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INVESTIGATING INDOOR VENTILATION IN MULTI-HABITED HOUSES: A CASE OF OGBOMOSO, NIGERIA

Abdulrasaq Kunle Ayinla[1*] and Ilelabayo Ismail Adebisi[1*],
1. Department of Architecture, Ladoke Akintola University of Technology, Ogbomoso, Nigeria

ABSTRACT: *The study investigated the indoor natural ventilation condition in multi-habited houses in the traditional core of Ogbomoso. Factors affecting natural ventilation in buildings such as orientation, external spacing, landscape and opening conditions were assessed through physical observations and direct measurements. Data on indoor air movement (velocity) was obtained with the use of kestrel 4500 pocket weather and environmental metre after due calibration with the climatic data of Ogbomoso which had earlier been obtained from the Nigeria meteorological station; the data was obtained in order to assess the level of ventilation and air movement in their various spaces. A living room, a bedroom and a kitchen (which are spaces where residents spend most time) were randomly selected in each multi-habited building for the purpose of the study. Obtained results were compared with the standard values given by scholars Borda-Dias and Chand. The study found all factors affecting natural ventilation to be grossly inadequate when compared with standards just as low air velocity level was also recorded in all their spaces (0.08 minimum and 0.48m/s maximum observed as against minimum of 0.50m/s recommended by Borda-Dias). The study concluded that there is a likelihood of high dependency on active driven mechanical devices in the study area if suitable indoor thermal comfort is to be achieved. The study recommended that a more awareness level on natural ventilation systems should be created and a rehabilitation of multi-habited homes in the study area is suggested.*

KEYWORDS: natural ventilation, multi-habitation, energy, thermal comfort, natural cooling

INTRODUCTION

Rapid urbanization in the world and particularly in Nigeria has led to a drastic increase in energy consumption in buildings. The Intergovernmental panel on climate change [1] reported that building sector in the world accounted for approximately 32% of the Global energy consumption in 2010, 51% of the global electricity consumption and invariably is responsible for 19% of energy related CO_2 emissions. However, commercial buildings consume only 8% of the world energy in the same year. A further breakdown per continental energy consumption according to the same report indicated that residential buildings in Africa consumes over 79% of the energy used in buildings. This is however very similar to the findings of Authors [2] and [3] that both reported that residential buildings in Nigeria consumes approximately 78% of total energy use in buildings and that of Author [4] who also noted that residential buildings in Nigeria consumes approximately 50.4% of electricity distributed in Nigeria.

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Apart from the drastic urbanization being experienced in Nigeria, the high energy consumption in residential buildings can be attributed to the climatic condition of the country and Architects not paying attention to strategies of designing with climate [3]. Nigeria is located in the tropical region, with its climate characterised by high temperature resulting in heat build up in spaces thereby leading to high thermal stress experienced by building occupants [5]. The constant challenge is hence how to avoid heat from building up in spaces and how to swiftly remove once it builds up [6].

Authors [6] and [7] in their studies found that most energy consumed in buildings in Nigeria is expended on active driven devices used in achieving indoor comfort in buildings such as Fans, Air conditioners, Humidifiers etc. this is in a bid to regulate indoor spaces to suite residents comfort desires. However, many scholars have indicated that these devices are heavily dependent on energy and are uneconomical. The growing trend in the use of these devices has led to a geometric increase in energy consumption, energy crises, increased green house gas emissions, global warming among others [6].

However, the mandate to limit energy consumption in the world has called for a growing interest and attention in the studies of natural ventilation in buildings owning to its efficiency, effectiveness, practical zero energy consumption and economic advantage over mechanical devices [8]. The fact that these mechanical devices are heavily dependent on energy/ electricity which has been reported by several scholars to come with very high cost, low generation, epileptic and erratic supply in Nigeria makes the study of natural ventilation for indoor comfort in Nigeria more necessary and even more significant in multi habited homes predominant in the traditional core areas of cities in the country. This is because according to Author [10], residents of multi habited homes in the traditional core of Nigeria cities are mainly agglomeration of people who do not define themselves as one house hold but sharing a living space that is clearly not designed for multi-family purposes, they are low income tenants from different backgrounds living together in a dwelling and sharing a common living space; they are adjudged to be very poor, because their monthly earning is less than the fixed minimum wage in the country and hence cannot afford the cost of procurement and maintenance of active driven devices used in maintaining comfort in buildings and neither can they afford the running cost expected to be expended on electricity.

Ventilation is the replacement of used air in buildings with fresh ones from outside, it plays a significant role in maintaining an acceptable indoor thermal environment, and it limits energy consumption in buildings while also ensuring a physiological and psychological comfort / balance for building occupants [10]. Natural ventilation is an important strategy to improve thermal comfort in buildings in the warm humid and hot arid regions and may be sufficient to guarantee the thermal comfort of occupants [10]. In his findings, Author [11] submitted that natural ventilation is the most efficient instrument to improve indoor air quality, protect health of occupants and the cheapest means of achieving thermal comfort in buildings. Apart from this, Author [12] also found that the final energy cost of a naturally ventilated building is 40% less than a conditioned building. Therefore, ensuring proper natural ventilation in buildings should be of top priority to Architects and design teams in the building industry. Authors [8]

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and [10] submitted that factors affecting ventilation in buildings include location of openings, opening positions, number and sizes of openings, opening types, proper landscape, spacing (buildings position in relation to one another), proper orientation etc.

Author [13] as cited by [10] highlighted building orientation and architectural features as factors affecting ventilation in buildings. In a broader study conducted in 2006, Author [14] indicated that Natural ventilation in buildings is affected by site and its local landscaping features, building form and building envelope designs, internal planning and room design. To facilitate effective Natural ventilation in buildings, [14] highlighted that resistance to air flow through buildings has to be minimised, large openings for air passage has to be ensured and numbers of rooms through which air has to pass should be reduced. This is however in line with the submission of Author [15] who posited that opening is a critical point of focus if effective natural ventilation is to be achieved and hence should be widely distributed over individual surfaces and at different facades to ensure an effective flow of air. Minimum opening sizes are specified by various scholars though this varies according to geographic and climatic zones, there is no guide for maximum size of opening [10]. Ideally, for warm humid climates, it might be desirable to have virtually 100% openings but other factors of comfort such as solar control, security, privacy and potential heat /loss during harmattan should be considered when choosing choice of opening, opening size, type, positions and locations [10].

Site and its landscape features are other factors that affect airflow and effective ventilation in buildings. Landscape and vegetation is an effective means of protecting buildings from unwanted solar gains and redirecting wind flow to enter the house [8]. Similarly, building orientation enhances Natural ventilation and air flow in buildings and ensures that solar radiation is drastically reduced. To achieve this effectively in the humid region, buildings should be positioned with their longer axis on East- West direction; longer axis of buildings on North-South axis is however discouraged [8], [10], and [3]. Spacing is another critical factor to be considered when ensuring Natural ventilation in buildings. Buildings standing within the network of another affect air circulation through and around them [16]. In warm humid climates, large free spaces should be ensured between buildings if Natural ventilation is to be achieved, compact design should be avoided and buildings should be spaced five (5) times their height. [17]. Natural ventilated buildings should be orientated to maximize their exposure to the required wind direction and designed with a relatively narrow plan form to facilitate the passage of air through and around them [14].

This study is aimed at investigating Natural ventilation in Multi habited buildings in the traditional core of Ogbomoso; it specifically focuses on ascertaining the effectiveness of indoor natural ventilation for comfort in their multi-habited buildings with a view to giving appropriate recommendations on ways of achieving indoor comfort in these buildings devoid of artificial ventilation systems in the future, it is believed that this will be a further step to ensuring a reduced energy use in residential buildings in Nigeria.

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Multi Habitation

Multi-habitation is a classification of housing where multiple families are contained within one building and sharing common facilities [9]. This house form is a dominant house type in cities of developing countries because of the provision it makes for the increasingly large poor immigrant population in the rapidly expanding cities in African nations [19]. The term was first coined by Graham Tipple in his study on compound house in West Africa in year 2000. Multi-habited house forms are set of rooming houses whereby the building is divided into separate rooms either opposing each other along a common corridor or surrounding a common courtyard [20]. This house forms allows different families to live in full view of one another within the same building, sharing the same facilities and in a relatively small space [9]. Multi-habited dwelling is a way of meeting up with the accommodation demands of the low income groups living in urban centres as it provides inexpensive accommodation who doesn't mind living a collectivist life or who are too poor to afford the cost associated with single family apartments. The commonest types of multi habited buildings in West Africa cities are the Compound impluvium (Traditional compound system and Modified compound systems) and the Brazilian rooming houses locally called the *face me- I face you* apartment [9], [18] and [20].

The Compound impluvium house is the most common multi-habited house type in the traditional core of Nigeria cities. It accommodates large number of rooms arranged rectilinearly along the central courtyard with verandas overlooking the courtyard. The courtyard improves indoor comfort by offering climatically open air movement. It also serves other functions of privacy, serves as a venue for communal meetings and other social gatherings.

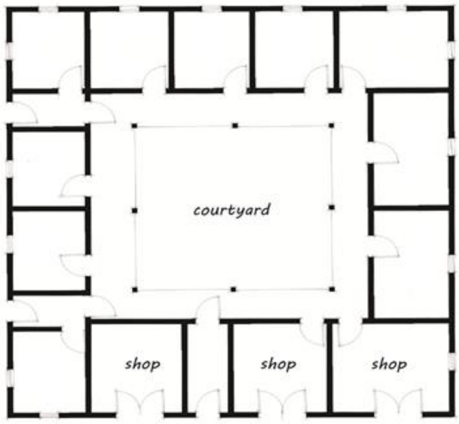

Figure 1: Plan of a Compound Impluvium
Source: Author [21]

Plate 1: View of a Compound Impluvium
Source: Author [21]

The Brazilian rooming house types "locally called *face me- I face you* because of its rooms arranged with their doors facing each other along a long corridor" are either available as storey or bungalow. These residential building types are more dominant and popular in traditional core of cities. Brazilian rooming house in its common form has rooms arranged linearly on both sides of an access corridor. It also has facilities like kitchen, toilets and bathrooms arranged at the backyard.

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Plate 2: Front view of a Brazilian rooming house
Source: Author [21]

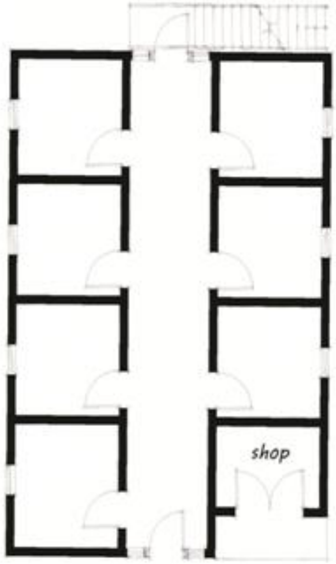

Figure 2: Plan of a Brazilian rooming house
Source: Author [21]

Studies conducted by Authors [21] and [10] in Ogbomoso in 2007 and 2011 respectively indicated that the Compound impluvium buildings (Traditional and modified) were the most common house-type in Ogbomoso, while the Brazilian house-type locally called the *face – me – I – face* you was the second most common house type in City; these are house types occupied by multi families and hence houses a high population of low income dwellers who presumably cannot afford the cost of active driven devices used alternatively in achieving desired indoor comfort in buildings. Studies of Natural ventilation in these buildings is however expedient with a view to providing appropriate recommendation on how to improve on their indoor comfort condition naturally or upholding the existing ones if found to be adequate.

Study Area

Situated on latitude 8 degrees, 10 minutes North and longitude 4 degrees, 10 minutes East of the Greenwich Meridian, Ogbomoso falls within the derived savannah region in South west Nigeria. Ogbomoso is the second largest city in Oyo state, Nigeria and is administrative headquarter to 9 local governments [22].

The climate of Ogbomoso is warm humid and characterised by high temperature, high humidity, high rainfall and a relatively low wind velocity with maximum temperature rising above 33 degrees in some months and relative humidity rising above 89 percent [17].

Traditionally, the core area of Ogbomoso like most cities in Oyo State is derived from the socio- political and cultural background of the inhabitants. The major physical elements in the area include the palace, the king's markets which are located at the immediate vicinity of the

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palace, the religious centres (the central mosque), and also the residential quarters and the wards [22].

Like other cities in Oyo state, most buildings in the traditional core of Ogbomoso are land-locked, their planning is haphazard and are compactly built, there by hampering air flow in their spaces. Mostly, buildings in this area are accessible by foot paths except some that are benefitting from available less motorable earth roads

Plate 3: Traditional core of Ogbomoso
Source: Author [23]

METHODOLOGY

Primary and secondary data were collected for the study; the primary data was acquired through reconnaissance survey, physical inspection, direct measurements with the use of instruments and direct observation. Secondary data was sourced from relevant literatures, authorities and books.

A survey of 321 Multi-habited buildings which were randomly selected was conducted in the traditional core of the city. Several architectural attributes such as plans, forms and spatial dimensions were used to group the buildings into three typologies of seven (7) variants. The three identified house typologies are Traditional Compound Impluvium (TCI) with two identified variants according to their architectural features, Modified Compound Impluvium (MCI) with two variants and Brazilian Rooming Houses (BRH) with three variants (Tables 2

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and 3). Out of the 321 buildings surveyed, 157 (48.9%) are Traditional compound impluvium, 105 (32.7%) are modified compound impluvium and 59 (18.4%) are Brazilian rooming houses. Selected buildings were assessed for Natural ventilation after a careful and thorough examination of various factors affecting Natural Ventilation in buildings. Analysis of openings and air flow movement in buildings were carried out to determine their efficiency and effectiveness. Analysis of opening involved direct measurement of external wall area, external opening areas, opening height, sill level, opening width and floor area. This exercise was done typically for selected living room, bedroom and kitchen spaces in each of the buildings. These three spaces were found by Author [22] to be spaces where occupants spend most of their times in their various residential buildings. Summarily, three (3) spaces was analysed in each of the building and a total of 963 openings were evaluated in all. Each space has a maximum of one (1) opening (which is typical for Multi –habited homes).

Ventilation analysis was done by taking the average indoor air velocities in the selected living room, bedroom and kitchen spaces, this was done with the use of kestrel 4500 pocket weather and environmental metre. Instruments were properly calibrated in line with the climatic data of Ogbomoso obtained from the Nigeria Meteorological station and the data was presented.

Air velocity reading was compared with the mostly accepted recommendation of Borda-Dias [24] who submitted that air movements should be between 0.5- 1.5 m/s if effective ventilation and indoor comfort is to be achieved in residential buildings in the warm humid climate. Data obtained from opening analysis was also compared with the guidelines for the determination of opening ratio for warm humid climate as proposed by Chand [13] who recommended 30-50% of exposed wall area and 20-30% of floor area of a room. This method has previously been used by [22], [25], [26] and [27]

Adequacy of other factors affecting ventilation in buildings such as landscape, building orientation and external spacing were also accessed through physical inspection (direct observation). Data were analysed descriptively.

FINDINGS AND DISCUSSIONS

Typologies and variants of multi-habited buildings in the study area.

Obtained result of reconnaissance survey indicated that there are basically three typologies of Multi-habited buildings in the study area; they are the Traditional compound impluvium, Modified compound impluvium and Brazilian rooming houses. As reported in Table 1, out of a total of 321 buildings sampled, 157 (48.9%) are Traditional compound impluvium, 105 (32.7%) are Modified compound impluvium and 59 (18.4%) are Brazilian rooming houses. However, these house typologies are of different variants based on the analysis of their architectural features such as plans, forms and spatial dimensions. As shown in Table 2, two (2) variants of the traditional compound impluvium were identified; they are the "*rectilinear arrangement of rooms around an open courtyard"* and "*Arrangement of rooms along an open corridor"*. Similarly, identified variants of the modified compound impluvium are "*Multiple of rooms within a building (Rooming house)*" and "*Cluster of rooms within a building with*

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veranda and/or courtyard". However, three (3) variants of the Brazilian rooming houses were identified; they are "*Bungalow*", "*two (2) floors*" and "*three (3) floor Brazilian rooming houses*".

Table 1: Multi-habited building typologies and Orientation

1	**Multi habited building typologies**	**Frequency (n)**	**Percentage (%)**
i	Traditional Compound Impluvium	157	48.9
ii	Modified Compound Impluvium	105	32.7
iii	Brazilian Rooming houses	59	18.4
	Total	321	100
2	**Orientation**		
i	North-South	199	62.0
ii	East-West	68	21.2
iii	Northwest-Southeast	35	10.9
iv	Northeast-Southwest	19	5.9
	Total	321	100

Source: Authors field survey, 2021.

Table 2: Variants of typologies

S/n	**Typologies**		**Variants**	**Frequency**	**Percentage (%)**
1	Traditional Compound Impluvium	A	Rectilinear arrangement of rooms around an open courtyard	96	61.15
		B	Arrangement of rooms along an open corridor	61	38.85
			Total	157	100
2	Modified Compound Impluvium	A	Multiple of rooms within a building (Rooming house)	60	57.14
		B	Cluster of rooms within a building with veranda and/or courtyard.	45	42.86
			Total	105	100
3	Brazilian Rooming houses	A	Bungalow	47	79.66
		B	Two (2) floors	11	18.64
		C	Three (3) floors	1	1.3
			Total	59	100

Source: Authors analysis from field survey, 2021.

Building Orientation

Data on building orientation obtained in the study area revealed that out of 321 buildings surveyed, 199 (62.0%) are orientated with their longer sides on North-South axis, 68 (21.2%)

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are orientated with their longer sides on East-West axis, 35 (10.9%) are orientated on Northwest-Southwest axis and 19 (5.9%) are orientated on Northeast- Southwest axis. The implication of this is that majority of buildings (62.0% orientated on North-South axis) in the study area are badly orientated and hence exposes buildings to high solar penetration which invariably will cause heat build up in building internal spaces and will as well debar maximum utilization of outdoor air movements while only 21.2% of buildings with their longer sides on East-West axis are properly orientated. It was also observed that most openings are positioned in conformity with the building orientations. Building orientation in the study area could hence be said to be inappropriate as indicated in Table 1.

Spacing

As recommended by [17], building within the network of each other should be a minimum of five (5) times their height for effective air flow in and within spaces. However, physical measurements of spaces between buildings and height of buildings in the study area show an average of 2.4m and 3.6m respectively. The maximum spacing recorded was 3m and minimum was 1.1m. This is an indication that buildings are compactly built in the study area and hence, air movement within and around the buildings would be seriously hindered.

Ventilation and Opening Analysis

The location of opening along the height of a wall is defined by the height of the window sill. The air passing through a window is dependent on the level of the window sill [10]. Authors [13] and [29] as cited in [22] both recommended a maximum sill height of 0.9m in residential buildings if effective ventilation is to be achieved in buildings in the warm humid regions. However, as shown on Table 4, data obtained indicated that 81 (8.4%) windows have a sill height of between 0.00 – 0.90m, 78 (8.1%) have between 0.91-1.2m, 262 (27.2%) have a sill height of between 1.21 - 1.50m, 330 (34.3%) have between 1.51 - 1.80m and 212 (22.0%) buildings have a sill level of above 1.80m. This implies that majority of windows (91.6%) in Multi-habited buildings in Ogbomoso were located more than 0.9m above the ground level. Data indicated that none of the windows in the Traditional compound impluvium and Modified compound impluvium meets the above recommendation. However, majority of living room 42 (71.2%) and bedroom 36 (61.0%) spaces in the Brazilian rooming houses satisfy the above recommendation except the kitchens where only 2 (3.4%) satisfy the condition.

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Table 4: Window sill height

M-H Typology	Window Sill Height (m)															
	0.00-0.90			**0.91-1.20**			**1.21-1.50**			**1.51-1.80**			**Above 1.8**			**Total**
	L/Rm	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm.**	**Kit.**	**L/Rm**	**B/Rm**	**Kit**	**L/Rm**	**B/Rm**	**Kit.**	
Traditional compound impluvium	0	0	0	0	4	2	67	5	3	89	61	67	0	88	85	471 (48.9 %)
Modified compound impluvium	0	0	0	0	36	1	104	42	20	1	6	71	0	21	13	315 (32.7 %)
Brazillian rooming houses	42	36	2	17	18	1	0	0	21	0	1	34	0	4	1	177 (18.4 %)
Total	81 (8.4%)			78 (8.1%)			262 (27.2%)			330 (34.3%)			212 (22.0%)			963 (100 %)

Source: Authors analysis from field data, 2021

Table 5: Window/wall area and Window/floor area ratio

Average area ratio	**M-H Typologies**								
	Traditional compound impluvium			Modified compound impluvium			Brazilian rooming houses		
	L/Rm	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm.**	**Kit.**
Window/wall area ratio (%)	16.01	2.98	7.12	22.74	6.93	7.69	28.08	18.13	7.03
Window/floor area ratio (%)	13.13	3.02	8.39	14.42	6.22	9.38	23.30	14.82	7.96

Source: Authors analysis from field data, 2021

In terms of the ratio of window area to the wall area and the ratio of window area to the floor area, guidelines for the determination of these ratios for warm humid climate have been proposed; Chand [13] have prescribed the range of opening (window) for effective ventilation in warm humid climate to be between 30 – 50% of the exposed wall area and between 20–30% of the floor area of a room.

The results shown in Table 5 revealed the calculated window/floor area ratio and window to exposed wall area ratio. Using Chand's recommendation, none of the investigated spaces in all

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the multi-habited building types attained the recommended value of 20 – 30% of window/ floor area except the living room of the Brazilian rooming houses where an average value of 23.3.% was recorded. The lowest observed value was recorded in the bedroom of the Traditional compound impluvium with an average recorded value of 3.02%.

Similarly, analysis of the window/wall area ratio also indicated that none of the investigated spaces in all the buildings meet up with the Chand's recommendation of 30-50% of widow/wall area. The highest value recorded was also in the living room of the Brazilian rooming houses with an average value of 28.08% recorded and the lowest value also recorded in the bedroom of the Traditional compound impluvium with an average observed value of 2.98%.

Considering the obtained data on window sill, window/wall and window/floor area ratios, it can be inferred that opening condition in the study area is not appropriate for ventilation comfort in all of the spaces, only the living room of the Brazilian rooming houses has a likelihood of being naturally ventilated and consequently, providing a desirable comfort.

Table 6: Climatic data of Ogbomoso.
Town: ***Ogbomoso*** *latitude* 8^0, 10^1 *longitude* 4^0, 10^1 *Year: 2011-2015*
Source: Nigeria meteorological station, 2015

Month	Temp. °C (Max.)	Temp. °C (Min.)	Temp. °C Mean monthly	RH(AM) %	RH(PM) %	Rainfall (mm)	Radiation MJ/m^2/day	Wind Speed(m/s)
Jan	35.5	*19.6*	*26.6*	*66.3*	*41.3*	*0.3*	*12.1*	*1.47*
Feb	*34.8*	*20.5*	*27.7*	*68.2*	*35.9*	*10.8*	*12.8*	*1.45*
March	*34.6*	*22.6*	*28.6*	*62.6*	*46*	*47.7*	*13.6*	*1.44*
April	*33.1*	*22.2*	*27.7*	*77.2*	*61*	*103.2*	*13.1*	*1.42*
May	*32.0*	*22.2*	*27.1*	*80.8*	*65.6*	*149.5*	*12.3*	*1.51*
June	*30.9*	*21.8*	*26.4*	*84.7*	*69.1*	*180.1*	*10.9*	*1.51*
July	*29.3*	*21.5*	*25.4*	*89.1*	*71.6*	*181.6*	*9.7*	*1.49*
August	*28.9*	*20.8*	*24.9*	*84.8*	*73.6*	*141.3*	*8.9*	*1.47*
September	*29.4*	*20.8*	*25.1*	*87.3*	*71.6*	*222.6*	*9.5*	*1.5*
October	*31.3*	*19.6*	*25.5*	*85.3*	*66.3*	*185.2*	*10.6*	*1.47*
November	*33.0*	*20.5*	*26.8*	*83.5*	*54.9*	*79.7*	*11.9*	*1.47*
December	*33.2*	*18.7*	*26.0*	*73.9*	*44.5*	*12.2*	*11.8*	*1.43*
Average	*31.9*	*20.9*	*26.4*	*78.6*	*58.5*		*11.4*	*1.47*

Table 7: ventilation analysis.

	M-H Typologies								
	Traditional compound impluvium			Modified compound impluvium			Brazilian rooming houses		
	L/Rm	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm**	**Kit.**	**L/Rm**	**B/Rm.**	**Kit.**
Avearage Indoor air velocity (m/s)	0.28	0.08	0.17	0.42	0.17	0.19	0.48	0.36	0.17

Source: Authors analysis from field data, 2021

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Average indoor air velocities in the living room, bedroom and kitchen spaces were also taken with the use of kestrel 4500 pocket weather and Environmental meter in order to validate the data obtained from opening analysis as earlier discussed. The recommendation of Borda–Dias [24] that the average indoor air velocity in residential houses of warm humid climate for effective ventilation should be between 0.5 – 1.5 m/s was adopted. This was adopted because the values provided wide range of ventilation comfort and also, other Scholars like [22] and [26] have adopted and used it in the past. The measurements were taken in the referenced living room, bedroom and kitchen in each building. Result as indicated on table 7 shows that none of the spaces under consideration in all the three typologies satisfies the above criteria. The highest value was recorded in the living room of the Brazilian rooming houses with an average value of 0.48m/s and the worst situation was observed in the bedroom of the Traditional compound impluvium buildings with an average value of 0.08m/s. The average recorded value in other spaces ranges from 0.17-0.38m/s. The implication of this is that generally, natural ventilation condition in multi-habited buildings in Ogbomoso is poor which invariably would mean that hot thermal discomfort would be experienced in their indoor spaces and hence, there is likely to be a very high dependence on active driven devices as supplements if desirable indoor comfort is to be achieved or be forced to endure hot discomforting situations if the cost of procurement, operation and maintenance of the devices cannot be afforded. This result is in conformity with result obtained from the analysis of opening.

Landscape

No proper natural (soft) landscape was observed in the study area, though a few scanty trees could be seen, hard landscape and bare land was dominant. Landscape in the study area could hence be said to be inappropriate.

Table 8: Factors affecting Natural ventilation in Multi-habited homes

Factors	Adequacy
Landscape	Inadequate
Building Orientation	Inadequate
External Spacing	Inadequate
Window Openings	Inadequate

Source: Authors analysis, 2021

CONCLUSION AND RECOMMENDATIONS

The objective of the study was to investigate indoor natural ventilation condition in multi-habited buildings in the traditional core of Ogbomoso. The study employs physical observation and direct measurements to determine the adequacy of each factors affecting ventilation in buildings. Kestrel 4500 pocket weather and environmental metre was used to determine the velocity and flow of air in selected spaces of living room, bedroom and kitchen in each of the building.

The study identified three (3) typologies of seven (7) variants of multi-habited buildings in the study area. The typologies are the Traditional compound impluvium, the modified compound

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impluvium and the Brazilian rooming houses. Data obtained revealed that most multi-habited buildings in the study area are poorly orientated i.e., Sixty two percent (62.0%) of buildings are orientated with their longer sides on North-South axis; the implication is that majority of the buildings are exposed to high solar glare and air penetration into the buildings will be debarred. Building spacing is also grossly inadequate when compared with standards just as no planned natural landscape was observed in the study area. Result obtained on analysis of opening indicated also that there is generally a gross inadequacy in the opening provided in the Traditional compound impluvium and the Modified compound impluvium buildings though an improvement was observed in the Brazilian rooming houses. The opening result clearly aligns with the data obtained in the analysis of air movements (velocity) in the examined internal spaces. Data obtained revealed a generally poor air velocity level when compared with standards except the living room of the Brazilian rooming houses which have a very close result.

The outcome of the study has clearly shown that there is a generally poor ventilation condition in multi-habited buildings in the traditional core of Ogbomoso and hence, residents are likely to depend on active driven mechanical if indoor comfort is to be achieved or be forced to endure hot discomforting situations if the cost of procurement, operation and maintenance of the devices cannot be afforded.

The study hence recommends that a more awareness on factors affecting natural ventilation should be created, rehabilitation of Multi-habited buildings especially as it concerns landscape, external spacing and window sill levels for improved Natural ventilation systems should be embarked upon. Also, the study is delimited to Multi-habited homes in the traditional core of the city, research frontiers should however endeavour to carry out similar

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Conflict of Interest
Authors have not declared any conflict of interest

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