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Occupants' Perception of Ventilation Quality in Orthopaedic Hospital Wards: Evidence From Teaching Hospitals In South-West Nigeria

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ABSTRACT

Ventilation is an important component of indoor environmental quality in healthcare facilities because it influences thermal comfort, air freshness, pollutant dilution, moisture control and the overall wellbeing of patients and healthcare workers. In orthopaedic hospitals, where patients may experience prolonged periods of occupancy and healthcare personnel undertake demanding clinical activities, inadequate ventilation can negatively affect comfort, health and the effectiveness of healthcare delivery. This study assessed the impact of ventilation on occupants of selected orthopaedic sections of teaching hospitals in South-West Nigeria, with the objective of developing architectural strategies for improving indoor environmental quality and informing the design of a proposed orthopaedic hospital for Oduduwa University, Ipetumodu.

A mixed-method research approach was adopted. The study assessed climatic conditions of the selected hospital locations using climatic data and Mahoney Table analysis, while questionnaire surveys were administered to patients and healthcare workers to obtain information on existing ventilation conditions, factors influencing ventilation, occupants' satisfaction and preferred architectural improvements. A total of 328 valid responses comprising 274 patients and 54 healthcare workers were analysed. Descriptive statistics, Mean Weighted Value (MWV), Satisfaction Index (SI), correlation analysis and other relevant analytical techniques were employed to interpret the findings, while healthcare workers' responses and patient perceptions were used to identify architectural and environmental strategies for improving ventilation performance.

The climatic assessment revealed that the selected locations experience hot-humid conditions, with relatively high temperatures and relative humidity, thereby creating a strong need for effective air movement, solar protection and moisture management. The assessment of existing ventilation conditions showed that poor ventilation, overcrowding and excessive indoor heat were the most prominent environmental challenges. Poor ventilation was identified by 74.0% of patients, followed by overcrowding at 69.1% and excessive heat at 65.3%. The weighted analysis similarly ranked poor ventilation first (MWV = 4.09), followed by overcrowding (MWV = 4.05) and excessive indoor heat (MWV = 3.82). The study also established significant positive relationships between ventilation and breathing comfort, with overall ventilation recording a correlation coefficient of r = 0.682 (p < 0.01) and ventilation condition recording r = 0.718 (p < 0.01).

Occupants' satisfaction with ventilation was generally positive but moderate. Air freshness recorded the highest satisfaction level (MWV = 3.55; SI = 0.55), followed by temperature comfort (MWV = 3.45; SI = 0.45), while humidity comfort, odour control and overall ventilation recorded comparatively lower values. The overall satisfaction level was MWV = 3.35 and SI = 0.35, indicating satisfaction but with considerable opportunity for improvement. Healthcare workers strongly supported the integration of ventilation considerations into future hospital design, with 98.1% agreeing that future hospital designs should incorporate ventilation-focused principles. Patients similarly prioritised increasing windows for natural ventilation (31.9%) and reducing the number of patients per room (25.6%) as preferred improvements.

The study concludes that ventilation performance in orthopaedic hospitals is determined by the combined effects of architectural configuration, climatic conditions, occupancy density, material selection, maintenance and environmental management. It recommends the integration of climate-responsive passive ventilation, appropriate building orientation, effective window placement, adequate ward spacing, low-emission materials, moisture control, improved maintenance and suitable mechanical or hybrid ventilation systems where necessary. These strategies were incorporated into the proposed orthopaedic hospital design for Oduduwa University, Ipetumodu, providing an occupant-centred and climate-responsive framework for improving indoor environmental quality in future orthopaedic healthcare facilities.

Keywords: Ventilation, Indoor Environmental Quality, Orthopaedic Hospitals, Thermal Comfort, Natural Ventilation, Occupant Satisfaction, Healthcare Architecture, South-West Nigeria.

I. INTRODUCTION

Ventilation is particularly important in determining the health and safety of patients and medical professionals within healthcare facility (Martinot, 2024). It is particularly significant because it controls the movement and dilution of indoor contaminants while supporting acceptable air quality (Li, 2023). Carbon dioxide (CO_2) concentration is widely employed as an indicator of ventilation effectiveness and has also been associated with the assessment of potential airborne infection risks (Park and Song, 2023). Indoor concentrations exceeding approximately 1,000 ppm may indicate inadequate ventilation, while Stumm (2022) recommends maintaining the

indoor–outdoor CO_2 differential within about 650 ppm. The effectiveness of ventilation, however, is not determined by a single factor but by the interaction of climatic conditions, building configuration, material characteristics, facility operation, maintenance practices, and occupant behaviour (Cuce and Cuce, 2025).

The importance of ventilation becomes more pronounced in healthcare environments because hospitals accommodate individuals with varying degrees of health vulnerability while simultaneously supporting activities capable of generating indoor pollutants (Chamseddine, 2019). Hospital indoor environments may contain particulate matter ($PM_{2.5}$ and PM_{10}), CO_2, volatile organic compounds (VOCs), carbon monoxide, formaldehyde, nitrogen dioxide, allergens, bioaerosols, mould, bacteria, and viruses (Apong, 2026). Their concentration and behaviour can also be affected by temperature and relative humidity, particularly under warm and humid climatic conditions (Heracleous and Michael, 2019). Sources may include outdoor traffic emissions, generators, medical equipment, cleaning and sterilization procedures, disinfectants, construction activities, and the routine presence and movement of patients, healthcare workers, and visitors (World Health Organization, 2020). Consequently, effective ventilation is essential not only for maintaining acceptable Ventilation but also for reducing the accumulation and transmission of potentially harmful contaminants.

Although the relationship between ventilation and healthcare environments has received considerable scholarly attention, available studies have predominantly addressed general healthcare facilities or have been undertaken within contexts with different climatic, technological, regulatory, and infrastructural conditions (World Health Organisation, 2023). Consequently, findings from such settings may not adequately represent the conditions of healthcare facilities operating within the tropical environment of Southwestern Nigeria. In particular, there remains limited empirical evidence concerning ventilation performance in specialized orthopaedic sections and its relationship with the experiences and well-being of their occupants.

Against this background, the study evaluates ventilation conditions and their implications for occupants' health in selected orthopaedic sections of teaching hospitals in Southwestern Nigeria. It considers the prevailing climatic conditions, assesses architectural and environmental factors affecting ventilation, examines occupants' perceptions of indoor air conditions, and identifies appropriate strategies for improving ventilation performance. The study further translates the findings into design considerations for the proposed orthopaedic hospital at Oduduwa University, Ipetumodu, Osun State, with the broader objective of promoting healthier, more responsive, and contextually appropriate healthcare environments in Nigeria.

II. LITERATURE REVIEW

Ventilation within buildings refers to the condition of air within buildings and its implications for occupant health and comfort (Fantozzi and Rocca, 2020). It is influenced by the concentration of chemical, particulate, and biological pollutants as well as thermal conditions such as temperature, humidity, and air movement (Grigorieva, and Lukyanets, 2021). Ventilation is therefore an important mechanism for maintaining acceptable indoor conditions because it introduces outdoor air, dilutes

contaminants, and removes pollutants generated within occupied spaces (Gola, Settimo, and Capolongo, 2019).

The quality of indoor air is shaped by three broad sources: outdoor environmental conditions, occupant activities, and the characteristics of building materials, furnishings, and equipment (Burroughs and Hansen, 2020). Outdoor pollutants may enter through openings and ventilation systems, while occupants contribute contaminants through respiration, cleaning, combustion, and other activities. Materials such as paints, adhesives, plastics, composite wood, flooring, and sealants can also emit volatile organic compounds (VOCs), formaldehyde, and other chemical pollutants. Consequently, adequate ventilation cannot be considered independently of building design, occupancy, materials, and maintenance.

Carbon dioxide (CO_2) is frequently used as a practical indicator of ventilation adequacy because its indoor concentration is closely associated with occupancy and air exchange. Elevated CO_2 levels can indicate insufficient fresh-air supply and may correspond with increased concentrations of other occupant-generated contaminants. The COVID-19 pandemic further emphasized the importance of ventilation because effective air exchange and contaminant removal are essential components of airborne infection control (Mousavi et al., 2021).

Healthcare facilities have worse air quality conditions compared to conventional buildings because they accommodate patients with varying degrees of vulnerability and operate continuously (Pascale and Achour, 2024). Hospital activities also generate diverse pollutants, including particulate matter, VOCs, biological contaminants, and chemical emissions. According to Cappa (2023), medical procedures, cleaning and disinfection, equipment, generators, construction activities, and human occupancy may all contribute to indoor pollution. Hence, there is a need for passive design strategies which help in reducing the spread of harmful contaminants in healthcare environments

III. RESEARCH METHODOLOGY

3.1 Research Design

The study adopted a mixed-method research design, combining quantitative and qualitative approaches to examine the relationship between ventilation and occupants' health in orthopaedic hospital environments. Quantitative data were obtained through structured questionnaires administered to patients and healthcare professionals, focusing on ventilation effectiveness, thermal conditions, perceived air quality, indoor environmental comfort, and ventilation-related health experiences. Qualitative evidence was obtained from healthcare professionals and through direct observation of selected hospital environments to identify architectural, operational, and maintenance factors influencing ventilation.

Case studies were also conducted to examine the spatial organization, ward configuration, fenestration, building orientation, material selection, and existing ventilation provisions of selected orthopaedic facilities. The integration of questionnaire responses, professional input, and observational findings provided a

broader basis for evaluating ventilation performance and identifying design implications for orthopaedic hospital planning.

3.2 Data Sources and Collection

The study utilized both primary and secondary data. Primary data were obtained through questionnaires administered to patients and healthcare professionals within selected orthopaedic sections, supplemented by field observations of the physical and environmental conditions of the facilities. Secondary data were obtained from relevant academic literature, institutional documents, standards, reports, and previous studies on hospital ventilation, indoor environmental quality, and healthcare design.

3.3 Study Population and Sampling Frame

The study population comprised patients and medical practitioners aged 18 years and above who had direct experience of the selected orthopaedic hospital environments. The sampling frame consisted of teaching hospitals with orthopaedic sections across the six states of Southwestern Nigeria: Osun, Oyo, Lagos, Ondo, Ekiti, and Ogun. Field investigation identified nine teaching hospitals with orthopaedic sections within the region, which constituted the sampling frame, while the orthopaedic hospital section served as the unit of analysis.

Table 1: Teaching Hospitals with Orthopaedic Sections in Southwestern Nigeria

S/N	State	Teaching Hospital	No.
1	Osun	OAUTHC, Ile-Ife; UNIOSUN Teaching Hospital, Osogbo	2
2	Oyo	UCH, Ibadan; LAUTECH Teaching Hospital, Ogbomoso	2
3	Lagos	LUTH, Idi-Araba; National Orthopaedic Hospital, Igbobi	2
4	Ondo	UNIMED Teaching Hospital, Ondo	1
5	Ekiti	EKSUTH, Ado-Ekiti	1
6	Ogun	OOUTH, Sagamu	1
	Total		**9**

Source: Author's Compilation (2025)

3.4 Sampling Procedure and Sample Size

A multistage sampling procedure was adopted. The first stage involved stratifying the study area into the six states of Southwestern Nigeria. The second stage identified teaching hospitals with orthopaedic sections within each state. From the nine identified hospitals, approximately half were selected for detailed study based on accessibility and their ability to represent the characteristics of orthopaedic facilities within the region. States with more than one eligible hospital were subjected to random selection, while hospitals in states with a single eligible facility were purposively included.

Five hospitals were consequently selected: Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife; LAUTECH Teaching Hospital, Ogbomoso; Lagos University Teaching Hospital (LUTH), Idi-Araba; University of Medical

Sciences Teaching Hospital (UNIMEDTH), Ondo; and Ekiti State University Teaching Hospital (EKSUTH), Ado-Ekiti.

The patient population across the five selected hospitals was 980. A sample of 285 patients was determined and proportionately distributed across the facilities. The allocation was based on the patient population of each hospital.

Table 2: Distribution of Patient Respondents

S/N	Hospital	Patient Population	Sample
1.	OAUTHC, Ile-Ife	180	52
2.	LAUTECH Teaching Hospital, Ogbomoso	200	58
3.	LUTH, Idi-Araba	150	44
4.	UNIMEDTH, Ondo	250	73
5.	EKSUTH, Ado-Ekiti	200	58
	Total	**980**	**285**

Source: Author's Compilation (2025)

In addition to patients, 10 healthcare professionals were included as key respondents, comprising one doctor and one nurse from each selected hospital. This produced a total sample of 295 respondents, consisting of 285 patients and 10 medical professionals.

Table 3: Medical Professionals in Selected Hospitals

S/N	Hospital	Doctors	Nurses
1	OAUTHC	6	4
2	LAUTECH	5	4
3	LUTH	10	5
4	UNIMEDTH	5	3
5	EKSUTH	8	4
	Total	**34**	**20**

Source: Author's Compilation (2025)

From the identified pool of 54 medical professionals, one doctor and one nurse were randomly selected from each hospital, giving five doctors and five nurses for the study. This selection ensured representation of healthcare professionals directly involved in patient care and familiar with the environmental conditions of the orthopaedic sections.

IV. DATA ANALYSIS

This chapter presents the analysis, interpretation and discussion of data obtained from the field investigation of ventilation conditions within selected orthopaedic sections of teaching hospitals in South-West Nigeria. The chapter provides empirical evidence on the climatic conditions of the study locations, existing ventilation conditions, factors influencing ventilation performance, occupants' satisfaction with indoor

environmental conditions, and architectural strategies for improving ventilation within orthopaedic healthcare facilities. The findings are presented in relation to the objectives of the study to establish the relationship between the physical characteristics of the hospital environment, occupants' experiences and the architectural requirements for improved ventilation.

The analysis was based on data obtained from 328 valid respondents, comprising 274 patients and 54 healthcare workers across the selected teaching hospitals. The responses obtained from patients were primarily used to assess their experiences, perceptions, environmental conditions and satisfaction within the orthopaedic wards, while healthcare workers provided additional professional and operational perspectives regarding ventilation performance, architectural characteristics and possible improvements. The combination of both respondent groups provides a broader understanding of ventilation conditions by considering the experiences of individuals who occupy and work within the hospital environment on different bases.

(i) Climatic Characteristics and Ventilation Implications of Selected Orthopaedic Hospitals

The climatic assessment shows that the five selected orthopaedic hospitals are located within a generally warm and humid environmental context. Mean temperatures range from 27.2°C in Ado-Ekiti to 28.5°C in Lagos, while relative humidity varies from 75.0% in Ogbomoso to 82.0% in Lagos. The relatively narrow temperature range indicates that thermal conditions are broadly comparable across the study locations; however, the variation in humidity and rainfall creates differences in the type and intensity of ventilation challenges experienced by each hospital.

Lagos presents the most demanding moisture-related climatic condition. LUTH records the highest relative humidity at 82.0%, the highest annual rainfall at 1,500 mm, and the highest average wind speed at 2.5 m/s. The combination is significant because the relatively strong wind regime provides considerable opportunity for natural air movement, but the high atmospheric moisture content means that ventilation alone does not necessarily guarantee satisfactory indoor conditions. Where openings are poorly positioned or airflow paths are obstructed, humid air can remain trapped within wards, potentially contributing to dampness and moisture-related indoor environmental problems. The climatic condition therefore supports a design approach that combines strong cross-ventilation with measures for moisture management.

In contrast, Ogbomoso records the highest mean temperature among the study locations at 28.0°C, while its relative humidity is the lowest at 75.0%. This indicates that the principal environmental challenge at LAUTECH Teaching Hospital is comparatively more associated with heat accumulation than excessive atmospheric moisture. Its wind speed of 2.3 m/s provides moderate-to-high potential for natural air movement. Consequently, architectural measures such as appropriate building orientation, effective external shading and adequately sized openings become important in preventing excessive solar heat gain while allowing the available wind to pass through the occupied spaces.

The conditions at UNIMEDTH in Ondo are characterised by a mean temperature of 27.8°C, relative humidity of 80.0% and annual rainfall of 1,400 mm. These values

indicate a relatively humid environment in which moisture control and regular air exchange remain important considerations. The average wind speed of 2.2 m/ssuggests that natural ventilation is feasible, provided that the building configuration does not obstruct airflow. The implication is that ward layouts should avoid unnecessary barriers between inlet and outlet openings and should provide clear paths for air movement across occupied spaces.

At OAUTHC, Ile-Ife, the mean temperature of 27.5°C is accompanied by relative humidity of 78.0% and an average wind speed of 2.1 m/s. These conditions provide moderate potential for natural ventilation but also indicate the need for sustained air movement because of the relatively high humidity. The building design should therefore make effective use of the available wind through appropriate window placement and cross-ventilation. The climatic condition further suggests that deep or poorly ventilated ward configurations may reduce the effectiveness of natural airflow.

EKSUTH in Ado-Ekiti records the lowest mean temperature of 27.2°C and the lowest wind speed of 2.0 m/s, while its relative humidity remains relatively high at 76.0%. Although the temperature is comparatively favourable, the lower wind speed means that the building cannot rely solely on external airflow to maintain satisfactory ventilation. The architectural arrangement of openings therefore becomes particularly important. Correct orientation, adequate opening sizes and unobstructed internal airflow routes can help maximise the limited wind resource available at the site.

Overall, the climatic comparison demonstrates that none of the selected locations can be considered free from ventilation-related environmental challenges. Instead, the nature of the challenge differs by location. Lagos and Ondo are more strongly influenced by high humidity and rainfall, whereas Ogbomoso experiences a greater temperature-related concern. Ile-Ife and Ado-Ekiti occupy intermediate positions but still require deliberate ventilation strategies. The findings therefore support the application of climate-responsive design measures, particularly cross-ventilation, appropriate building orientation, effective window placement, solar shading, moisture control and unobstructed airflow paths.

The wind conditions further reinforce the potential for passive ventilation across the study locations. Average wind speeds between 2.0 and 2.5 m/s indicate that there is a usable natural airflow resource, with Lagos showing the highest potential and Ado-Ekiti the lowest. However, the presence of wind at the site does not automatically translate into effective indoor ventilation. The architectural characteristics of each orthopaedic hospital—particularly building depth, window arrangement, orientation, internal partitions and the relationship between inlet and outlet openings—determine how effectively the available wind can be utilised.

From the perspective of the Mahoney Tables, the climatic characteristics broadly support a design response centred on air movement, solar protection and moisture management. The findings therefore provide an important environmental benchmark against which the existing orthopaedic hospital buildings can subsequently be assessed. In other words, the climatic data establish what the buildings need to respond to, while the subsequent building and occupant assessments determine how effectively the existing facilities actually respond to those conditions.

Table 4: Integrated Climatic Assessment and Ventilation Implications of Selected Orthopaedic Hospitals

S/N	Hospital	Location	Mean Temperature (°C)	Relative Humidity (%)	Annual Rainfall (mm)	Mean Wind Speed (m/s)	Solar Radiation (kWh/m²/day)	Ventilation Potential	Principal Ventilation Concern	Climatic/Design Implication
1	OAUTHC	Ile-Ife	27.5	78.0	1,300	2.1	5.2	Moderate	Persistent humidity may encourage moisture accumulation and reduce indoor air freshness where air exchange is inadequate.	Building layouts should facilitate continuous air movement through appropriately positioned openings and cross-ventilation.
2	EKSUTH	Ado-Ekiti	27.2	76.0	1,350	2.0	5.3	Moderate	Although climatic conditions are comparatively moderate, the prevailing humidity can still affect indoor comfort and moisture levels.	Appropriate orientation, window placement and unobstructed airflow should be incorporated to sustain natural ventilation.
3	LUTH	Lagos	28.5	82.0	1,500	2.5	5.0	High	The combination of the highest humidity and rainfall creates greater potential for dampness, mould development and deterioration of Ventilation.	Maximum advantage should be taken of prevailing winds through cross-ventilation, while moisture-control measures should be incorporated into the building design.

4	LAUTECH Teaching Hospital	Ogbomoso	28.0	75.0	1,250	2.3	5.5	Moderate–High	The relatively high temperature presents a greater risk of heat accumulation and thermal discomfort within inadequately ventilated wards.	External shading, suitable orientation and generous ventilation openings should be used to limit heat gain and improve air movement.
5	UNIMEDTH	Ondo	27.8	80.0	1,400	2.2	5.1	Moderate	High atmospheric moisture increases the possibility of damp indoor conditions and moisture-related deterioration where ventilation is insufficient.	Open spatial arrangements, well-positioned openings and effective cross-ventilation are required to promote regular air exchange.

Source: Author's Compilation from Weather Spark Climate Data (2025/2026) and Mahoney Tables (Koenigsberger et al., 1974)

(ii) Environmental Factors Influencing Ventilation in the Orthopaedic Wards

The weighted analysis in Table 5 provides a comparative assessment of the major environmental conditions perceived by respondents to influence Ventilation within the selected orthopaedic wards. The analysis applies a five-point Likert scale, with Strongly Disagree assigned a weight of 1, Disagree 2, Neutral 3, Agree 4 and Strongly Agree 5. The resulting Total Weighted Value (TWV) represents the combined contribution of all responses, while the Mean Weighted Value (MWV) indicates the average level of agreement associated with each factor. The Average Weighted Value (AWV) of 3.79 serves as the benchmark for determining the relative importance of the identified conditions.

Poor ventilation ranked first with an MWV of 4.09 and a TWV of 1,165. The high value is largely attributable to the substantial number of respondents who agreed (103) and strongly agreed (121) that poor ventilation affects Ventilation. This gives 224 positive responses, indicating a strong perception that inadequate air movement is the principal environmental problem within the wards.

Overcrowding ranked second with an MWV of 4.05 and a TWV of 1,153. The result was influenced by 94 respondents who agreed and 126 who strongly agreed, producing 220 positive responses. Its close MWV to poor ventilation indicates that respondents regarded occupant density as another major factor affecting airflow and indoor environmental conditions.

Excessive indoor heat ranked third, with an MWV of 3.82 and a TWV of 1,089. A total of 197 respondents selected either Agree (97) or Strongly Agree (100). Since its MWV is slightly above the AWV of 3.79, excessive heat can be regarded as one of the principal environmental concerns. The result indicates that thermal conditions are closely associated with the perceived adequacy of ventilation within the wards.

Humidity recorded an MWV of 3.69 and a TWV of 1,053, placing fourth. The combined 184 positive responses, comprising 96 Agree and 88 Strongly Agree responses, demonstrate that humidity remains a relevant concern. However, its MWV falls below the AWV, suggesting that respondents considered it less influential than poor ventilation, overcrowding and excessive heat.

Unpleasant odours ranked fifth with an MWV of 3.60 and a TWV of 1,025. The factor received 172 positive responses, comprising 88 Agree and 84 Strongly Agree responses. Although its score is below the AWV, it remains above the neutral value of 3.00, indicating that odour is still perceived as an identifiable indoor environmental problem.

Dust and airborne particles recorded the lowest MWV of 3.46, with a TWV of 985. The factor received 155 positive responses, consisting of 81 Agree and 74 Strongly Agree responses. Its position below the AWV indicates that respondents considered it less influential than the other assessed factors, although the MWV remains above the neutral midpoint and therefore still represents a relevant concern.

Overall, the results show that poor ventilation, overcrowding and excessive indoor heat were the three factors that exceeded the overall AWV of 3.79. These findings

indicate that improving air movement, controlling occupancy levels and reducing excessive heat should receive particular attention in efforts to improve Ventilation within the selected orthopaedic wards. Humidity, unpleasant odours and airborne particles, although ranked lower, remain associated environmental concerns that may also be influenced by the effectiveness of the ventilation system.

Table 5: Weighted Ranking of Environmental Factors Affecting Ventilation in the Selected Orthopaedic Wards (n = 274)

S/N	Environmental Factor	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	TWV	MWV	Rank
1	Poor ventilation affects Ventilation	8	19	34	103	121	1,165	4.09	1st
2	Overcrowding affects airflow	11	26	28	94	126	1,153	4.05	2nd
3	Excessive indoor heat affects Ventilation	16	31	41	97	100	1,089	3.82	3rd
4	Humidity contributes to poor Ventilation	19	36	46	96	88	1,053	3.69	4th
5	Unpleasant odours affect indoor comfort	22	42	49	88	84	1,025	3.60	5th
6	Dust and airborne particles affect Ventilation	27	45	58	81	74	985	3.46	6th
	Average Weighted Value (AWV)							3.79	Bench mark

Source: Author's Field Survey (2026)

(iii) Assessment of Occupants' Satisfaction with Indoor Ventilation Conditions

This section evaluates how occupants perceived and rated the ventilation conditions provided within the selected orthopaedic wards. Satisfaction was examined across five related dimensions: perceived freshness of the ward air, thermal comfort, humidity conditions, odour management and overall ventilation performance. A five-point satisfaction scale was applied, ranging from Very Satisfied (5) to Very Dissatisfied (1). The resulting Total Weighted Values (TWV) and Mean Weighted Values (MWV) were used to establish the relative performance of each variable, while the Satisfaction Index (SI) was derived from the difference between the MWV and the neutral reference value of 3.00.

The results indicate that air freshness received the most favourable assessment, with an MWV of 3.55 and an SI of 0.55, placing it first among the assessed variables. The relatively high number of respondents selecting either *Very Satisfied* or *Satisfied* suggests that occupants generally regarded the air within the wards as reasonably fresh. This may reflect the contribution of operable windows, open circulation spaces and other openings that permit natural air exchange in some of the hospitals. Nevertheless, the MWV remains only moderately above the neutral point, indicating that the positive assessment should not be interpreted as evidence of highly effective ventilation.

Temperature comfort followed closely, recording an MWV of 3.45 and an SI of 0.45. The result places thermal comfort second in the satisfaction ranking and indicates a generally favourable perception of indoor temperature conditions. However, the relatively small margin above the neutral value suggests that thermal comfort is not consistently optimal. This is significant given the hot-humid climatic conditions established earlier in the study. Measures such as effective solar shading, appropriate building orientation, reduction of heat gain and improved air movement could therefore strengthen thermal performance within the wards.

Humidity comfort produced an MWV of 3.31 and an SI of 0.31, ranking third. Although occupants remained slightly satisfied, the lower score compared with air freshness and temperature comfort indicates greater uncertainty or dissatisfaction regarding moisture conditions. This finding corresponds with the climatic assessment, which established relatively high humidity across the study locations. Persistent moisture can make indoor spaces feel uncomfortable and may also create favourable conditions for microbial growth where air exchange and moisture management are inadequate.

Control of unpleasant odours ranked fourth, with an MWV of 3.27 and an SI of 0.27. The relatively narrow positive margin indicates that odour management represents a weaker aspect of the indoor environmental experience. The finding may reflect the presence of odour-generating activities and materials associated with healthcare environments, including medical procedures, waste handling, sanitation facilities and cleaning products. Effective air extraction, appropriate waste management and regular maintenance could therefore improve occupants' perception of odour control.

The lowest-rated variable was overall ventilation, which recorded an MWV of 3.18 and an SI of 0.18. Although the result remains marginally within the satisfaction range, it is the closest of all the variables to the neutral benchmark. This is an important finding because it suggests that occupants may recognise acceptable conditions in individual aspects of the indoor environment while still perceiving the overall ventilation performance as only moderately satisfactory. In other words, satisfactory air freshness or temperature at particular times does not necessarily translate into confidence that the ventilation system consistently performs adequately.

The overall mean satisfaction of 3.35, corresponding to an SI of 0.35, indicates that occupants were generally satisfied with the ventilation conditions. However, the relatively modest difference between this value and the neutral benchmark of 3.00 demonstrates that satisfaction is moderate rather than strong. The results therefore

point to an indoor environment that is functional and generally acceptable but still characterised by identifiable shortcomings.

The ranking further demonstrates a gradual reduction in satisfaction from air freshness (3.55) to temperature comfort (3.45), humidity comfort (3.31), odour control (3.27) and finally overall ventilation (3.18). This progression is important because it shows that occupants' dissatisfaction is not concentrated around a single environmental variable. Instead, it appears to emerge from the combined performance of air movement, thermal conditions, moisture control and odour management.

Overall, the findings suggest that the selected orthopaedic wards provide a generally acceptable but improvable ventilation environment. Air freshness and thermal conditions represent the relatively stronger aspects of performance, whereas overall ventilation, odour management and humidity control require greater attention. The results reinforce the need for ventilation strategies that do not rely solely on individual openings or intermittent air movement but integrate natural ventilation, appropriate building orientation, solar protection, moisture control, occupancy management and, where necessary, mechanical assistance.

Table 6: Weighted Evaluation of Occupants' Satisfaction with Ventilation Conditions in the Selected Orthopaedic Wards (n = 274)

S/N	Satisfaction Variable	Very Satisfied (5)	Satisfied (4)	Indifferent (3)	Dissatisfied (2)	Very Dissatisfied (1)	TWV	MWV	SI	Rank	Interpretation
1	Freshness of air within the ward	58	101	63	37	15	972	3.55	0.55	1st	Satisfied
2	Comfort of indoor temperature	51	94	71	42	16	944	3.45	0.45	2nd	Satisfied
3	Comfort regarding humidity levels	42	88	76	48	20	906	3.31	0.31	3rd	Slightly Satisfied
4	Effectiveness of odour control	38	86	81	50	19	896	3.27	0.27	4th	Slightly Satisfied
5	Overall ventilation performance	33	79	87	55	20	872	3.18	0.18	5th	Slightly Satisfied
	Overall Mean Satisfaction							3.35	0.35		Satisfied

Scale: Very Satisfied = 5; Satisfied = 4; Indifferent = 3; Dissatisfied = 2; Very Dissatisfied = 1.

(iv) Assessment of Architectural Measures for Enhancing Ventilation Performance in Orthopaedic Hospitals

The assessment of architectural measures for improving ventilation within the selected orthopaedic hospitals examined both the views of healthcare workers and the

experiences of patients. The aim was to identify building-related characteristics, spatial conditions and design interventions that could contribute to improved air movement, thermal comfort, indoor environmental quality and user wellbeing. The assessment therefore considered two complementary dimensions: the professional evaluation of existing architectural conditions by healthcare workers and the environmental preferences expressed by patients who occupy the wards for extended periods.

The responses of healthcare workers in Table 7 indicate that the overall indoor environmental condition was viewed positively, although the level of satisfaction remained moderate. The calculated overall MWV of approximately 3.34 indicates that patients were generally satisfied, but the relatively small margin above the neutral value of 3.00 suggests that the existing environment does not represent a highly satisfactory condition. This distinction is important because a generally positive satisfaction score should not be interpreted as evidence that the environmental conditions are optimal.

The highest-rated patient satisfaction variable was availability of fresh air, which recorded an MWV of 3.55. This indicates that access to fresh air was the strongest aspect of the indoor environmental conditions evaluated. Thermal comfort followed with an MWV of 3.45, while adequacy of natural lighting recorded an MWV of 3.44 after recalculation from the supplied response frequencies. These results suggest that patients tend to respond more positively to environmental characteristics that directly affect their immediate sensory experience, particularly air freshness, temperature and natural illumination.

Other variables recorded lower levels of satisfaction. Humidity control produced an MWV of 3.31, while odour control recorded 3.27. These results indicate that moisture and unpleasant smells remain areas where patients experience comparatively less favourable conditions. The finding is consistent with the earlier assessment, where humidity, unpleasant odours and inadequate environmental control were identified as recurring concerns within the wards. Cleanliness and maintenance recorded an MWV of 3.24, while adequacy of space between patient beds produced the lowest value of 3.11. The latter finding is particularly significant because limited spacing between beds can simultaneously affect privacy, movement, occupancy density and airflow.

The patients' preferred improvements provide further insight into the architectural and operational interventions that may have the greatest perceived value. The supplied frequencies indicate that increasing the number of windows for natural ventilation was the most frequently selected intervention, with 91 respondents (33.2%). This was followed by reducing the number of patients per room, selected by 73 respondents (26.6%), and improving cleaning practices, selected by 52 respondents (19.0%). The provision of ceiling fans was selected by 38 respondents (13.9%), while air conditioning was selected by 20 respondents (7.3%).

The preference for additional windows and reduced occupancy is particularly noteworthy because it corresponds closely with the healthcare workers' assessment. Both groups therefore identify natural ventilation and occupancy control as important aspects of improving the ward environment. The relatively lower preference for air conditioning also suggests that patients do not necessarily perceive mechanical

cooling as the primary solution to ventilation problems. Instead, improvements to the building itself, particularly through better openings and spatial planning, may provide more direct and sustainable responses.

Taken together, the two user groups provide a complementary assessment of ventilation-related architectural requirements. Healthcare workers draw attention to building materials, window configuration, ward planning, ventilation systems, maintenance and occupancy, while patients emphasise fresh air, thermal conditions, humidity, odour, cleanliness, bed spacing and additional ventilation openings. The overlap between these perspectives strengthens the argument that ventilation improvement requires an integrated approach involving architectural design, environmental control, occupancy management and facility maintenance. Future orthopaedic hospitals should therefore incorporate ventilation considerations into site orientation, building form, opening design, ward planning, material selection and environmental management rather than treating ventilation as an isolated building-service issue.

Table 7: Healthcare Workers' Assessment of Existing Ventilation Design and Preferred Improvement Measures in Orthopaedic Wards (n = 54)

S/N	Architectural/Environmental Assessment	Yes	No	Not Sure	Total
1	Building materials and interior finishes may contribute to unpleasant smells or irritation within the wards	37 (68.5%)	10 (18.5%)	7 (13.0%)	54 (100%)
2	Existing window positions facilitate effective cross-ventilation within the wards	34 (63.0%)	14 (25.9%)	6 (11.1%)	54 (100%)
3	Existing ward layouts provide adequate pathways for fresh-air movement	31 (57.4%)	17 (31.5%)	6 (11.1%)	54 (100%)
4	Natural ventilation provisions should be strengthened in orthopaedic hospitals	50 (92.6%)	4 (7.4%)	–	54 (100%)
5	Ventilation principles should be incorporated into future hospital design	53 (98.1%)	1 (1.9%)	–	54 (100%)

Source: Author's Field Survey (2026)

The results in Table 8 demonstrate a clear professional preference for incorporating ventilation into the architectural design process. The particularly high agreement of 98.1% on integrating ventilation principles into future hospital designs provides strong evidence that ventilation is regarded by healthcare workers as a fundamental architectural consideration rather than merely a mechanical-services issue. Similarly, the 92.6% support for strengthening natural ventilation indicates that passive environmental strategies remain highly relevant to future orthopaedic hospital development.

The existing conditions, however, appear less satisfactory. While 63.0% of respondents considered the current window arrangements effective for cross-ventilation, the 25.9% who disagreed indicate that a substantial minority experience limitation in the existing opening configuration. The situation is even more pronounced for ward layout, where only 57.4% gave a positive assessment and 31.5% disagreed. This suggests that internal spatial organisation may represent a more significant architectural limitation than the mere availability of windows.

The preferred interventions reinforce these observations. The dominance of better ventilation systems (40.7%) indicates that healthcare workers consider improvement of the actual air-exchange mechanism to be the most immediate requirement. Reduced overcrowding (24.1%) ranks second, demonstrating that respondents recognise the relationship between occupancy density and ventilation effectiveness. Maintenance, material selection and orientation receive lower but still meaningful levels of preference, showing that these factors should complement rather than replace improvements to the ventilation system.

Table 8: Patients' Satisfaction with Indoor Environmental Conditions and Preferred Ventilation Improvements in Orthopaedic Wards (n = 274)

S/N	Indoor Environmental Variable	VDS (1)	DS (2)	Neutral (3)	Satisfied (4)	VS (5)	TWV	MWV	SI	Rank	Satisfaction Level
1	Availability of fresh air within the ward	15	37	63	101	58	972	3.55	0.55	1st	Satisfied
2	Thermal comfort within the ward	16	42	71	94	51	944	3.45	0.45	2nd	Satisfied
3	Control of indoor humidity	20	48	76	88	42	906	3.31	0.31	3rd	Satisfied
4	Control of unpleasant odours	19	50	81	86	38	896	3.27	0.27	4th	Satisfied
5	Cleanliness and maintenance of ward environment	22	55	74	82	41	887	3.24	0.24	5th	Satisfied
6	Adequacy of space between patient beds	26	61	79	72	36	853	3.11	0.11	7th	Satisfied
7	Overall indoor environmental quality	18	43	72	97	43	923	3.37	0.37	6th	Satisfied

Interpretation: SI > 1.00 = Very Satisfied; SI = 0.01–1.00 = Satisfied; SI = 0.00 = Indifferent; SI = −0.01 to −1.00 = Not Satisfied; SI < −1.00 = Not Satisfied at All.

Source:Author's Field Survey (2026)

The patient responses indicate that fresh-air availability is the strongest aspect of the ward environment, with an MWV of 3.55 and an SI of 0.55. The positive SI indicates that satisfaction is above the neutral benchmark, although it does not imply an exceptionally high level of satisfaction. Thermal comfort (MWV = 3.45; SI = 0.45) and natural lighting (MWV = 3.44; SI = 0.44) also received relatively favourable assessments. These results indicate that environmental characteristics associated with air movement, temperature and daylight generally meet patients' basic expectations.

The lower MWVs associated with humidity (3.31), odour control (3.27), cleanliness and maintenance (3.24) and particularly bed spacing (3.11) reveal where environmental improvements may have the greatest benefit. The low score for bed spacing is important because spatial separation between beds has implications beyond privacy. Closely positioned beds can restrict air movement, increase perceived crowding and reduce the effectiveness of natural ventilation. Thus, the patient's satisfaction assessment provides additional evidence that spatial planning and ventilation performance are closely connected.

V. CONCLUSION

The study examined the ventilation conditions within selected orthopaedic sections of teaching hospitals in South-West Nigeria, with particular attention to climatic conditions, existing ventilation performance, factors influencing indoor environmental quality, occupants' satisfaction, and architectural strategies for improving ventilation. The findings demonstrate that ventilation performance within the selected hospitals is influenced by the interaction of climatic, architectural, spatial, operational and occupancy-related conditions. Although the hospitals generally provide an acceptable level of indoor environmental quality, the findings indicate that their performance remains moderate and requires substantial improvement to achieve more consistent and healthier conditions for both patients and healthcare workers.

The assessment of occupants' satisfaction produced a generally positive but moderate outcome. Air freshness recorded the highest satisfaction level, followed by temperature comfort, while humidity comfort, odour control and overall ventilation received comparatively lower ratings. The overall satisfaction MWV of 3.35 indicates that occupants were satisfied with the existing conditions; however, the relatively small margin above the neutral benchmark of 3.00 suggests that this satisfaction should be interpreted as acceptable rather than optimal. In other words, the existing environmental conditions are functioning at a tolerable level, but they do not provide sufficient evidence of a highly comfortable or consistently well-controlled hospital environment.

Overall, the study concludes that improving ventilation in orthopaedic hospitals in South-West Nigeria requires a combination of passive architectural strategies, appropriate mechanical support, effective spatial planning and continuous facility management. The proposed orthopaedic hospital design for Oduduwa University, Ipetumodu provides an architectural response to these findings by incorporating natural ventilation, appropriate orientation, controlled openings, adequate ward spacing, climatic protection, suitable materials and improved environmental management. Such an integrated approach has the potential to create hospital

environments that are more comfortable, healthier, resilient to the hot-humid climate and better suited to the needs of patients and healthcare professionals.

Recommendations

Based on the findings and conclusion of the study, the following recommendations are proposed:

1. Improve Natural Ventilation

Existing orthopaedic wards should be assessed and upgraded to improve natural airflow. Windows should be appropriately positioned, sized and oriented to facilitate cross-ventilation, while obstructed openings should be identified and corrected where possible. Future hospital designs should incorporate clearly defined airflow paths between inlet and outlet openings.

2. Integrate Ventilation into the Initial Design Process

Ventilation should be considered from the earliest stages of hospital planning rather than treated as an issue to be resolved after construction. Architects should integrate building orientation, window placement, ward configuration, circulation patterns, courtyards and ventilation zones into the overall design strategy.

3. Reduce Overcrowding in Orthopaedic Wards

Hospital administrators should ensure that the number of patients accommodated within each ward corresponds with the intended design capacity. Adequate spacing between beds should be maintained, while circulation areas should remain sufficiently open to avoid obstructing air movement. Where possible, ward sizes and bed arrangements should be reviewed during renovation.

4. Improve Ward Spatial Configuration

Ward layouts should be organised to encourage unobstructed movement of air. Patient beds, partitions, medical equipment and storage elements should be positioned without unnecessarily blocking windows or major airflow pathways. Clinical and support spaces should also be appropriately zoned to minimise interference with ventilation.

5. Provide Appropriate Mechanical Ventilation Where Necessary

Natural ventilation should remain an important strategy within the hot-humid context; however, mechanical or hybrid ventilation should be introduced where natural ventilation cannot consistently provide adequate environmental conditions. Such systems should be appropriately designed for healthcare applications and regularly maintained.

6. Adopt Low-Emission Building Materials

Low-VOC and low-emission materials should be prioritised for walls, ceilings, floors, furniture, finishes and other interior components. Materials should also be selected based on durability, ease of cleaning and resistance to moisture, since inappropriate materials may contribute to odour, pollutant accumulation and deterioration of indoor environmental quality.

7. Strengthen Moisture and Humidity Control

Because high relative humidity was identified across the study locations, hospitals should incorporate measures for moisture control. These should include adequate air movement, appropriate building envelope detailing, prevention of water leakage, proper drainage and regular inspection of areas susceptible to dampness.

8. Improve Cleaning and Maintenance Practices

Routine maintenance should be strengthened to ensure that windows, ventilation openings, fans, mechanical systems, ceilings, walls and other environmental components remain functional and clean. Cleaning schedules should also address dust accumulation, waste storage and potential sources of unpleasant odours within the wards.

9. Incorporate Climate-Responsive Design Strategies

Future orthopaedic hospitals should respond directly to the hot-humid climate of South-West Nigeria through appropriate orientation, external shading, roof design, vegetation, protected openings and other passive design measures. These strategies should reduce solar heat gain while maintaining opportunities for natural airflow.

10. Establish Indoor Environmental Monitoring Programmes

Hospital management should periodically monitor important environmental parameters such as temperature, relative humidity, carbon dioxide concentration, particulate matter and other relevant indicators of indoor environmental quality. The results should be used to identify ventilation deficiencies and guide maintenance or renovation decisions.

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