carbon dioxide (CO2). The main source of CO2 indoors could be the building's occupants (i.e., church members). According to Sakamoto *et al.* (2022), the rate of CO2 produced by respiration is proportional to the metabolic rate. Through respiration, a sitting adult produces roughly 5 ml s-1 (18 h-1) of CO2. According to most ventilation guidelines, the CO2 content should not exceed 0.5 percent or 500 ppm. A recent study, however, has demonstrated that this level is considerably too high for human comfort. At this quantity, occupants may experience headaches and tiredness, and 1000 ppm is now universally considered as a safe limit. Estimating ventilation rates based on CO2 emissions is possible if an average outside CO2 concentration of 400 ppm is used, which may differ depending on whether the building is in an urban, suburban, or rural setting (Sakamoto *et al.*, 2022). According to Huang et al. (2021), formaldehyde (HCHO) is a chemical that is extensively used in the manufacturing of building materials, furniture, cosmetics, toiletries, and food packaging. Formaldehyde polymers are also employed to manufacture church wallpapers, carpets, and linens. Indoors, both unvented combustion appliances and tobacco smoke emit formaldehyde. The low-cost urea-formaldehyde (UF) resin is the most often used adhesive in producing plywood, wood chipboard, hardboard, and plasterboard in the plaster of fibreglass insulation.

Particulate matter suspended in air (aerosols), according to Riley *et al.* (2002), is a substantial source of indoor air pollution. Depending on their size and room airflow, aerosols can settle on a surface in minutes or remain airborne for weeks. Dust, dander, fibres, pollen, fungi, moulds, mites, bacteria, viruses, and other pollutants can be found in aerosols. Dust particles less than 0.5g/m3 can accumulate in the lungs, fining and blocking the breathing passages. Biogenic particles have the potential to spread disease or allergies. The most effective way to reduce aerosol concentrations is by air filtration. Other pollutants include noise, which is a sound, especially one that is loud or unpleasant or causes a disruption, and irregular fluctuations that accompany a transmission. Excessive noise, according to the World Health Organisation (2014), gradually impacts many areas of people's everyday life and continues to be an issue in all regions of the world. It is also predicted that due to dangerous listening practices, over 1.1 billion young people globally are at risk of hearing loss and other severe repercussions (WHO, 2014; NIOSH, 1988). Bands, choirs, and organs are noise sources in churches that might occur during preaching, rehearsals, and other related or special events (Quarteri *et al.*, 2009). Chronic exposure to moderate sound levels (90dB) in the environment might induce hair cells to degenerate within the Organ of Corti, particularly the outer hair cells of the members' inner ear, during each exposure period (Bredberg, 1968).

Against the backdrop of the aforementioned indoor environment parameters prevalent in interior church environments, the purpose of this paper was to compare the indoor environmental performance of church buildings in order to develop additional design guidelines for improving the environmental performance of churches in North-East Nigeria. The paper's objectives are to (i) identify the indoor environmental indices that influence the performance of church buildings in North-East Nigeria, and (ii) assess users' perceptions of the interior environmental performance of church buildings in North-East Nigeria.

Materials and Method

Study location

This study was carried in North East geopolitical zones of Nigeria (Figure 1) comprising of six states namely: Adamawa (9° 11' 60"N; 12° 28' 60"E), Bauchi (10° 18' 48"N; 9° 50' 36"E), Borno (11° 50' 49"N;13° 9' 26"E), Gombe (10° 17' 23"N;11° 10' 2"E), Taraba (8° 52' 60"N;11° 22' 0"E), and Yobe (11° 42' 50"N;11° 4' 52"E) (Figure 2). Geographically, the North East is the largest geopolitical zone in Nigeria, accounting for roughly one-third of the country's total area.

Figure 1: Map of Nigeria showing the six geopolitical
(Source: Google Maps, 2016)

Figure 2: Map of Nigeria showing the North-east zones.

The zone is generally separated into the semi-desert Sahelian savanna and the tropical West Sudanian savanna ecoregions (Figure 3). The northeast climatic zone encompasses three climates: tropical savannah, Sahelian hot, and semi-arid (Figure 4). The Sahelian hot and semi-arid climates have typical daytime temperatures of 35 °C (95 °F) and nighttime temperatures of 21 °C (70 °F). The yearly mean rainfall in these areas is less than 700mm. The Christian Association of Nigeria (CAN) represents all churches in Nigeria's North-East. Borno, Adamawa, and Taraba were chosen to symbolise Nigeria's North-East geographical zone since they possessed three of the country's five meteorological features (Figure 3.6).

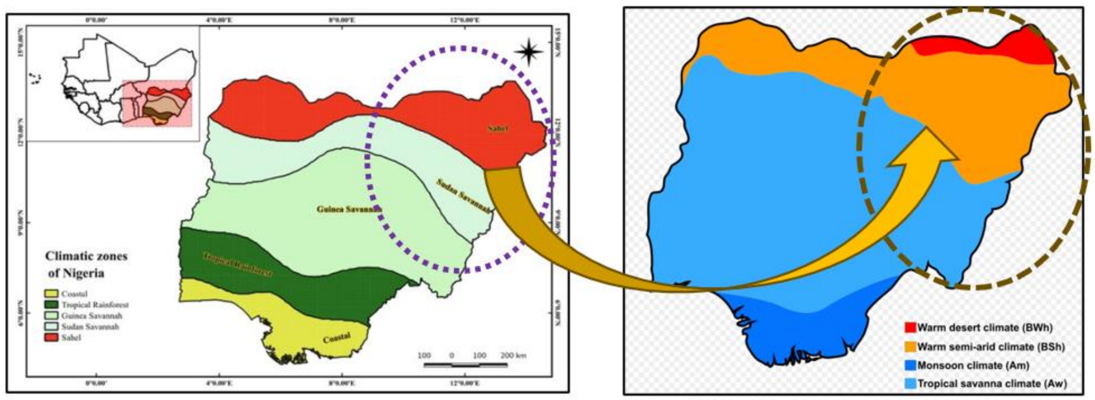

Figure 3: Map showing the climatic zones in Nigeria

Figure 4: Map showing climatic areas in the North east

Source: Ragatoa *et al.* (2018)

Study Population and sample size

The study population consisted of churches from the five (5) CAN blocs. These groups are responsible for 95% of Nigeria's church buildings and 90% of its Christians. As a result, the study's population includes 69 congregations or faiths. Purposive sampling was used to choose 10 churches from Adamawa, Borno, and Taraba states from 69 congregations or denominations, with each congregation having 200 or more members. The churches were chosen using purposive sampling based on their categories and distinguishing characteristics. Because of the variety of church building styles, the study employed maximum variation sampling, also known as heterogeneous sampling, as a purposive sampling approach to acquire various congregational perspectives on church indoor environmental conditions. Because of the large number of people in the research region, stratified sampling was used to divide the entire area into layers.

Data Collection Instruments, exposure limits and analysis method

For data collection, an observation schedule, questionnaire, interview schedule, a camera, and Google Earth were used. According to Dianne (2018), IEP was measured using a decibel metre, a light metre, a bar-o-meter, a thermometer, a hygrometer, an olfactometer, and an air quality detector. These methods enabled the researcher to collect data on the indoor environmental performance of church facilities and the perspectives of church members and leaders. Setters' acceptable permitted exposure limits (PELs) were also used in this investigation. The PELs were derived from the Occupational Safety and Health Administration (OSHA), the National Australian Built Environment Rating System (NABERS), the Leadership in Energy and Environmental Design (LEED V4), and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) (NABERS). SPSS (Statistical Package for the Social Sciences) was employed as a statistical tool in this investigation.

Findings and Discussion

500 questionnaires were distributed to congregation members at the chosen churches, and 492 were returned, obtaining a 98.4% response rate. Figure 5 presents the results obtained from the IEQ based on the quantity of particulate matter PM1.0 recorded in the Churches when compared with the selected permissible exposure limits established by indoor environmental standards in order to achieve objective one, which is to determine the indoor comfort indices that affect the performance of church buildings. The allowable exposure levels obtained from LEED V4 were used in this investigation, which was 0.05µg/m3. The result is 0.60µg/m3 indoors during the wet season and 0.23µg/m3 indoors during the rainy season. This signifies that PM1.0 levels exceeded the PELs in dry and wet seasons. The dry season PM1.0 surpassed the PELs by 55µg/m3 indoors, while the rainy season PM1.0 exceeded the PELs by 0.18µg/m3 indoors. With these findings, it is possible to assume that worshippers in some churches were exposed to higher particulate matter (PM1.0) during the dry and wet seasons, which could be hazardous to the worshippers' health.

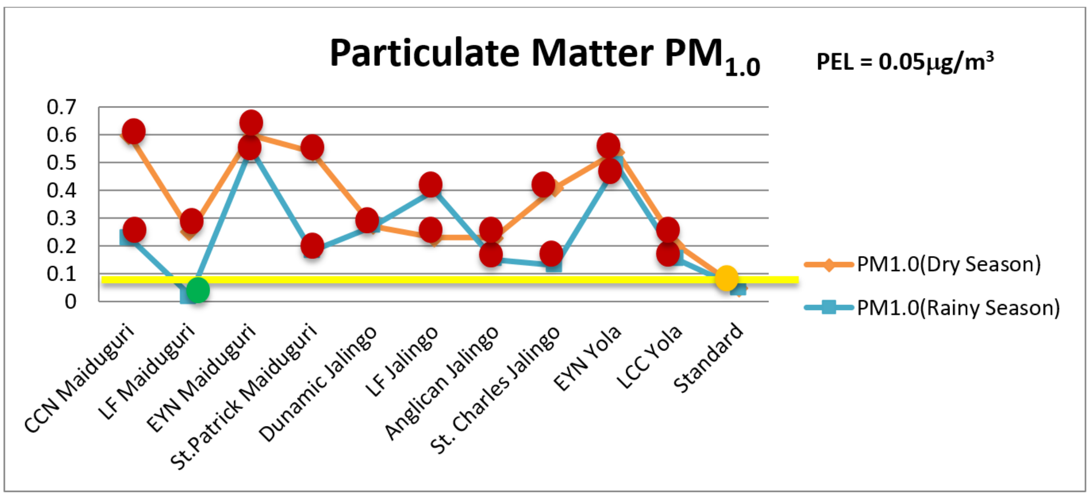

Figure 5: Performance of the churches based on the quantity of particulate matter $PM_{1.0}$ found in the indoor

PM1.0 levels were high in all churches during the dry season. Meanwhile, during the rainy season, it was discovered to be below the standard only in LF Maiduguri, where the environment is comfortable, whereas, in others, the condition is not comfortable, which may lead to various ailments or illnesses due to excess PM1.0. However, for PM2.5, 0.12µg/m3 was found for the indoor environment during the wet season and 0.03µg/m3 during the dry season, indicating that PM2.5 was under control in both seasons in several churches, including LFC. Figure 6 depicts the performance of churches based on the adequacy of sufficient ventilation. Adequate ventilation improves air quality by regulating interior humidity and airborne pollutants, which can harm human health. Inadequate ventilation can lead to the buildup of contaminated air. The air supply-per-person-per-minutes in various churches (e.g., COCIN) employing natural ventilation using ASHRAE standards (i.e., 8-10litres-per-person-per-minute) indicates 2.5litres-per-person-per-minute in the dry season and 4.5litres-per-person-per-minute in the wet season. This suggests that certain churches had more air supply during the rainy than during the dry season, despite the fact that neither the dry nor wet seasons met the PEL for air. The findings could be attributed to the fact that some churches had enough mechanical ventilation, such as ceiling fans, wall fans, standing fans, humidifiers, and external air through open windows, to offer adequate ventilation for the churches' indoor environment.

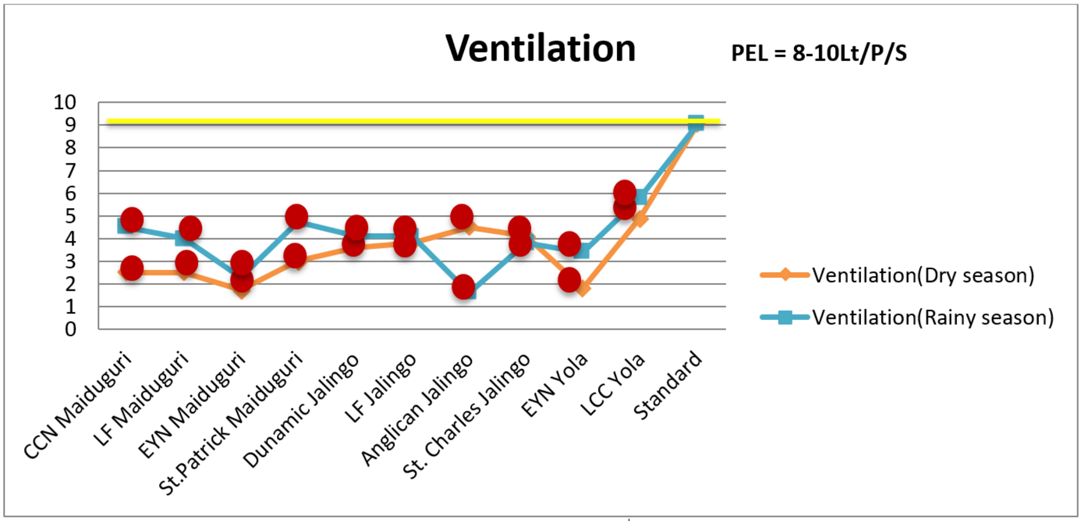

Figure 6: Performance of the churches based on the adequacy of ventilation in the churches

It is recommended that ventilation be between 8 and 10 L/t/p/s, however, only a few churches have values higher than 4. We can conclude that some of the churches' ventilation was inadequate. Figure 7 depicts the performance of the churches based on the intensity of the sound in the churches. According to the findings, certain churches are subjected to loud sounds that exceed the recommended value for human health. Loud noises can cause hearing loss, which is dangerous to one's health. St. Charles Jalingo, EYN Yola, LCCN Yola, and St. Patrick Maiduguri, on the other hand, meet the criterion in both the dry and wet seasons.

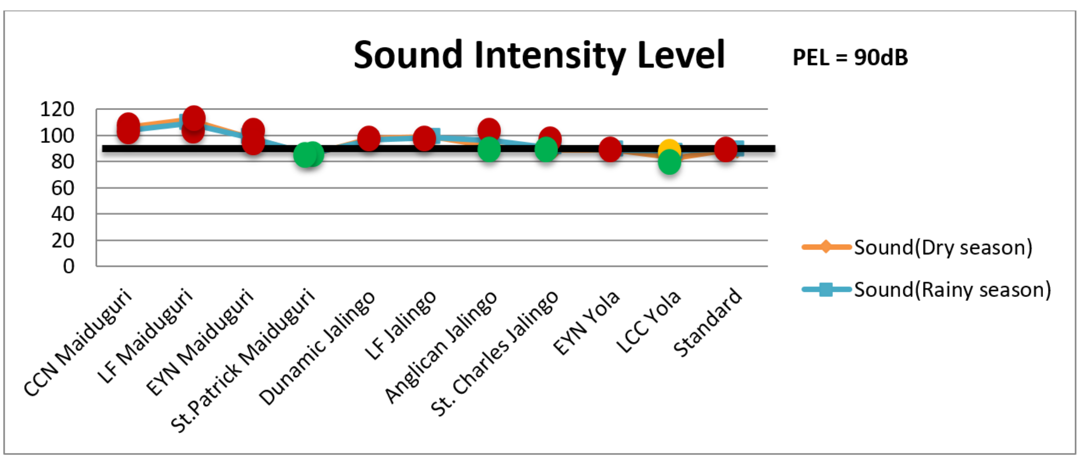

Figure 7: Performance of the churches based on the sound intensity in the churches

Table 1 shows the findings of the IEQ when compared to the specified acceptable exposure limits (PELs) established by indoor environmental standards. The table displays the results of a comparison of the present indoor environmental performance of churches with the specified norms and guidelines of IEQ between churches and between states. Only parameter 14 (dampness) recorded 0% in all seasons, earning the designation of 'HIGH' because it has no influence on worshippers, according to the data.

Table 1: Summary of Quantitative results (Performance per church)

	Parameters and Exposure limits	Church of Christ in Nations Maiduguri		Living Faith Bulunkutu Maiduguri		Eklisiyar Yan'uwa a Nigeria Maiduguri		St. Patrick Catholic church Maiduguri		Dunamis church Jalingo		Living Faith Jalingo		Anglican church Jalingo		St. Charles catholic church Jalingo		Eklisiyar Yan'uwa a Nigeria Yola		Lutheran church of Christ in Nigeria Yola	
	Particulate Matters	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Dry	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
1	($PM_{1.0}$ 0.05µg/m^3)	0.60	0.23	0.21	0.02	0.60	0.55	0.54	0.18	0.27	0.27	0.23	0.40	0.23	0.15	0.41	0.13	0.54	0.49	0.20	0.15
	($PM_{2.5}$ 0.15µg/m^3)	0.58	0.19	0.12	0.03	0.58	0.48	0.54	0.15	0.10	0.10	0.15	0.40	0.19	0.10	0.30	0.13	0.22	0.20	0.11	0.06
2	Relative Humidity (40 – 60%)	19.2	49	15.2	51.2	15.2	25	14.4	24.1	17	45	18	48	12	64	20	54	13	58	13	51
3	Temperature (21 – 24^{o}C)	28	46.3	23.9	24.8	32.1	44.9	35.6	40.4	31.3	32.5	32.7	29.2	34.8	31.9	30.8	34.2	34	46.3	24.7	26
4	Carbon dioxide CO_2 (1000ppm)	603	629	1283	1188	970	868	1621	1532	862	924	819	743	786	824	910	864	1051	1301	2011	2141
5	Sound (90dB)	106	104	112	109	98.4	98.2	85.2	86	98.1	96.8	99.0	98.7	91	96	88.7	90.2	88.6	88.6	82.8	88.1
6	Lighting (P300, C300, N150Lux) = 250 average	168	172	410	132	349	258	120	128	179	183	210	205	211	182	246	243	119	123	174	172
7	Ventilation (8-10Lt/p/s)	2.5	4.5	2.5	4.0	1.75	2.3	3.0	4.75	3.6	4.1	3.8	4.1	4.5	1.6	4.1	3.8	1.8	3.4	4.9	5.8
8	TVOCs (0.3-0.5µg/m^3)	0.06	0.04	0.02	0.02	0.06	0.03	0.04	0.03	0.02	0.04	0.06	0.12	0.04	0.04	0.03	0.03	0.07	0.09	0.02	0.02
9	Radon (100Bq/m^3)	26	28	48	52	23	25	30	32	27	34	34	37	16	36	21	24	18	24	14	18
10	Carbon monoxide (CO 9ppm)	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0
11	Formaldehyde (HCHO 0.010µg/m^3)	.007	.006	.002	.002	.008	.000	.009	.007	.001	.000	.000	.001	.001	.000	.010	.000	.009	.008	.014	.012
12	Odour Scale 1 - 4	3	2	2	3	4	4	3	2	0	0	1	0	0	1	0	1	1	1	0	2
13	Dewpoint (<18.3^{o}C) Dp	8.1	19.8	4.7	30.8	0.2	-6.4	0.5	1.9	2.5	22	4.1	18.3	-2.1	27.6	-3.3	23.3	-0.5	35.1	4.2	34.9
14	Dampness 90%(ERH)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Keys = High Performance 7 Medium Performance 1 Low Performance 6

Total Volatile Organic Compounds, Radon, Carbon Monoxide, Formaldehyde, and Odour, were rated 'HIGH' in both seasons since their influence on worshippers was insignificant and less than the PEL. This is in line with the result obtained by Molhave (1990). Dewpoint has a 'HIGH' performance in the dry season and a 'MEDIUM' performance in the rainy season because the results during the dry season were less than the PEL, which was ideal for worshippers, but only in Borno was the result less than the PEL during the rainy season. Relative Humidity granted Taraba and Adamawa states a 'HIGH' score for being within the PEL during the rainy season.

Borno had the lowest percentage (3%). During the dry season, however, readings in all three states fell below the PEL, resulting in a 'LOW' performance. Ventilation, Lighting, Carbon Dioxide, and Temperature all received a 'LOW' rating because they were either over or below the PEL, making attendees uncomfortable throughout church service. Because it had two PELs below and four above the threshold, the sound intensity limit received a 'FAIR' rating. Particulate matter (PM1.0) was rated 'LOW' in both seasons because levels surpassed the PEL. However, because it is harmattan season, PM2.5 registered a 'LOW' performance in the dry season, resulting in a higher metre than the PEL.

The rainy season record was 'MEDIUM' because it was not harmattan season; as a result, the sky had less dust, and the metre was recorded below PEL. As a consequence of this research, 7 out of 14 criteria were determined to be negatively harming the interior environment in North-East Nigeria. To achieve aim two, which is to determine the users' perceptions of the church buildings' indoor environmental performance. The measuring scale (i.e., Always = 5, Often = 4, Occasionally = 3, Rarely = 2, Never = 1) was employed. The graded combined selection of characteristics whose frequencies were perceived by church members is shown in Table 2. The findings of the grading revealed that the members felt the most discomfort from hot air, cold weather, hot weather, and excessive speaker volume. These four factors each received a score of ten. Temperature, stuffy air, cough, and discomfort in the eye, nose, or throat received a second rating of 9 each. The following category includes persons who received the honour of 8 as perceived by church members. Among them are throat dryness, dust, direct glaring to the eye, and insufficient light.

Table 2: Users' perception of the indoor environmental performance of the church buildings

S/N	Parameters	Borno Decision	Adamawa Decision	Taraba Decision	Ranking
1	Hot temperature	Rarely	Sometimes	Often	9
2	Dry air	Often	Sometimes	Sometimes	10
3	Dryness of throat	Sometimes	Rarely	Sometimes	8
4	Allergy	Never	Rarely	Sometimes	6
5	Inability to view pulpit from seat	Rarely	Sometimes	Sometimes	7
6	Odour	Rarely	Sometimes	Sometimes	7
7	Stuffy air	Sometimes	Sometimes	Sometimes	9
8	Cough	Sometimes	Sometimes	Sometimes	9
9	Slippery floor	Never	Rarely	Sometimes	6
10	Hot weather	Often	Sometimes	Sometimes	10
11	Dry weather	Often	Sometimes	Sometimes	10
12	Dusty	Rarely	Sometimes	Sometimes	8
13	Pesty	Rarely	Rarely	Sometimes	7
14	Light direct glaring to eyes	Rarely	Often	Rarely	8
15	Speaker volume too high	Sometimes	Often	Sometimes	10
16	Discomfort in eye, nose or throat	Sometimes	Sometimes	Sometimes	9
17	Insufficient light	Rarely	Sometimes	Sometimes	8

Another three factors that received seven points each were the inability to see the pulpit from the seat, the odour, and the pesty. They were the fourth most common source of discomfort in churches in North-East Nigeria. Those in group five were the last and lowest. These parameters received a score of 6. They had allergic guests and slick floors. Table 4.3 summarises the locations of discomforts within the church building as experienced by church members. The table also displays the level of discomfort in various locations of the church. According to the findings, the nave, where congregation seats are located, is the most uncomfortably located (48%). In North-East Nigerian churches, the choir seat was placed second (19%) as the source of suffering. Outdoor centres were ranked third (18%) as a source of discomfort within churches. According to Table 3, the pulpit was the least comfortable spot in the church (15). This finding implies that the pulpits are the most comfortable portions of the churches' interiors.

Table 3: Summary of places of discomfort in church and rank

	Borno		Adamawa		Taraba		Overall	Rank
	f	%	f	%	f	%	%	
Place of Discomfort								
Choir seats	7	27%	3	15%	4	16%	19%	2nd
Pulpit	4	15%	3	14%	4	16%	15%	4th
Nave	12	50%	9	41%	14	55%	49%	1st
Outdoor	2	8%	7	30%	3	13%	17%	3rd
Place most time is spent								
Choir seats	5	19%	4	16%	7	29%	21%	2nd
Pulpit	3	12%	5	21%	3	13%	15%	4th
Nave	13	53%	8	37%	12	51%	47%	1st
Outdoor	4	16%	6	26%	2	7%	16%	3rd
Most frequent place in church								
Choir seats	5	22%	3	12%	2	16%	17%	3rd
Pulpit	4	18%	4	17%	3	14%	16%	4th
Nave	11	47%	8	39%	9	57%	48%	1st
Outdoor	3	13%	7	34%	9	13%	20%	2nd

The ‘middle of service' scored highest (36%) as the commencement of pain during service, according to Table 4. The table also shows that 'Never' was the second most common cause of discomfort during service (23%). The commencement of discomfort during service was placed third (22%) as the end of service. Finally, 'Onset of service' was ranked fourth in terms of pain during church services (19%). Over the course of the week, the soreness grew. 'Weekend end' was ranked first (34%). 'Never' came in second (25%) on the day of the week when discomfort increased. The 'Beginning of the week' rated third (23%) and the 'Mid of the week' ranked fourth (21%) on the weekday when discomfort worsened. When it came to the time of day when discomfort rose, 'Afternoon' came in first (32%), 'Never' came in second (25%), 'Morning' came in third (24%), and 'Evening' came in fourth. Similarly, the Table shows that 'Dry season' rated top (42%) as the season of the year discomfort worsened in rainy season' placed second (23%). On the basis of the season of the year, 'Never' rated third (22%), and 'Rainy season' ranked fourth (13%).

Table 4: Summary of time of discomfort in church and ranking

	Borno		Taraba		Adamawa		Overall	Rank
	f	%	f	%	f	%		
Start of discomfort during service								
Onset of service	7	29%	5	21%	2	7%	19%	4th
Middle of service	6	36%	12	52%	5	21%	36%	1st
End of service	3	12%	2	10%	9	43%	22%	3rd
Never	9	23%	4	17%	8	29%	23%	2nd
Period of the week discomfort got worsened								
Beginning of the week	7	28%	8	35%	2	7%	23%	3rd
Mid of the week	6	13%	5	23%	6	26%	21%	4th
End of the week	10	42%	4	27%	7	32%	34%	1st
Never	8	25%	5	15%	8	35%	25%	2nd
Time of the day discomfort got worsened								
Morning	7	29%	7	31%	3	12%	24%	3rd
Afternoon	7	29%	5	32%	8	36%	32%	1st
Evening	3	14%	4	19%	5	24%	19%	4th
Never	7	28%	4	18%	6	28%	25%	2nd
Season of the year discomfort got worsened								
Rainy season	5	21%	3	14%	1	5%	13%	4th
Dry season	10	43%	12	53%	6	29%	42%	1st
rainy season	4	15%	3	17%	8	38%	23%	2nd
Never	5	21%	4	16%	6	28%	22%	3rd

Table 5 shows the time it takes to recover after catching an illness. According to Table 5, 'After leaving church' had the highest rating (66%), indicating that church members are more uncomfortable after leaving the church than after leaving a specific area within the church, which received the lowest rating (55%). Furthermore, 0-30 minutes rated top (45%) in terms of recovery time per minute, according to the Table. Members of the church perceived a healing time per minute of 31-60 minutes (31%). In Table 6, the third (25%) recovery time per minute is 0-30 minutes. The findings of this article may be able to pinpoint moments when church members are uneasy.

Table 5: Summary of recovery period and ranking

	After leaving church			After leaving the place			Overall	Rank
	Borno	Taraba	Adamawa	Borno	Taraba	Adamawa		
Agreed	71%	51%	76%	58%	56%	50%	ALC 66%	1st
Not agreed	29%	49%	24%	42%	44%	50%	ALP 55%	2nd
Recovery time per minutes								
0-30	55%	51%	29%	39%	61%	32%	45%	1st
31-60	11%	34%	34%	11%	17%	40%	25%	3rd
>60	34%	15%	37%	50%	22%	28%	31%	2nd

Table 6 shows the indoor environmental indices that influence church building performance improvement. The Table also ranked the impact of the location of discomfort, time and season of discomfort, and healing period.

Table 6: Location of discomfort, time of discomfort and recovery period

Rank	Quantitative parameters	Qualitative parameters	Location of discomfort	Start of discomfort	Period of week discomfort worsened	Time of the day discomfort worsened	Season of the year discomfort worsened	Recovery period: After leaving church/place	Recovery Time
1st	-Hot Temperature -Carbon dioxide -Lighting -Ventilation	-Cold weather -Dry air -Speaker volume -Wet weather	Nave	Middle of service	End of the week	Afternoon	Dry season	After leaving church	From 0 – 30 minutes
2nd	-Particulate matters -Relative Humidity	-Hot Temperature -Hot air -Stuffy air -Discomfort in eye nose or throat	Choir area	Throughout the service period	Throughout the service period	Throughout the service period	rainy season	After leaving place	From 60 minutes and above
3rd	-Sound Intensity -Dewpoint	-Dusty -Dryness of throat -Insufficient light	Outdoor seating area	End of service	Beginning of the week	Morning	Throughout the Year		From 31 – 60 minutes

		-Light direct glairing to eye					
4th	-Total Volatile Organic Compound -Radon -Carbon monoxide -Formaldehyde -Odour	-Odour -Inability to view pulpit -Pesty	Pulpit	Onset of service	Middle of the week	Evening	Combined season
5th	-Dampness	-Allergy Slippery floor					

5. Conclusion and Recommendations

The study examined the performance of indoor environmental parameters in churches in North-East Nigeria. It discovered that more deliberate effort was required to measure parameters within safe exposure levels. The necessity for environmentally friendly churches is critical owing to the positive effects on users' health and wellness as well as the health and wellness of the buildings. This study discovered that substantial environmental design has considerable benefits and consequences on humans and church structures regarding health and welfare. It has a favourable impact on both current and future generations. In that regard, the following suggestions are made by this study: (i) At the start of the design process, the client and consultants should be informed of the goals and strategies of indoor environmental design and encouraged to incorporate them into the design and construction phases. (ii) The risks of prolonged exposure to low-performing indoor environmental indicators such as temperature, relative humidity, particulate matter, sound, ventilation, and lighting should be periodically communicated to the general public.

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Conflict of Interests

The authors declare no conflict of interest.

References

Adesanya, I. (2011). Environmental effect of churches proliferation: the redeemed Christian church of God as a case study. *International Journal of Humanities and Social Sciences*, 1(15): 177 – 182.

Akintaro, O. A. (2014). Perceived effects of noise generated by religious houses on the health of the people of Osun State, Nigeria. *Journal of Education and Practice 5(19): 91-95.*

ASHRAE Standard 62-1989 R. (1966). Ventilation for Acceptable Indoor Air Quality. Atlanta: American Society of Heating, Refrigeration and Air-Conditioning Engineers, 1966.

Bredberg, G. (1968). Cellular pattern and nerve supply of the human organ of Corti. Acta Oto-Laryngol Supply, 236, 1-135.

Dianne, J. (2018). Tools for Measuring Abiotic Ecological Factors. Sciencing. Retrieved on 23rd May, 2019

Godish, T. (2016). *Indoor environmental quality*. CRC Press, Taylor and Francis Group, 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742 https://doi.org/10.1201/9781420056747

Huang, L., Fantke, P., Ritscher, A. & Jolliet, O. (2021). Chemicals of concern in building materials: A high-throughput screening. *Journal of Hazardous Materials* 424(7):127574. DOI: 10.1016/j.jhazmat.2021.127574

Hussain, Z., Khan, M. S., Kundi, K., Alaf, K., & Ullah, Y. (2021). Assessment of integrated indoor environmental air quality parameters in selected church buildings of Faisalabad city: a statistical based comparative study. *Scientific Review Engineering and Environmental Sciences*, *30*(1), 134-147. DOI: 10.22630/PNIKS.2021.30.1.12

Indoor Air Quality Association Inc. (2017). IAQA Tech Tipp: Defining Indoor Air Quality. Accessed on 8th December, 2019 from: IAQA.org (301) 231-8388

Klepeis, N., Nelson, W., Ott, W., Robinson, J., Tsang, A., Switzer, P., Behar, J., Hern, J., & Engelmann, W. (2001*)*. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Sci Environ Epidemiol* **11,** 231–252. https://doi.org/10.1038/sj.jea.7500165

Lilly-Tariah, O. B., Chibuike N., Victor O. I., & Okechi C. M. (2017). Sound Pressure Levels in Churches in Port Harcourt: A Study of Some Catholic, Anglican and Pentecostal Churches. Glob J Oto 2017; 9(2): 555758. DOI: 10.19080/GJO.2017.08.555758.

Molhave L. (1990). Volatile organic compounds, indoor air, quality and health. Proceedings of Fifth International Conference on Indoor Air Quality and Climate, Indoor Air, 1990. Vol. 5, p. 15-34. DOI: 10.1111/j.1600-0668.1991.00001.x

Monica W. (2018). Analysis of indoor air quality in a naturally ventilated church. E3S Web of Conferences. DOI: 10.1051/e3sconf/20184900134

NIOH (National institute of occupation safety and health) (1988). Self-reported hearing loss among workers potentially exposed to industrial noise in the USA. Journal of American Medical Association 259(15): 2213-2217. doi:10.1001/jama.1988.03720150013009

Quartieri, J., D'Ambrosio, S., Guarnaccia, C., & Iannone, G. (2009). Experiments in room acoustics: modelling of a church sound field and reverberation time measurements. *WSEAS Transactions on Signal Processing*, *5*(3), 126-135.

Ragatoa, D.S., Ogunjobi, K.O., Okhimamhe, A.A., Klutse, N.A.B. & Lamptey, B.L. (2018). A predictive study of heat wave characteristics and their spatio-temporal trends in climatic zones of Nigeria. *Modeling Earth Systems and Environment*. 4: 1125–1151. https://doi.org/10.1007/s40808-018-0480-7

Riley, W. J., McKone, T. E., Lai, A. C., & Nazaroff, W. W. (2002). Indoor particulate matter of outdoor origin: importance of size-dependent removal mechanisms. *Environmental science and technology*, *36*(2), 200-207. DOI: 10.1021/es020595t

Ruffolo, M. R., Gettys, F. K., Montijo, H. E., Seymour, R. B., & Karunakar, M. A. (2015). Complications of high-energy bicondylar tibial plateau fractures treated with dual plating through 2 incisions. *Journal of Orthopaedic Trauma*, *29*(2), 85-90. doi: 10.1097/BOT.0000000000000203.

Sakamoto, M., Li, M., Kuga, K., Ito, K., Bekö, G., Williams, J., & Wargocki, P. (2022). CO2 emission rates from sedentary subjects under controlled laboratory conditions. Building and Environment Volume 211, 1. https://doi.org/10.1016/j.buildenv.2021.108735

Tessus, A. (2014). *Church History and Building*. Published by ACTS Limited, Bukuru, Jos, Plateau State, Nigeria.

Ţurcanu, F. E., Verdeş, M., Ciocan, V., Burlacu, A., Luciu, R. S., Bălan, M. C., & Şosoi, G. (2019). Numerical analysis of the thermal comfort in a church building. In *E3S Web of Conferences* (Vol. 85, p. 02008). EDP Sciences. DOI: 10.1051/e3sconf/20198502008

U.S. EPA (2011). An Office Building Occupant's Guide to Indoor Air Quality. http://www.epa.gov/iaq/pubs/occupgd.html accessed on 5th June, 2020.

Weschler, C. J. (2009). Changes in indoor pollutants since the 1950s. *Atmospheric Environment*, *43*(1), 153-169. https://doi.org/10.1016/j.atmosenv.2008.09.044

World health organisation, (2014). Occupational noise: assessing the burden of disease from work-related hearing impairment at national and levels. (2014).

Yaglou, C.P., Riley, E.C. & Coggins, D.I. (1936) Ventilation requirements. ASHVE Trans 42:133–162

Zubairu, S, N. (2018). Post-Occupancy Evaluation: A Necessary Tool for Architects, Facilities Managers and Other Professionals in the Building Industry. Published by Global links communications, Minna, Nigeria.