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EMPIRICAL INVESTIGATION OF INDOOR ENVIRONMENTAL QUALITY (IEQ) PERFORMANCE IN HOSPITAL BUILDINGS IN NIGERIA

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Graphical abstract

Abstract

This study investigates and summarises the results of physical measurement of the indoor environmental quality (IEQ) in hospital building wards in Plateau State, Nigeria comparing two hospital settings. The results indicate that the mean indoor air temperature in the case study hospital ward buildings exceeded the range of 23-26°C as recommended by international standards. The temperature levels in the teaching hospital ward buildings were relatively lower than what was obtained in the specialist hospital whose ward buildings lack proper ventilation. The amount of daylight requirement on an average were below 300Lux in the specialist hospital whose façade orientation and window-wall-ratio (WWR) could not allow for maximum sunlight penetration, while it was above 300Lux in the teaching hospital. However, the sound intensity level in both hospital ward buildings ranged between 52.7dBA and 71.3dBA. This study therefore recommend that, hospital building design or retrofitting should employed common strategies towards increasing ventilation and daylight with minimal energy consumption.

Keywords: Indoor, environmental quality, measurement, parameters, hospital buildings.

1.0 INTRODUCTION

Indoor environmental quality (IEQ) evaluation as one of the aspects of green building rating criteria focuses not only on achieving a safe healthy environment for the occupants but also an environment that promotes health and productivity. The significance of sustaining better IEQ in a hospital building should therefore be a concern for both planners and managers of the built environment. The need to protect people from the adverse effect of the environment had been an issue of consideration even by nurses in the early days of their profession. In the practice of nursing, a healthy environment has also been noted as having great impacts on the health of people. An environment that contributes to healing does not only adds to patient's wellbeing, but also to the wellbeing of the medical and supporting staff of the hospital.

A hospital building which is rated as a high performance building in terms of its indoor environmental quality would attracts, retains, and enhanced patient healing process and workers efficiency [1]. Ramaswamy et al. [2] describe a hospital as a diagnostic human treatment environment where activities such as health education, training and research could be undertaken. The need therefore to pay particular attention to the environmental quality of a hospital facility cannot be overlooked. The concern towards IEQ importance should be a major factor of consideration in government policy agenda. The empirical monitoring of IEQ in hospital buildings is to highlight its importance in order to draw the attention of the design professionals and policy makers towards green buildings initiatives.

The campaign for healthy and comfortable work environment in buildings has not yet taken root in the aspect of healthcare facilities. Researchers are however, beginning to understand the need to centre on sustainable occupant environment as a measure of attaining sustainable development [3]. Hospital services and facilities quality and performance can be enhanced where continuous performance evaluation of the hospital environment is carried out in order to solve apparent problems.

Standards and guidelines concerning indoor environment are based on individual IEQ parameters [4]. These parameters have been remarkably seen to have combined effects on occupants' satisfaction and efficiency [5]. A study which evaluated the IEQ and its implication on medical activity in an Iranian hospital [6] shows that, either standards are not followed in the design of hospital buildings or the standards do not meet the requirements of the occupants. The interaction among this IEQ parameters is emphasize in ASHRAE guideline 10P [7] and recommended that more detail research is carried out to determine the level of this interaction.

The performance indicators used today in assessing the indoor environment of buildings is far from applicable due to incomplete or wrong information applied [8]. These indicators do not reflect in totality what constitute the indoor environment of a building. There is a need to have a standard measures for the overall indoor environmental quality of hospital buildings as preclude to the negative impact of the environment. In developing an IEQ assessment procedure, [9] categorized the healthcare facility into different zones with respect to IEQ parameters importance. This categorization resulted into the identification of thermal comfort, acoustic comfort, visual comfort, and indoor air quality (IAQ) as the major parameters that determine IEQ in buildings. Alzoubi et al. [10], on the other hand stated that, the parameters that constitute the IEQ of a building includes; thermal comfort, acoustic, lighting, electromagnetic frequency levels, portable water surveillance, and indoor air quality (IAQ), which comprises of airborne pollutants, as well as other health, safety and interior design issues such as aesthetic [10]. The assessment of IEQ based on its different parameters can be burdensome. According to Parson [11], a single index value known as Environmental Index can be used as an indicator of optimum IEQ. This index value defines the relationship between the stress exerted by the physical indoor environment parameters on occupants and the resulting strain develop by the occupant.

The healthcare setting in Nigeria is categorized into three namely: the primary, secondary and tertiary healthcare facility. The primary healthcare facility referred to as the 'General Hospital' provides the basic clinical services to the local communities. The general hospital render services considered to be known as general medicine. It has departments which includes; maternity, dental care unit, laboratory inpatient and outpatient units, and X-ray department [12]. The secondary healthcare facility apart from providing the general medical services also provides specialised medical care especially on health challenges that cannot be provided for by the general hospital. The tertiary healthcare facility mostly refer to as the teaching hospital has a setting that serves as both a professional training institution for medical personnel and provision of medical services. However, this study investigate the IEQ performance in the secondary and tertiary healthcare facility only. The Plateau Specialist Hospital was selected as the secondary healthcare facility while the Jos University Teaching Hospital was selected as the tertiary healthcare facility. The main goal is to understand the nature of the IEQ performance towards promoting the design and construction of environmentally friendly healthcare facilities. The measured variables will be compared to international guidelines and standards.

2.0 METHODS

The field measurement were obtained in three different months in each of the case study hospitals under consideration. The three different monthly data were collected in order to capture the likely changes in IEQ parameters within the period of April to June 2014. This is the period within which the case study area experience a seasonal change from the dry harmattan to rainy season. This investigation conducted across a period of three months was to ensure that the conditions are representative of the changes in environmental conditions within the period. The evaluation of the IEQ in the hospital buildings is based on an assessment method of the physical environment developed by international standard organization [13]. This method provides the evaluation of comfort and wellbeing of occupants in an environment using both physical measures of the environment and subjective measure of the occupants. The data were collected between the hours of 11am and 1pm as conditions to which people are exposed to within the building can be affected by changes in external weather condition with time.

The physical measurement of IEQ parameter variables was conducted intermittently within the hospital wards. The measuring instrument was set to measure the variables continuously for a period of 2 hours at 5 minutes intervals. The physical measurement is conducted at central location in between patients' bed in the hospital wards. The IEQ variables were measured using the IEQ mobile measurement station as shown in Figure 1. The variables were measured at a height of 1m above the floor level with the IEQ mobile measurement station positioned in the centre of the ward in between patients' bed spaces. The instruments that made up the IEQ mobile measurement station is described in Table 1.

This study investigates the IEQ performance in ward buildings of a secondary and tertiary healthcare facilities in Nigeria. The secondary case study healthcare facility is represented by Plateau Specialist Hospital and the Jos University Teaching hospital represents the tertiary healthcare facility as categorized according to the Nigeria's healthcare system. The case study hospitals were selected based on the structure of healthcare system delivery in Nigeria. The two case study hospitals are both located in Jos the Plateau State capital, which is also the geographical centre of Nigeria located on latitude 9°56' N and longitude 8°53'E.

Jos is located on a highland Plateau at 4216ft (1287m) above sea level [14]. Jos has a climate condition which is more temperate than all other parts of Nigeria having a mean temperature range of 21-25°C. This temperature minimum range can drop to as low as 11°C especially at night from November to January. The mean annual rainfall experienced in Jos is 1324mm, which is often refer to as a tropical savannah climate [15]. Plateau Specialist Hospital is an accredited healthcare institution for residency in family medicine and internship training. It has a bed-space capacity of about 200 for inpatients medical services and outpatients services (Figure 2). Jos University Teaching Hospital on the other hand, has a total bed-space capacity of 620 for inpatients and offers specialized services in different areas of healthcare, training and research. The ward buildings are located on a two-storey building complex whose construction was completed and occupied in 2007 (Figure 3). The ward buildings are both naturally and mechanically ventilated with ceiling fan, and also, with split-level air-conditioning system which is most often not in use.

Figure 1 IEQ Mobile Measurement Station Data Logger

Figure 2 View of Plateau Specialist Hospital

Figure 3 View of Jos University Teaching Hospital

3.0 RESULTS AND DISCUSSION

3.1 Evaluation of Thermal Comfort Quality

The thermal comfort in the selected hospital buildings is measured by indoor temperature and relative humidity. A hospital environment is seen as being traumatic where excessive temperature could have great impact on the building occupants [16]. Temperature is a major determinant of thermal comfort which also has relative humidity as its function. The two variables considered for thermal comfort, temperature and relative humidity within the indoor spaces of the hospital ward buildings were measured consecutively within a period of three months.

The mean monthly temperature and relative humidity measured in the specialist hospital is presented in Figure 4. The recorded mean temperature within the period of measurement ranged from 29.9°C to 35.25°C. There was a relatively linear reduction in mean indoor temperature from April to May. A maximum temperature range of 33.2°C to 36.2°C was recorded in April while a minimum temperature range of 29.0°C to 31.9°C was recorded in June as presented in Figure 6. The variation in temperature increased with time in April while decreasing in May and June. The minimum temperature (30.80⁰C) was recorded in June at about 12.30 hours while the maximum temperature (36.20⁰C) was recorded at about 1.00pm in April (Figure 6). The relative humidity recorded showed an inverse variation to temperature within the period of measurement in this hospital buildings. The mean relative humidity recorded in April at 56.45% increased to 63.08% in June as a result of the significant effect of annual rainfall on the indoor air temperature.

The variation trend of temperature is the same in the teaching hospital as it was in the specialist hospital, as there was also a temperature decrease recorded for May and June. The mean temperature and relative humidity recorded during the monitoring periods is shown in Figure 5. The mean temperature range recorded in each of the ward buildings is between 29.30°C recorded in May and 32.90°C recorded in April. The mean temperature in May and June which are almost invariable, are relatively lower than the mean temperature recorded in April. The mean relative humidity level ranged between56.85% and 65.75% (Figure 5) as recorded in the ward buildings.

Table 1 Description of the IEQ mobile measurement station instruments

Variable	Instrument Model	Resolution	Range	Accuracy
Air Temperature	DrDAQ (USB) CO122/133	0.1°C @25°C	0°C - 70°C	±0.3°C
Relative Humidity	REED SD – 9901	0.10%	5 – 95%	±3%
Light Intensity	DrDAQ (USB) CO122/133	0.1	0 – 100	Manually Calibrated
Sound Level	DrDAQ (USB) CO122/133	1dBA	55 – 100dBA	±5dBA
Carbon dioxide (CO_2)	REED SD – 9901	1ppm	0 – 4000ppm	±5%(>1000ppm)
Carbon monoxide (CO)	REED SD – 9901	1ppm	1 – 1000ppm	± (5% + 2ppm)

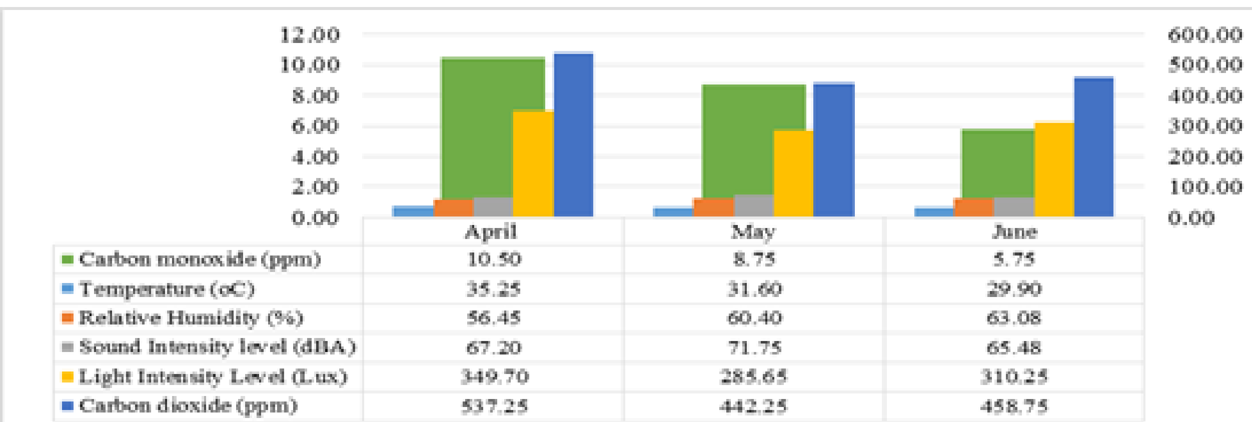
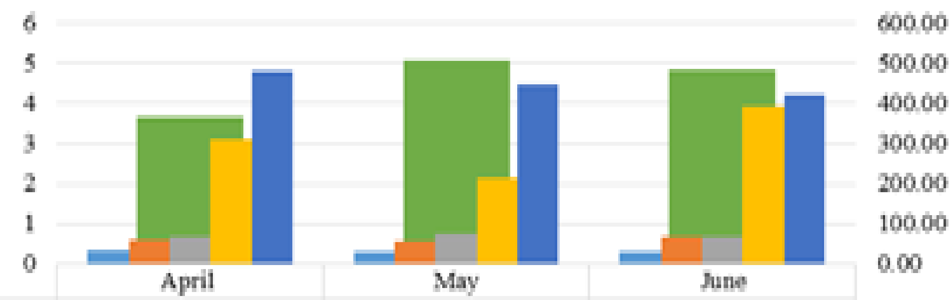


Figure 4 Mean values of measured indoor variables in specialist hospital



	April	May	June
Carbon monoxide (ppm)	3.67	5.09	4.84
Temperature (oC)	32.90	29.03	29.25
Relative Humidity (%)	60.78	56.85	65.75
Sound Intensity level (dBA)	67.98	75.73	67.15
Light Intensity Level (Lux)	311.05	215.15	392.95
Carbon dioxide (ppm)	479.52	448.1	420.32

Figure 5 Mean values of measured indoor variables in teaching hospital

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3.2 Thermal comfort Variations by Hospital

The thermal comfort variables temperature and relative humidity were recorded by the IEQ mobile measurement station data logger in selected ward buildings of the two case study hospitals as shown in Figure 1. There are variations in the thermal comfort quality as measured in the two hospitals at different periods. The variations in indoor air temperature and relative humidity in the hospitals are shown in Figure 6. Temperature recorded was lowest (26.20°C) in the teaching hospital. The indoor temperature of all the two hospitals changed with period of monitoring. The variations in the monthly temperatures in the two hospital buildings can said to be having the same trend as shown in Figure 6. In April, the mean indoor temperature as measured in the hospital ward buildings ranged between 33.20°C and 36.20°C in the specialist hospital, while the mean temperature ranged between 32.00°C and 35.40°C in the teaching hospital. The same trend is evident in measurement for May and June for both hospitals, however, there was a drop in temperature of between 1.50°C and 4.50°C in May and June. The variation trend of temperature in both hospitals tend to reduce between the hours of 12.00 noon and 1.00pm in May and June. As much as the teaching hospital has the minimum temperature range recorded within the periods of measurement, the fluctuations in the temperature within specific time of the day is highest. The mean relative humidity recorded lowest and highest values both in the teaching hospital in the month of June (Figure 6 and Table 2). Relative humidity tends to increase from April to June as measured in both the specialist hospital and teaching hospital. On an average, lower relative humidity was recorded at 12.00 noon in each monitoring day of the hospitals.

3.3 Evaluation of Acoustic Comfort Quality

The mean sound intensity levels in the specialist hospital is highest in May and lowest in June. The mean sound intensity level was between the range of 65.48dBA and 71.75dBA. The mean difference in sound intensity level between May and June is higher than the mean difference between April and May. The mean sound intensity levels in the specialist hospital is presented in Figure 4. The variations in sound intensity levels tend to reduce in May and June while increasing in April from 12.00 noon to 1.00pm as shown in Figure 7. The highest sound intensity level of about 78.2dBA was recorded at 12.00 noon in May and the minimum of 56.90dBA was recorded at 12.30pm in June. The variation in sound intensity level within the period of monitoring was affected mainly by the noise level resulting from the number pf visitors found within the ward buildings.

The mean difference in sound intensity level measure within the teaching hospital as shown in Figure 5 is 8.58dBA. Just like the specialist hospital, the highest sound intensity level was recorded in May and the lowest in June. The sound intensity level as measured within two hours were higher in May but lower in June. The highest sound level was recorded at 11.30am (83.80dBA) in May while the lowest was recorded at 12.30pm in June. There was no particular trend in the monthly variations of sound intensity level, as the sound level increased and decreased alternately in April but, reversed is the case in May. However in June, the sound intensity level decreased from 72.50dBA at 11.30am to 59.90dBA at 12.30pm. But there was an increased to 70.00dBA at 1.00pm.

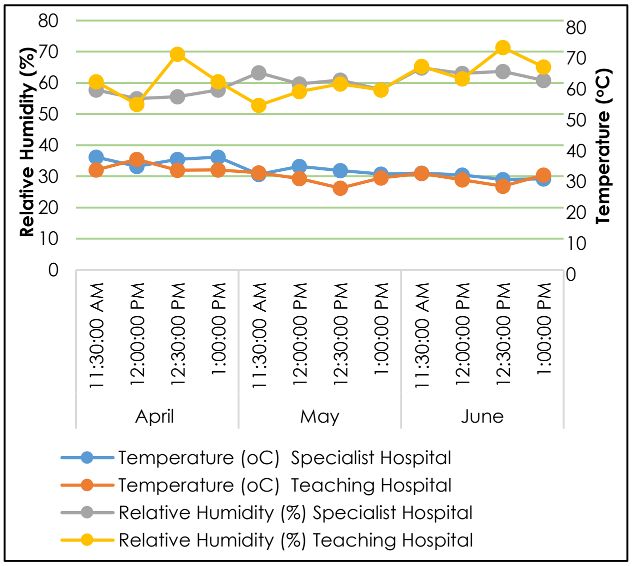

Figure 6 Periodic mean monthly temperature and relative humidity variations

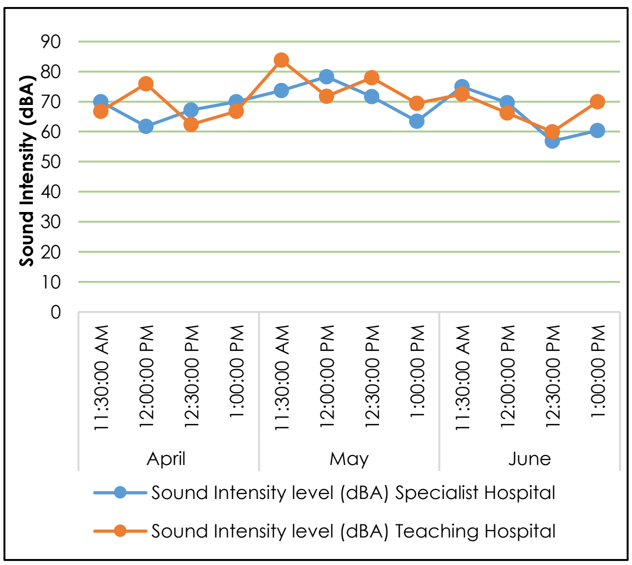

Figure 7 Periodic Mean Monthly Sound Intensity Level variations

3.4 Acoustic Comfort Variations by Hospital

Figure 7 shows the monthly variations in sound intensity levels in the two case study hospitals. The level of variations of sound intensity with time almost took the same pattern. The mean differences in sound intensity levels recorded ranged between 8.1dBA and 18.6dBA in the specialist hospital, and 12.6dBA and 14.4dBA in the teaching hospital. The highest sound intensity level (83.80dBA) was recorded in the teaching hospital at 11.30am in May. The location of the specialist hospital ward buildings are adjacent to a major road within the city centre while the locations of the teaching hospital is away from vehicular disturbances.

3.5 Evaluation of Visual Comfort Quality

The mean illuminance level recorded in the specialist hospital fell below 300Lux as the minimum recommended for working planes task performance. The mean difference in illuminance level between different periods of measurement ranged between 21.4Lux and 70.5Lux. Figure 4 shows the mean illuminance levels recorded in the specialist hospital. The variation in light intensity level with time showed an increased in April but a decrease in both May and June from 11.30am to 12.00 noon. Reverse is the case as from 12.00 noon to 12.30pm (Figure 8). Higher illuminance level was recorded in May between the hours of 12.30pm and 1.00pm.

In the teaching hospital, the mean illuminance levels recorded lower in April which was less than 300Lux. The mean illuminance levels in May and June are near equal in intensity and fall within the acceptable range of 300-500Lux [17], [18]. There was a mean difference in intensity level of about 101Lux between both May and June, and April. Figure 5 shows the mean intensity level recorded for each measurement period. As also shown in Figure 8, the periodic increased and decreased in illuminance level pattern in the teaching hospital is almost similar to that in the Specialist hospital, however, the change is higher in April than in May and June.

3.6 Visual Comfort Variations by Hospital

The monthly variations in light intensity levels in the studied hospital buildings is shown in Figure 8. The illuminance levels recorded highest in May and June, in the teaching hospital. Generally, the visual quality in the specialist hospital is poorer as compared with what was obtainable in the teaching hospital. The North-East and South-West window facing orientation of the teaching hospital allowed for optimum daylight penetration into the ward buildings. The orientation of the Specialist hospital followed the North-West and South-East direction. Daylight penetration is only through one façade of the ward buildings in the specialist hospital where the light intensity level is influence by Sun path position. However, the least light intensity level (222.4Lux) was recorded in the teaching hospital in the month of April which could have resulted from the effect of cloud cover at the time of measurement.

3.7 Evaluation of Indoor Air Quality (IAQ)

The mean concentration level of CO_2 in the Specialist hospital is higher in April as compared to the concentration levels in May and June. On the other hand, the CO concentration level is higher in June. (Figure 4). The CO_2 concentration level which fall within acceptable limits ranged between 446.00ppm and 608.00ppm in April, between 399ppm and 442ppm in May, and between 393ppm and 455ppm in June (Figure 9). Likewise, the CO concentration level ranged from 4 – 9ppm in April, from 4 – 8ppm in May and from 3 – 14ppm in June. The CO concentration level for June as shown in Figure A4-6 indicated that only the recorded value at 12.30pm fall within the acceptable limit that promotes occupants health and comfort.

The results of the measured CO_2 and CO concentration levels in the teaching hospital is shown in Figure 5. There was a small variation in the mean concentration levels of both CO_2 and CO in the teaching hospital, having a maximum mean difference of 30.25ppm and 2.25ppm respectively. The concentration level of CO_2 ranged between 413ppmm and 481.00ppm in April, 417.ooppm and 485.0ppm in May, and 400.0ppm and 451.0ppm in June. There was quite a stability in the concentration levels of CO_2 which were lower than the maximum acceptable range. CO level ranged from 2 – 5ppm, 3 – 10ppm, and 3 – 6ppm in April, May and June respectively as shown in Figure 9. The highest CO concentration level of 10ppm was recorded at 11.30am in May while the lowest concentration level of 2ppm was recorded between 12.00 noon and 12.30pm in April.

Table 2 Mean temperature, relative humidity and sound intensity level in the hospital buildings

		Temperature (°C)			Relative Humidity (%)			Sound intensity (dBA)		
Case Study Area	Statistics	April	May	June	April	May	June	April	May	June
Specialist Hospital	Mean	35.25	31.6	29.9	56.45	60.4	63.08	67.2	71.75	65.48
	SD	1.42	1.22	0.96	1.46	2.26	1.69	3.82	6.15	8.31
Teaching Hospital	Mean	32.9	29.03	29.25	60.78	56.85	65.75	67.98	75.73	67.15
	SD	1.67	2.05	1.84	6.59	2.91	4.13	5.68	6.46	5.48

Table 3 Mean light intensity, carbon dioxide, and carbon monoxide concentration in the hospital buildings

		Light intensity (Lux)			CO_2 (ppm)			CO (ppm)		
Case Study Area	Statistics	April	May	June	April	May	June	April	May	June
Specialist Hospital	Mean	236.6	285.7	215.6	523.5	419.3	430	6.5	5.25	10.25
	SD	73	68.87	41.56	66.87	20.16	26.7	2.38	1.89	5.19
Teaching Hospital	Mean	292.3	399.2	393.4	453.3	443	423	3	5.25	4.25
	SD	66.32	37.54	23.74	28.92	29.66	21.12	1.41	3.2	1.26

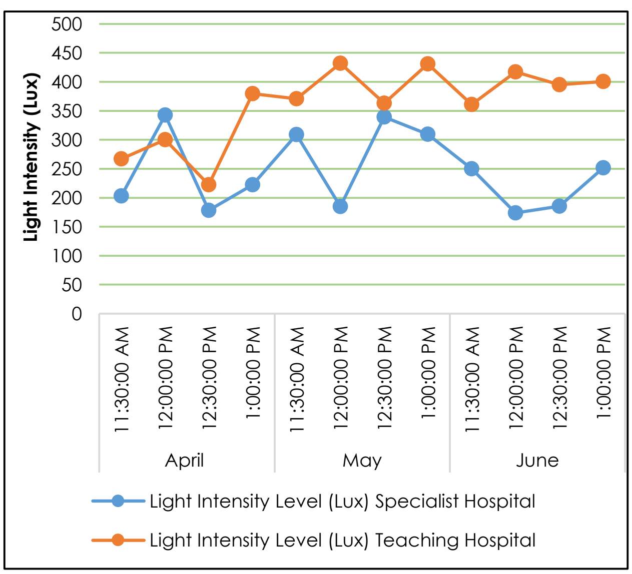

Figure 8 Periodic Mean Monthly Light Intensity Level variations.

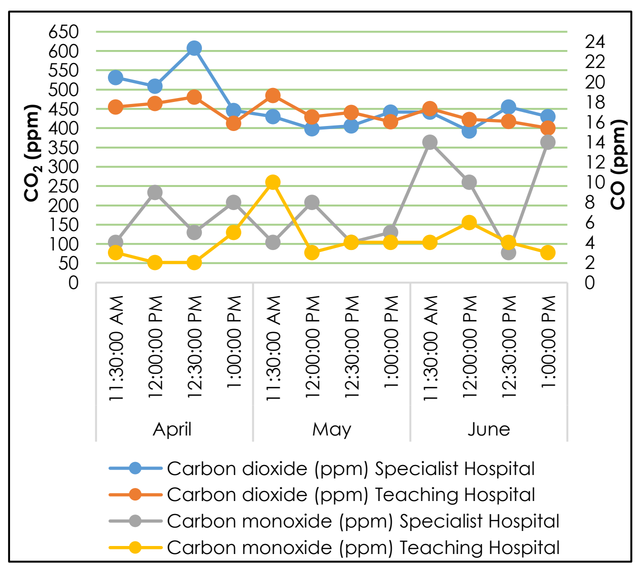

Figure 9 Periodic Mean Monthly Carbon Dioxide and Carbon Monoxide Concentration Level variations.

3.8 IAQ variations by hospitals

The IAQ of a building depends to a large extend on relative humidity [19], therefore, a building whose level of relative humidity is acceptable is appropriate for creating a good indoor environment for occupants' comfort. Figure 9 shows the variations in IAQ in the hospital buildings. There was no much variation in CO_2 concentration levels in the hospital buildings within the measurement periods. The CO2 concentration levels in the specialist hospital ranged between 393ppm and 608ppm, and in the teaching hospital between

400ppm and 485ppm. In April, the mean CO_2 concentration level was 523.5ppm, and 453.25ppm for the specialist and teaching hospitals respectively. The highest level of concentration of CO_2 (608ppm) was recorded in April in the specialist hospital and the lowest concentration level (393ppm) was also recorded in the specialist hospital but in June as seen in Figure 9. On a general note, the mean concentration levels of CO_2 in both case study hospitals fall below the maximum recommended limit [4], [20] within the periods of measurement. The IAQ in the teaching hospital is better compared to the Specialist hospital because of its design and age which are contributing factors to the concentration levels of air pollutants. The maximum recorded CO concentration level for the specialist hospital is 14ppm and 10ppm in the teaching hospital which are greater than 9ppm as the acceptable limit [21]. All the maximum recorded CO concentration levels are greater than the acceptable limit. The minimum CO concentration level was recorded in the teaching hospital. There was generally higher concentration of CO level in June than in April as recorded in both case study hospitals. This could be related to increase in humidity as a result of increased amount of rainfall. The IAQ can said to be much better in the teaching hospital whose design and configuration allowed for free flow of natural air in and out of the hospital wards. The design of the specialist hospital provided no cross ventilation within the ward buildings which could have been the result of the higher level of CO concentration recorded.

4.0 SUMMARY

The thermal comfort of any building occupant depends more on temperature as the most important indoor environmental variable. Table 2 shows the statistics of temperature and relative humidity recorded in the hospital buildings. Throughout the period of indoor environmental variables monitoring, temperatures were lower in the teaching hospital. The temperatures and relative humidity levels recorded in the hospitals are not uncommon for naturally ventilated buildings located in the tropical regions of the world. The design of windows in the teaching hospital allows for proper cross ventilation and air circulation while the specialist hospital building design lacks cross ventilation. Based on the design guidelines and standards, the temperatures recorded for the three case study hospitals exceeded the recommended range of 23-26^{o}C [4], [18], however, a temperature range of between 27^{o}C and 37^{o}C can provide for occupants' comfort in a building based on human physiological adaptive mechanism [22].

The mean relative humidity level for April in both hospitals is lower, as April always mark the end of dry season. According to Environmental Protection Agency [21], high humidity level in buildings stimulates the breeding of micro-organisms which have adverse effect on building occupants especially in healthcare facilities. The indoor relative humidity levels in both hospital buildings fall outside the acceptable range of 30 – 50% as recommended by the EPA. However based on [23] which recommended that relative humidity should not be greater than 65%, the mean relative humidity can said to be within acceptable range.

The Variations in sound intensity level in the two hospitals almost followed the same trend as seen in Figure 7. The average variation in sound intensity level is higher in the teaching hospital with a standard deviation of about 0.4 greater than the standard deviation for the specialist hospital. Table 2 shows the mean sound intensity levels recorded in each hospital within the period of measurement. The sound intensity level can said to be relatively the same in both hospitals within the three months measurement periods having a maximum difference in intensity level of less than 4dBA. The indoor sound levels in the hospitals are all above 60dBA which are above the acceptable range of 30 – 40dBA [24] and 45 – 50dBA [25].

One of the basic design indicators for green architecture in creating visual comfort in buildings is daylighting [26]. Natural daylight from the sun when effectively harness into a building design can provide a better environment for living and work. Daylighting quality in a building can be influenced by fenestration design, Sun path, cloud cover and adjacent physical environmental elements. The mean recorded illuminance level measured in the hospital buildings as shown in table 3 is an indication that the light intensity in the specialist hospital was relatively low with a value range of 215.15-285.65Lux. The mean differences in illuminance level between the teaching hospital and specialist hospital is only above 100Lux in May and June, with a mean difference of 55.75Lux recorded for the month of April.

The mean illuminance level recorded in April for the specialist hospital is 236.55Lux, and the teaching hospital is 292.3Lux. There was an increased in light intensity in both hospitals in May. The light intensity again decreased from 285.65Lux to 215.15Lux in the specialist hospital and 399.20Lux to 393.35Lux in the teaching hospital between the months of May and June. The decreased in light intensity from May to June is very insignificant in the teaching hospital while the difference is about 65Lux in the specialist hospital. The low level of light intensity recorded in the specialist hospital as compared to the Teaching hospital might be as a result of having a smaller window to wall ratio (WWR) while the latter have higher window-wall-ratio (WWR). The amount of daylight intensity that penetrate into a building depends on the WWR where [27] recommended an optimum value of 25%. Building orientation also play an important role in determining the amount of daylighting in a building as seen from this study. The mean daylight intensity in the teaching hospital is more than the intensity recorded in the specialist hospital. This hospital ward buildings have their facades and fenestration facing North-east and

South-west mostly within Sun path position. On the other hand, the specialist hospital orientation is North-west and South-east facing where it exposure to the Sun path direction is limited. The specialist hospital therefore, has showed the worst visual quality within the indoor spaces. The mean illuminance level in the teaching hospital (333.75Lux) is greater than the 300Lux as the minimum lighting required for work plane [17], [18]. An illuminance level of less than 300Lux as obtained in the specialist hospital (248.04Lux) is only good when working with self-illuminating objects as opined by [17]. For proper medication administration to patients and staff record keeping, it is required that the minimum light intensity level in a hospital ward building should not be less than 300Lux. The average light intensity level recorded in both case study hospitals is an indication that, the application of daylighting features into the design of hospital buildings would lead to energy savings and environmental sustainability in healthcare facilities.

The CO_2 concentration levels in the two hospitals within the measurement periods ranged between 393ppm and 608ppm. The maximum CO_2 concentration level of 608ppm was recorded in the specialist hospital. The design of the specialist hospital ward buildings was such that, toilets and bath rooms where positioned in between ward room spaces, which are not properly maintained and aerated. The overall mean CO_2 concentration level is highest in the specialist hospital (523.5ppm) in April (Table 3). The variation in CO_2 concentration levels is least in the teaching hospital and highest in the specialist hospital with a standard deviation of 28.92 and 66.87 respectively. The CO_2 concentration levels in both hospitals are less than 700ppm which fell within the recommended ranges by international standards [4], [7].

The concentration level of CO within any building indoor environment has adverse effect on the occupant's health. The maximum CO concentration level of 14ppm which is above recommended standards [21] was recorded in the specialist hospital. The minimum concentration levels of CO within the hospital buildings is less in the teaching hospital (SD=1.87) as compared to the specialist hospital (SD=4.01). Table 3 shows the mean recorded concentration levels of CO in the hospital buildings which ranged from 3ppm to 6.5ppm in April, 5.25ppm to 7.75ppm in May and 4.25ppm to 10.25ppm in June. The highest range was recorded in June for the period of measurement. The acceptable level of CO concentration as stated in the National Environmental Agency guidelines is less than 10ppm [28]. Therefore, the mean CO concentration levels in both hospitals ranged within recommended standards for occupants comfort and wellbeing. On an average, the IAQ measured through the level of CO_2 and CO concentration in the two hospitals can said to be within acceptable limit for comfort.

5.0 CONCLUSION

The performance of IEQ is influenced by certain building design attributes and features such as: ventilation systems, building orientation, configurations, fenestrations, and materials. There is a relationship between achieving energy efficiency in buildings and IEQ performance. IEQ performance in buildings which has thermal comfort and lighting comfort as part of it assessment parameters contribute more to building energy consumption. The amount of energy requirement for maintaining thermal comfort and visual comfort in buildings can be greatly enhanced through passive building design.

The IEQ performance in the teaching hospital is observed to be better on an average than that for the specialist hospital. The open plan configuration and design of the teaching hospital ward buildings provided for a more improved natural ventilation and lighting within the building environment. Conversely, the specialist hospital whose ward buildings design have 3-bed space partitioned rooms separated by a corridor limits the partitioned rooms from having enough access to cross ventilation and daylight.

In order to provide for optimum thermal comfort and indoor air quality for patients, staff and visitors as occupants, the hospital ward buildings in the specialist hospital requires retrofitting of the buildings' fenestration especially in the aspect of ventilation and lighting. The fluctuation in sound intensity level recorded within the hospital ward buildings could be a result of periodic sounds emanating from some patients agonising in pains. The presence of clean air and good indoor air quality within hospital building environment could lead to improved patient's recovery and length of stay, and hospital staff work efficiency.

This investigation was conducted across a period of three months to ensure that the conditions are representative of the changes in environmental conditions. However, there is a need for further study to be conducted throughout the year as a long-term measure. The results of this study suggest the need for the design of hospital ward buildings to have fenestrations that allow for cross ventilation and natural air circulation within the indoor space. It is therefore recommended that, hospital building design or retrofitting should employed common strategies towards increasing ventilation and daylight with minimal energy consumption. The outcome of this study has therefore exposed the understanding of IEQ conditions in hospital buildings in Nigeria, which is expected to serve as a spring board towards furtherance of IEQ assessment in hospital buildings and its impacts on occupants' health and comfort.

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