Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.10, No.4, 2018

# Analysis of Indoor Thermal Comfort Perception of Building Occupants in Jimeta, Nigeria

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## Abstract

The study examined the perception of occupants on thermal comfort in Jimeta, Nigeria where the temperature is high, hot and dry weather. The objectives are to assess factors impacting on indoor thermal comfort, and effect of ventilation on heath of occupants in the area. Indoor thermal comfort and room temperature survey of thirty occupants' living rooms were taken using thermometers. Results show that building forms and orientation, building openings to floor area ratio, landscaping, and building fenestration have direct effect on the average room temperature of residential buildings. Challenges of high temperature, insomnia, fatigue, boredom, headache, poor arousal, and asthma are among health implications of inadequate ventilation suffered by occupants. It is recommended that building professionals be engaged in planning, design and construction of buildings to aid the application of building orientation, ratio of building openings to floor area, and landscaping among others to achieve ventilation and comfortable temperature.

**Keywords:** Buildings, Hazards, Temperature, Thermal comfort, Ventilation

## 1. Introduction

A building, according Zainazlan, Mohammed, and Shahrizam (2007), is defined as 'an enclosure for the benefit of human habitation, work or recreation.' Buildings generally are built to adapt to the prevailing climate and provide an internal and external environment that is comfortable and conducive to its occupant. In Nigeria climate, comfort is the major consideration when contemplating the future demand for space heating and cooling. There are interactions between climate, behaviour, building design and heating, cooling and insulation technologies However, due to increase in global warming and climate change in the 21st century, providing comfort for occupants of residential buildings and maintaining body temperature of 37°C (98.6°F) is challenging and fundamental. When people are dissatisfied with their thermal environment, not only is it a potential health hazard, it also impacts on their ability to function effectively and their satisfaction at work. Nicol and Humphrey (2004) postulated adaptive approach to providing and improving thermal comfort for occupants through reduction in energy consumption in buildings and sustainable interactions between occupants and their environment. Thermal comfort is basically concerned with the temperature that occupants of residential and any other type of buildings consider as comfortable to live or stay in. 'Thermal comfort' is defined by the American Society of Heat, Refrigeration, and Air-conditioning Engineers (ASHRAE) as ''that condition of mind which expresses satisfaction with the thermal environment" (ASHRAE, 2004). Thermal comfort is a result of a combination/adaptation of parameters of both the environment and the human body itself. Comfortable temperature represents the small range of temperatures at which the air feels neither hot nor cold when wearing the typical indoor clothing. The range is approximately between 15°C (59°F) and 30°C (86°F) and various methods of climate control are often employed to maintain this thermal comfort level (Wikipedia, 2017).

The indoor thermal comfort of occupants is achieved when they are able to live without any hindrance to the functions for which the buildings are intended to perform; hence it is essential for occupants' wellbeing, productivity, and efficiency. According to Michael, Richard, and Gerald (2015), there have been thermal comfort studies on residential buildings carried out in Nigeria by Ogbonna and Harris (2007); Akande and Adebamowo (2010); Ojebode and Gidado (2011); Sangowawa and Adebamowo (2012); Adebamowo and Adeyemi (2013). However, none of the studies consider the room temperature of large numbers of different residential buildings.

The contribution of building sector electricity use to that of the total electricity use of the country is even higher. In 2003, nearly 60% of total net electricity consumption in the OECD (Organisation for Economic Co-operation and Development) economies was in the building sector both residential and commercial, each representing about half of this electricity consumption (EIA, 2003). In developing countries the residential building sector accounts for more than half of the electricity consumption (OECD). Furthermore, the robust economic growth in many of the non-OECD countries is expected to boost residential demand for electricity, supporting a major transformation in living standards as electric lighting, air-conditioning and other appliances, and new technologies become available to an increasing share of the world's population (EIA, 2006). Energy consumption for residential cooling shows an increasing trend worldwide and is, therefore, of primary concern not only for countries that are characterized by hot climatic conditions but also for cities suffering from the heat island effect. Apart from the thermal discomfort, heat islands are an energy efficiency concern because increased air temperatures, raise air-conditioning loads in buildings, in turn raising energy consumption, peak electricity demand and energy prices (Akbari, Davis, Dorsano, Huang, and Winert, 1992; Santamouris, Papanikolaou, Livada, Koronakis, Georgakis, Argiriou, and Assimakopoulos, 2001; Hassid, Santamouris, Papanikolaou, Linardi, Klitsikas, Georgakis, and Assimakopoulos, 2000). In Nigeria, the Federal Government's 2009 vision 2020 report in Oyedepo, (2014) showed that 55.3% of electricity generated was consumed by the residential building sector; 24.4% by the commercial and public sector while 20.0% went for the industrial sector. However, there's a lack of continuous and reliable power from the grid supply to run the fans and air conditioners, and the use of these mechanical systems requires lots of energy and energy costs money. Nigeria is a country with numerous resources but providing constant power to the domestic sector has been a herculean challenge due to corruption and resources mismanagement. Designers and house builders may also be seen as contributing to the problem. They construct buildings with little or no regard to the local climate and thermal comfort considerations. Most of the building materials used, especially sandcrete blocks, don't insulate or reflect sunlight; there's no effective shield or insulation between the outdoor environment and the building interior. As a consequence, a high level of solar gain enters the building through its opaque fabric. Given the hot climate of Nigeria, this causes thermal discomfort to the occupants. Sustainable low energy approaches should be encouraged to reduce the cooling load and energy consumption since most occupants are now relying on air conditioning systems as the best way to improve thermal comfort, increasing bills along the way.

Local climate affects the indoor heat and ventilation in buildings. In tropical climates buildings are overheated during the day due to solar heat gain through the building envelope and solar penetration through windows and other openings (Zainazlan, Mohammed, Shahrizam, 2007). Heat and ventilation in buildings is achieved where there is a physical and psychological balance within building interiors in terms of heat gains and losses. In the findings of Hyde (2000), thermal comfort can be achieved where indoor temperature is lowered below the outdoor temperature using passive and active methods in buildings. Passive method involves utilization of building materials and finishes that retards or reduces heat absorption and penetration into building. The active method requires controlling indoor temperature by using curtains on walls/windows as well as employment of mechanical and electrical appliances/systems such as electrical fans, air-conditioners. Housing community, as well as consumers, are generally poorly informed about thermal comfort issues pertaining to indoor ventilation, air quality and the occupants' health. The need for ventilation and thermal control in buildings is essential in achieving comfortable indoor thermal environment for building occupants. Therefore, the study examined the perception thermal comfort by occupants living in residential buildings in Jimeta, Adamawa state, Nigeria where the climatic condition is characterized by high temperature, excessive glare, hot and dusty air during the dry season with average daily temperature of 43$^{o}$C. The specific objectives are to determine factors impacting on thermal comfort/ventilation of residential buildings in the study area and effect of ventilation on heath of occupants of building in study area.

## 2. Ventilation of Residential Buildings

Ventilation is the process by which indoor air is replaced by the admission of fresh air and the exhaustion of stale air, by natural or mechanical means, in order to ensure the occupants' comfort (Pierre, Jean-Marc, and Marion, 2007). A residential building's ventilation requirements depend on many factors, which can vary from one residence to another. Pierre, et al., (2007) submitted that the differences in temperature between the indoors and outdoors, wind, and the equipment that exhausts or introduces the air are some factors likely to have an impact on a residence's air pressure, a phenomenon associated with air movement indoors. Akande and Adebamowo (2010) opined that the primary function of all building is to adapt to the prevailing climate and provide an internal and external environment that is comfortable and conducive to the occupants. The concept of thermal comfort is hinged on development of newer and more energy efficient materials to function in the built environment. In physiological terms, thermal comfort is what we experience when the body functions well, with a core temperature of around 37oc and skin temperature of 32-33oc.

Improvements to recent residential construction methods have made residences more airtight. With increase in the number of existing houses, there is need for improvements in insulation, the installation of windows and doors with high energy efficiency. In a great many of these houses, air infiltration through the doors and windows as well as through openings in the building envelope is generally no longer sufficient to provide appropriate and uniformly distributed ventilation in the habitable rooms of the house. Mechanical ventilation then becomes an additional means to be considered, particularly during the heating season. There are three main types of mechanical ventilation, namely exhaust only, supply only, and balanced. In apartment buildings, the typical installations are generally air supply systems in corridors, paired with exhaust fans in the apartments. A heat recovery ventilator (HRV) that provides balanced ventilation while recovering heat is the system currently referred to by experts and often recommended in the standards (Engvall, Wickman, and Norbäck, 2005).

Ibrahim, Ishaq, Muhammad, and Maksha (2014) identified the factors for the improvement of thermal comfort in residential buildings to include the following: proper orientation of building, creation of microclimate, proper ventilation, using shading devices, and proper lighting Proper orientation of buildings to reduce the impact of unfavourable weather conditions like solar radiation, driving rain and thunderstorm. In the house, the rooms should be located in such a way that the ones frequently used should be elongated along the east-west dimensions to mitigate heat gain in summer and also making efficient use of winters sun (Cengel, 2002). By proper positioning the windows and opening them, air movement can be created in the rooms. Walls and vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing air flow within the building. If possible, the rooms should be cross-ventilated. The most effective way of improving thermal comfort in residential buildings is to shade the windows, walls and roofs of buildings from direct solar radiation. The windows can be externally shaded by using overhangs or a horizontal projection to block off sun's rays completely in summer while letting in most of them in winter. Double pane windows with tinted glass and glass coated with reflective film should be used for windows instead of steels, wood and zincs. External shading can also be provided by growing deciduous trees which block off the sun's rays from reaching the building in summer and in winter, loose their leaves to allow about 60% of solar radiation to pass into the building envelope (Cengel, 2002). The roof of buildings can be shaded effectively by using removable canvass which can be used during the day time and rolled up during the night time to allow radiative cooling. A drapery could be used to internally shade the windows at the same providing privacy and aesthetic effect. A light colour drapery with close or semi-close woven fabric should be used in summer to reflect back the incident solar radiation while a dark coloured drapery with open or semi-open woven fabric should be used in winter to impede the escape of heat from the building. Using day light as much as possible will reduce cooling load because day light contains the least amount of heat per lumen of light. Compact Fluorescent Lamps (CFL) should be used in lieu of incandescent bulbs and kerosene lamps because they emit heat into the cooling space. The CFLs have different colour spectrum, used 75% less energy than incandescent bulbs; they are cheap and last 10 times longer than the incandescent bulbs. Trees can be planted to create micro-climate that is, small-scale climatic condition at a spot or area or site. The micro-climate of the adjoining trees can be explored to provide a cool comfortable environment in tropical climate (Olaoti, (2005). These living rooms and other areas which are frequently used by inhabitants should be carefully placed for micro-climate so that they are comfortable and more enjoyable, and can be used for a longer length of time. Thermal comfort plays a significant role in human performance at both mental and physical levels (Lawal, and Ojo, 2011). During hot weather, stroke cardiovascular abnormalities are common. Acute left ventricular failure, right ventricular dilation and sub-endocardiac haemorrhages can occur (Ogundele, 2005). The basic intention of a building is that they should be planned, designed, built and managed to offer an environment in which occupants can carry out their work and feel well, and to some extent be refreshed by the environment. The building should serve as a modifier of the microclimate (Olanipekan, 2002); that is a space isolated from environmental temperature and humidity fluctuations, sheltered from prevailing winds and precipitation, and with enhancement of natural light (Lawal, and Ojo, 2011).. The creation of microclimate in today's modern buildings is expensive which can be attributed to the modern materials used in building constructions. This however is at variance with the buildings in the past where comfortable microclimate is achieved with minimal artificial energy input (Shittu, and Ifesanya, 2003). The modern buildings are characterized by high energy requirement for cooling and lighting. With the erratic power supply and high cost of air conditioning systems, achieving thermal comfort through the use of active cooling systems is expensive (Olaobuchi, 1992).

### 2.1.1 Effects of Residential Building Ventilation on the Occupants' Respiratory Health

Inadequate ventilation provision to residential houses cause health problems and discomfort related to odours (bio effluents). Studies have been carried out to evaluate the effects of ventilation on health. The main problems according to Pierre, Jean-Marc, and Marion, (2007) are: acute respiratory and allergy symptoms, including asthma in particular. To measure the relationship between ventilation and respiratory health, researchers have compared the frequency of symptoms in relation to the presence of mechanical ventilation or natural ventilation and/or in relation to the ventilation rate measured in air changes per hour (ACH). The quality of lives of human beings to a very large extent depends on the quality of their indoor environments because people spend most of their time indoors. Human beings partake in various activities within building enclosures and these activities can only be performed best when the environmental conditions are favourable. Inside a building, people are affected either positively or negatively because of the physiological reactions and psychological responses to the environment. Thermal comfort plays a significant role in human performance at both mental and physical levels (Lawal, and Ojo, 2011). Failure of human beings to respond to the environment through thermo-regulatory mechanism causes thermal discomfort. The thermal discomfort experience by occupants of a built environment during hot season causes lower emotional health manifested as psychological distress, depression and anxiety as well as lower physical health manifested as heart disease, insomnia, headache, fatigue, boredom and poor arousal (Fanger, 1970; Markus, and Morris, 1980). The basic intention of a building is that they should be planned, designed, built and managed to offer an environment in which occupants can live and carry out their work and feel well, and to some extent be refreshed by the environment. The approach is to concentrate on getting the building materials, designs, location and shading of the building as suitable as possible for likely climate conditions, while ensuring that residents make living spaces comfortable by adopting energy-efficient engineered solutions.

## 3. Materials and Method

The methodology for the study included post-occupancy indoor thermal comfort surveys and simultaneous observance of room temperature of occupants' living rooms in March, 2017 at local time of 6:00 hours, 14:00 hours, and 22:00 hours in the morning, afternoon, and evening respectively using thermometers and presented in a chart (Figure 1). Average temperatures of buildings were also calculated and presented in tables. The month of March was used because the temperature of the study area reaches its peak at this month, with its attendant hot (dry) weather both at night and in day time. The study obtained design, construction and material details of residential buildings of respondent occupants to assess its impact on the room temperature. Questionnaires were used to obtain data in the post-occupancy field surveys of 30 residential buildings. The questionnaire was divided into two (2) main sections: Section A, includes background information about age of building, number of occupants in a building, and occupancy status; Section B, obtained data relating to factors of thermal comfort of buildings. Factors which affect indoor thermal comfort of living rooms were obtained from relevant literature, assessed, and presented in tables. The indoor room temperatures of 30 residential buildings were presented in a chart (Figure 1) while other data obtained were presented in tabular form. Data were analysed using descriptive analysis.

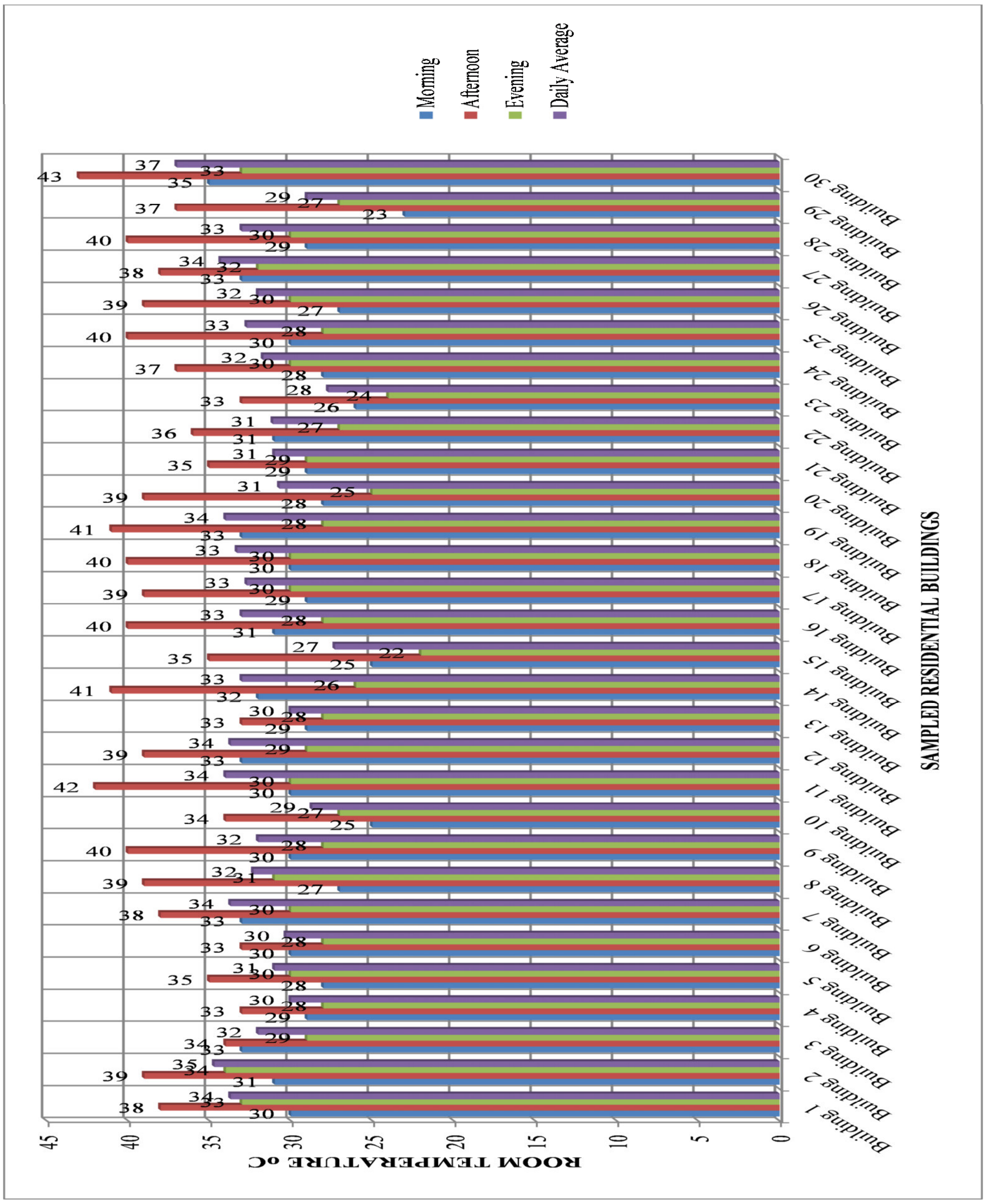

**Figure 1: March Room Temperature for Residential Buildings**

## 4. Results and Discussion

### 4.1 Age of Building, Number of Building Occupants, and Status of Occupants

Buildings numbered 19 to 30 indicated in Figure 1 are above twenty years (20years) old representing 40% of total buildings surveyed, with collective average temperature of 32.02°C as shown in Table 1. According to Health and Safety Executive (HSE, 2017) environmental factors (e.g. air temperature, radiant temperature, air velocity, and humidity) and personal factors (e.g. clothing and metabolic heat) influences thermal comfort of buildings, but the most commonly used indicator of thermal comfort is air temperature because, it is easy to use and most people can relate to it.

**Table 1: Age of Building**

| S/N | Age of Building (Years) | Building No. | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|---|
| 1 | Less than 5 | 1 to 4 | 4 | 13.30 | 32.60 |
| 2 | 5 – 10 | 5 to 7 | 3 | 10 | 33.67 |
| 3 | 11 – 15 | 8 to 12 | 5 | 16.70 | 32.14 |
| 4 | 16 – 20 | 13 to 18 | 6 | 20 | 31.55 |
| 5 | Above 20 | 19 to 30 | 12 | 40 | 32.02 |
|  | TOTAL |  | 30 | 100 |  |

It can be seen that 50% of the residential buildings surveyed have more than 8 occupants living in a building as indicated in Table 2. Twenty percent (20%) of the buildings surveyed have less than five (5) occupants residing in them.

**Table 2: Number of Occupants in a Building**

| S/N | No. of Occupants | Frequency | Percentage (%) |
|---|---|---|---|
| 1 | Less than 5 | 6 | 20 |
| 2 | 5-8 | 9 | 30 |
| 3 | Above 8 | 15 | 50 |
| | TOTAL | 30 | 100 |

The status of occupants of residential buildings shows that majority of the occupants (60%) are owner occupiers, with their collective average temperature of 31.86$^{o}$C, while only 40% are tenants with their collective average temperature of 32.18$^{o}$C as shown in Table 3. The result indicates that average room temperatures of tenants' buildings are higher than the average room temperature of owners' occupiers. This is due to short period that tenants occupy a building before moving to new residence.

**Table 3: Status of Building Occupants**

| S/N | Status of Occupants | Building No. | Frequency | Percentage (%) | Average Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| 1 | Tenants | 1 to 12 | 12 | 40 | 32.18 |
| 2 | Owners Occupier | 13 to 30 | 18 | 60 | 31.86 |
| | TOTAL | | 30 | 100 | |

The form of residential buildings shows that buildings having irregular form are 63.33%, and has the lowest average temperature of 31.54$^{o}$C. Only 20% of buildings are square in form with the highest average temperature of 32.81$^{o}$C as shown in Table 4. Buildings in rectangular form have the second highest average temperature of 32.68$^{o}$C. This shows that buildings in square and rectangular form reduce the achievement of comfortable temperature and cross ventilation.

**Table 4: Forms of Building**

| S/N | Form of Building | Building No. | Frequency | Percentage (%) | Average Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| 1 | Irregular | 1 to 16, and 21 to 23 | 19 | 63.33 | 31.54 |
| 2 | Rectangular | 17 to 20 | 5 | 16.67 | 32.68 |
| 4 | Square | 24 to 30 | 6 | 20 | 32.81 |
| | TOTAL | | 30 | 100 | |

Orientation of occupants' buildings shown in Table 5 revealed that 66.67% of the buildings have their length facing the east-west direction and collective average temperature of 33$^{o}$C. Longer walls of building should face North and South so that the building gets minimum solar exposure Sunlight on building surface is the most significant energy input in buildings resulting in immense heat gain. Buildings form whose width faces the east-west direction will result in less heat generated on the building surface. The layout of a residential building should be handled with the view to achieving proper shape and orientation. This can be achieved by making the longer side of the residential building to face north-south direction and shorter side of the residential building to face the east-west direction in order to minimize the volume of solar radiation that the exterior walls could absorb and consequently reduce the rate of transmittance of heat into the building.

**Table 5: Building Orientation**

| S/N | Building Orientation | Building No. | Frequency | Percentage (%) | Average Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| 1 | Length of building facing North-South direction | 4,5,6,10,13, 15, 20,21,23 and 29 | 10 | 33.33 | 29.57 |
| 2 | Length of building facing East-West direction | 1,2,3,7,8,9,11,12,14,16,17,18, 19, 22, 24, 26,26,27,28, and 30 | 20 | 66.67 | 33 |
| | TOTAL | | 30 | 100 | |

4.2 Building Fenestration

Table 6 shows window fenestration in buildings. In floor area provision for window openings, results indicate that 50% of the buildings have 15 – 20% of floor area as window openings with the least total average temperature of 31.94$^{o}$C, while 16.67% of the buildings have less than 10% of floor area as window openings with the highest total average temperature of 33.89$^{o}$C. On windows directional orientation, 40% of the buildings have windows fenestration in all corners and the lowest total average temperature of 30.08 $^{o}$C, while buildings with windows fenestration facing east – west direction have the highest total average temperature of 34.62 $^{o}$C.

**Table 6: Windows Fenestration**

| S/N | Window Fenestration | Less than 10% of floor area | 10 - 15% of floor area | 15 - 20% of floor area | Total |
|---|---|---|---|---|---|
| 1 | Windows facing North-South direction | N: 2<br>AT: 33.13 | N: 1<br>AT: 33 | N: 1<br>AT: 33 | N: 4<br>P: 13.33<br>AT: 33.04 |
| 2 | Windows facing East-West direction | N: 2<br>AT: 35.85 | N: 2<br>AT: 34.15 | N:<br>AT: 33.85 | N: 6<br>P: 20<br>AT: 34.62 |
| 3 | Windows in three directions | N: 1<br>AT: 32.70 | N: 3<br>AT: 32.33 | N: 4<br>AT: 31.70 | N: 8<br>P: 26.67<br>AT: 32.24 |
| 4 | Windows in four directions | NIL | N: 4<br>AT: 30.95 | N: 8<br>AT: 29.21 | N: 12<br>P: 40<br>AT: 30.08 |
|  | **Total** | N:5<br>P: 16.67<br>AT: 33.89 | N:10<br>P: 33.33<br>AT: 32.61 | N:15<br>P: 50<br>AT: 31.94 | **30** |

Key: N: Number P: Percentage (%) AT: Average Temperature ($^{o}$C)

External dimension of openings for windows and doors indicate that buildings with more windows or doors opening area have lower average temperature than those with less opening area as shown in Table 7. Windows with 1200mm x 1200mm dimension have the lowest average temperature of 31.83$^{o}$C than windows with lesser dimensions. Also, doors with 1200mm x 2100mm dimension have lower average temperature of 31.87$^{o}$C than door with 900mm x 2100mm dimension which is 33$^{o}$C.

**Table 7: Dimension of External Building Fenestration**

| S/N | Dimension (mm) |  | Building No. | Frequency | Percentage (%) | Average Temperature ($^{o}$C) |
|---|---|---|---|---|---|---|
| 1 | Windows | 1200mm x 1200mm | 14 to 28 | 15 | 50 | 31.83 |
| 2 |  | Less1200mm x 1200mm | 1 to 10 | 10 | 33.33 | 31.84 |
| 3 |  | 1200mm x 800mm | 11 to 13 | 3 | 10 | 32.57 |
| 4 |  | Less 1200mm x 800mm | 29 and 30 | 2 | 6.67 | 33 |
|  |  |  | Total | 30 | 100 |  |
| 5 | Doors | 900mm x 2100mm | 28 to 30 | 3 | 10 | 33 |
| 6 |  | 1200mm x 2100mm | 1 to 27 | 27 | 90 | 31.87 |
|  |  |  | Total | 30 | 100 |  |

4.3 Materials for Building Wall and Roof Covering

Only 10% of the buildings have wall fabric constructed with bricks while, buildings whose wall fabric is made of concretes are 90% as seen in Table 8. Buildings with brick walls have lower average temperature of 30.10$^{o}$C as compared with concrete wall buildings with 33$^{o}$C average temperature. This is due to the fact that concrete is a conductor of heat and conducts or transfer heat form the sun through radiation easily than bricks to the interior spaces of buildings.

**Table 8: Materials for Building Wall**

| S/N | Building Wall Materials | Building No. | Frequency | Percentage (%) | Average Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| 1 | Concrete blocks | 1 to 12,<br>16 to 30 | 27 | 90 | 33 |
| 2 | Burnt Bricks | 13, 14, and 15 | 3 | 10 | 30.1 |
|  | TOTAL |  | 30 | 100 |  |

Among roofing materials employed in the surveyed buildings as shown in Table 9, eight (8)of the thirty (30) buildings, representing 26.7% are covered with corrugated zinc without ceiling being provided, thus, recording the highest average temperature of 34.39$^{o}$C. Buildings with long span aluminium roof covering and ceiling have the least average temperature of 28.78$^{o}$C. Provision for ceiling in buildings help moderate room temperature of buildings as seen in table 8, where, buildings with ceiling provision have lower average temperature as compared with buildings without ceiling.

**Table 9: Roofing Materials**

| S/N | Roofing Materials | Building No. | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|---|
| 1 | Long span aluminum with ceiling | 4, 10, 13, 15, 23, and 29 | 6 | 20 | 28.78 |
| 2 | Long span aluminum without ceiling | 14, 16, 18, and 28 | 4 | 13.3 | 33.01 |
| 3 | Corrugated zinc with ceiling | 3, 5, 6, 8, 9, 17, 20, 21, 22, 24, 25, and 26 | 12 | 40 | 31.63 |
| 4 | Corrugated zinc without ceiling | 1, 2, 7, 11, 12, 19, 27, and 30 | 8 | 26.7 | 34.39 |
| | TOTAL | | 30 | 100 | |

4.4 Provision for Ventilation and Landscape

Buildings with provision for landscape such as concrete interlocks, short grass and trees have lower average temperatures than buildings that are not provided with landscape as shown in Table 10. Buildings with natural ventilation and landscape have average temperature of 31.30°C while buildings without landscape have average temperature of 34.24°C. it shows that landscaping the surrounding of buildings contribute in lowering the room temperature of residential houses.

**Table 10: Landscape Provision**

| S/N | Provision of Landscape | Building No. | Frequency | Percentage | Average Temperature (°C) |
|---|---|---|---|---|---|
| 1 | No landscape provided | 1, 2, 7, 18, 27, 28, and 30 | 7 | 23.33 | 34.24 |
| 2 | Natural ventilation and landscape provided (e.g. short grass/trees, concrete interlocks) | 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, and 29 | 23 | 76.67 | 31.30 |
| | **TOTAL** | | 30 | 100 | |

The type of mechanical ventilation provided in buildings is shown in Table 11. It indicates that the room average temperatures of buildings where fans and air conditioners are provided (28.54°C) are lower than buildings where only air conditioners (30.83°C) or only fans (33.01°C) are provided. Mechanical or active ventilation of residential buildings contribute in reducing the room temperature of buildings.

**Table 11: Types of Mechanical Ventilation Provided**

| S/N | Types of Mechanical Ventilation | Building No. | Frequency | Percentage | Average Temperature (°C) |
|---|---|---|---|---|---|
| 1 | Electric fans only | 1, 3, 7. 8. 9. 11. 12. 14, 16, 17, 18, 19, 25, 26, and 28 | 15 | 50 | 33.01 |
| 2 | Air conditioners only | 5, 6, 13, 20, 21, 22, and 24 | 7 | 23.3 | 30.83 |
| 3 | Fans and air conditioners | 4, 10, 15, 23, and 29 | 5 | 16.7 | 28.54 |
| 4 | None provided | 2, 27, and 30 | 3 | 10 | 35.33 |
| | TOTAL | | 30 | 100 | |

4.5 Effect of Inadequate Ventilation on Occupants' Health

The effect of inadequate ventilation on occupants' health is shown in Table 12. Results indicate that occupants of nine (9) out of ten (10) residential buildings (i.e. 90%) are confronted mostly with twin challenge of high temperature and insomnia (sleep difficulty) due to inadequacy of ventilation. Fatigue and boredom is the second effect of inadequate ventilation which occupants are challenged with, as result shows eight (8) out of ten (10) occupants of residential buildings (i.e. 80%) suffered fatigue and boredom. Headache and poor arousal, depression and anxiety, psychological distress, and acute respiratory and allergy (e.g. Asthma) are the third ways inadequate ventilation impacted on occupants, with 60% (i.e. six out of ten residential buildings' occupants) said to have suffered these effects.

**Table 12: Effect of Inadequate Ventilation on Occupants' Health**

| S/N | Health Effect | Frequency | Total Number of Buildings | Ratio of Buildings |
|---|---|---|---|---|
| **1** | Unpleasant smell | 12 | 30 | 2:5 (40%) |
| **2** | High temperature | 27 | 30 | 9:10 (90%) |
| **3** | Headache and poor arousal | 18 | 30 | 3:5 (60) |
| **4** | Fatigue and boredom | 24 | 30 | 8:10 (80%) |
| **5** | Depression and Anxiety | 18 | 30 | 3:5 (60%) |
| **6** | Insomnia | 27 | 30 | 9:10 (90%) |
| **7** | Psychological Distress | 18 | 30 | 3:5 (60%) |
| **8** | Acute respiratory and allergy e.g. Asthma | 12 | 30 | 2:5 (60%) |
| **9** | Stroke and other cardiovascular abnormalities | 9 | 30 | 3:10 (30%) |
| **10** | Acute left ventricular failure and right ventricular dilation | 0 | 30 | 0 |

## 5. Conclusion

Environmental factors (e.g. air temperature, radiant temperature, air velocity, and humidity) and personal factors (e.g. clothing and metabolic heat) influences thermal comfort of buildings, however, the most commonly used indicator of thermal comfort is air temperature as claimed by Health and Safety Executive (HSE, 2017). Therefore, considering the room temperature of the thirty (30) residential buildings of occupants surveyed, the average temperature of buildings occupied by tenants, 32.18$^{o}$C is higher than that of owners' occupiers which is 31.86$^{o}$C. The results of the study reveals that forms and orientation of buildings, ratio of building openings to floor area, materials for building walls and roof coverings, landscaping, and dimension of building fenestration have direct effect on the average room temperature of residents' buildings. The twin challenges of high temperature and insomnia (sleep difficulty) due to inadequacy of ventilation; fatigue and boredom; headache and poor arousal; depression and anxiety; psychological distress, and acute respiratory and allergy (e.g. Asthma) are the major health implications of inadequate ventilation suffered by residential occupants.

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