ASSESSMENT OF INDOOR AIR QUALITY IN STUDENT HOSTEL IN FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

By

AKOH, Shadrach Akoh

MTech/SET/2019/9632

DEPARTMENT OF ARCHITECTURE

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE

AUGUST 2023

ASSESSMENT OF INDOOR AIR QUALITY IN STUDENTS' HOSTEL IN FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

BY

AKOH, Shadrach Akoh

MTech/SET/2019/9632

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ARCHITECTURE

AUGUST, 2023

DECLARATION

I hereby declare that this thesis titled: **Assessment of Indoor Air Quality in Students' Hostel in Federal University of Technology, Minna, Niger State,** is a collection of my original research work and has not been presented for any other degree anywhere. Information from other source (published or unpublished) has been duly acknowledged.

AKOH SHADRACH AKOH
MTech/SET/2019/9632
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA, NIGERIA

SIGNATURE/DATE

CERTIFICATION

The Thesis titled: **Assessment of Indoor Air Quality in Student Hostel in Federal University of Technology Minna, Niger State** by: Akoh Shadrach Akoh (MTech/SET/2019/9632) meets the regulations governing the award of the degree of (MTech) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Prof. P. Ayuba ______________________________
Supervisor Signature & Date

Dr. A. D. Isah ______________________________
Head of Department Signature & Date

Prof. O.A. Kemiki ______________________________
Dean, School of Environmental Technology Signature & Date

Engr. Prof. O. K. Abubakre ______________________________
Dean of Postgraduate School Signature & Date

DEDICATION

This work is dedicated to the all loving God for the abilities he has bestowed in me, my father, Dr. S.O Akoh, siblings and immediate family members for their prayers, encouragement and support and also to my supervisor for the effort inputted throughout the entire project.

ACKNOWLEDGEMENT

I am deeply indebted to God Almighty whose hand of help was available at every point to ensure that this thesis is a success. Special thanks go to my father, Dr. S. O. Akoh, my uncle, Dr. S. R. Akoh and my siblings for their prayers, moral and financial efforts to give me education for a bright future. My acknowledgement and appreciation go to my supervisor, Prof. P. Ayuba, for the guide, criticism and counsel which has led to the success of this thesis. I want to appreciate some other lecturers I consulted with in person of Dr. I. B Muhammad and Dr. O. K. Akande. I also want to appreciate all the lecturers of the Department of Architecture, Federal University of Technology Minna, for their individual and collective mentorship throughout my years of studies.

Also, special thanks goes to my friends in persons of Francis Basil, Menegbe Majiyebo Momoh Thankgod, Jiya John and Abdusalam Mubarak, who have contributed in every possible way and every one of my course mates, who in one way or the other inputted and helped in the realization of this thesis. A big thanks goes to my research assistants who helped in the process of data collection and documentation; Emmanuel Agbonghale, Isah Nicholas, Adi Sarah, Blessing Thomas, Oluwoyo Christiana and Najimi Daphne. Last but not the least, a shout out to my friend and esteemed statistician in person of Sunday Peter for his sleepless nights and relentless efforts to ensuring accurate results. God Almighty bless you all.

ABSTRACT

Indoor air pollution is a significant global public health concern, ranking among the top five environmental risks associated with morbidity and mortality. Poor indoor air quality (IAQ) can lead to a wide range of adverse health effects. Moreover, the recent pandemic has underscored the importance of maintaining good indoor environmental quality. This issue is particularly pressing in Nigerian tertiary institutions where accommodation facilities, especially in hostels, often face challenges such as inadequate maintenance, improper design, overcrowding, and problematic occupant behavior, all contributing to indoor air contamination. In response to these concerns, this study aims to assess the indoor air quality in the student hostels at the Federal University of Technology, Minna. The ultimate goal is to integrate IAQ improvement strategies into hostel design. The study sought to identify factors affecting IAQ, conduct building assessments, and investigate the impact of IAQ on occupants' health. A hypothesis posited that occupants' behavior is the primary factor influencing indoor particulate concentrations. To gather empirical evidence and conduct building assessments, the study employed a mixed research method, utilizing the Building Assessment and Study Evaluation (BASE) strategy. The quantitative phase involved a questionnaire survey of occupants and air quality testing using air visual nodes. The qualitative phase comprised a case study survey of each existing student hostel. Findings revealed the presence of biological pollutants like mold and mildew, as well as chemical pollutants including carbon monoxide (CO), carbon dioxide (CO2), and particulate matter (PM2.5 and PM10). Areas where students cooked had higher CO2 levels. Hostel spaces with more occupants exhibited elevated pollutant concentrations (1326 ppm of CO_2 $PM_{2.5}$ and PM_{10}, with values as high as 116.78 ug/m^3 and 172.99 ug/m^3 respectively), often influenced by occupant behavior. Additionally, the study highlighted the positive relationship (0.998) between particulate matter levels in different hostel blocks. Indoor air quality significantly impacted occupants' health, with reported cases of respiratory symptoms and diseases. Malaria was the most commonly recorded disease (with a Weighted Mean as high as 3.53), followed by respiratory conditions like asthma and influenza. In conclusion, the study established that both the number of occupants and occupant behavior play pivotal roles in determining indoor air quality and particulate concentrations. Furthermore, the findings suggest the existence of respiratory diseases beyond those recorded, emphasizing the need for expanded testing. Recommendations include the provision of more hostel accommodations to alleviate overcrowding, improved hostel management for maintenance and policy enforcement, and expanded testing for respiratory-related diseases at the university health center. Addressing these issues will contribute to healthier indoor environments for students.

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The National Health and Medical Research Council NHMRC (1996), defines indoor air as the air within a building occupied for at least one hour by people of varying states of health. This space can include the office, classroom, hostels, shopping centres, hospitals and homes. The air within these spaces can be polluted. The presence of harmful substances such as gases, particulates or biological molecules in the Earth's atmosphere is known as air pollution (Loomis *et al.,* 2013). Human exposure to air pollution has serious implications for health: Short term exposure may exacerbate asthma and be responsible for hospital admissions (Zheng *et al.,* 2015), whilst long term exposure to ambient air pollution is repeatedly associated with a higher incidence of cardiovascular and respiratory diseases (Pope *et al.,* 2011; Atkinson *et al.,* 2016; COMEAP, 2018), birth defects (Padula *et al.,* 2013) and neuro-degenerative disorders (Moulton and Yang, 2012). Indoor air pollution is placed among the top five environmental public health risks that cause morbidity and mortality globally.

The majority of people spend more than 90% of their time in indoor environments (Abraham and Li, 2016; Amaotey *et al.,* 2018), and health problems and diseases associated with poor indoor air quality (IAQ) can cause a variety of adverse health effects to them (Amaotey *et al.,* 2020; Koivisto *et al.,* 2019). The time spent indoors recently increased significantly in year 2020 due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic when people are advised to 'stay home stay safe' to protect health workers (Brittain *et al.,* 2020; Kumar and Morawska, 2019).

Clean air should be everyone’s right just as clean water (UNEP, 2019). Unfortunately, indoor air quality is often compromised because of air pollution, mould and many other factors (Marjo, 2021). Oxygen a component of air is needed for man to breathe and for the total running of his system. A polluted air creates discomfort to man and can cause respiratory diseases and an eventual death. Indoor air quality is a factor for humans to live comfortably in any enclosed space. A number of factors affects indoor air quality; this ranges from the factors in the enclosed space even to the factors of the environment. Enclosed factors include; space configuration, ventilation, room temperature, humidity of the space, materials used. The environmental factor involves; the building orientation, the outdoor air pollution level, vegetation cover and air flow.

A hostel is referred to as a place where people can stay when their residence is located far from the educational institution and which is considered essential to students' needs, which also called student housing (Yazeed and Halil, 2018). The chief goal of hostels is to provide quality living and sleeping environment for the occupants (Abiodun, 2014). According to Schrager (1986), “students’ accommodation is more than just a place to live; it is an organization in which students are participants”. The provision of students’ accommodation helps in catering for students’ housing needs in accomplishing academic, living, and social goals during their study life span at the university (Hassanain, 2008).

1.2 Statement of the Research Problem

According to Maina and Aji (2017), factors affecting students’ performance are broadly categorized into three; namely; family, students and school characteristics. Under the student category, well-being, health status of the students affects the academic performance of the student. The state of any hostel directly affects the health status of the students inhabiting these spaces. The time spent indoors recently increased significantly in year 2020 due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic when people are advised to ‘stay home stay safe’ to protect health workers (Brittain *et al.*, 2020; Kumar and Morawska, 2019). This points to the fact that in the work from home policy introduced during the pandemic period will be upheld by organisations as well as tertiary institutions thereby increasing the time spent indoors.

Having stayed five (5) years in the male hostel (blocks A and B precisely), it was observed the poor state of indoor air quality arising from a load of factors which include; overcrowding of space, air pollutants generated from cooking indoors as well as the poorly maintained general toilets, improper waste disposal systems especially for rooms in the upper floors, clogged drainages in the courtyards, poorly landscaped outdoor environment which has generated air pollutants within the environment, polluting the air coming into the indoor environment. This generated a concern and need to access the indoor air quality of the existing hostels generally.

1.3 Aim and Objectives of the study

The aim of this thesis is to assess the indoor air quality of the students’ hostels in Federal University of Technology Minna, towards integrating indoor air quality strategies in the design of student hostel. To achieve this aim, the following objectives were considered;

1. To determine the factors that affect indoor air quality.
2. To assess the indoor air quality of the existing hostel accommodation with the factors gotten from the first objective.
3. To investigate the impact of indoor air quality on the health status of the students occupying the spaces

4. To integrate indoor air quality strategies both passively and actively in the proposed student hostel design.

1.4 Research Questions

This research seeks to answer the following research questions;

1. What are the factors that affect indoor air quality in the study area?
2. What is the state of the hostel facility in regards to indoor air quality?
3. What impact does indoor air quality have on the health status of the students occupying the spaces?

1.5 Research justification

The 2030 Agenda for Sustainable development, adopted by all UN member states in 2015, provided a blueprint having 17 sustainable development goals. The third goal entails good health and well-being for all within a proximal location. This entails a quality indoor air and its assessment is a step to ensure good health and well-being of users in their spaces. World Health Organization (WHO, 2018) states that 3,8 million people a year die prematurely from illnesses such as pneumonia, stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer which are attributed to one of the major aspects that falls under this category: indoor air pollution.

The European Public Health Alliance has warned that people living in polluted cities are more at risk from COVID-19, because asthma, chronic obstructive pulmonary disease, high blood pressure and diabetes. COVID-19 has more serious consequences on patients with pre-existing health issues that are in many cases caused by air pollution. Dr. Meredith McCormack from the American Lung Association and Johns Hopkins

University states that “a person who is exposed to air pollution would likely have a worse outcome if they were exposed to coronavirus”.

Several researches have been conducted on indoor air quality as well as indoor air pollution level, but none has been conducted on the study area. Adama *et al.* (2019) did a research on Influence of Availability and Serviceability of Student Accommodation Facilities on student performance in Federal University of Technology Minna. Lauren *et al.* (2020) did a research on Exposure to indoor air pollution across socio-economic groups in high income countries: A scoping review of the literature and a modelling methodology.

1.6 Scope of the Study

The geographical scope of this study will cover the selected halls of residence within the Federal university of technology Minna, Gidan Kwano campus for both the male and female hostels with regards to the set aim of the study. The scope of this research will assess the indoor living spaces with respect to indoor air quality requirements as regards to ventilation, space configuration, number of occupants, time spent in the space per day, air pollutants present in the space. The outdoor environment within the building facility will the assessed as regards to sanitary areas and potential sources of air pollutants which affects the air quality of the interior spaces. The environmental factors to be considered include building orientation, landscape design, waste dump site if any. The halls of residence to be assessed which are primarily allocated to the undergraduate students include;

i. Male hostel blocks A and B

ii. Old female hostel blocks C-G

iii. Shehu Aliyu Hostel (female)

iv. New Public Private Partnered Hostel blocks (male and female separately)

1.7 The Study Area

The study area is Niger state, Nigeria. Minna, the state capital of Niger State and a famous railway town, lies approximately on latitude 90711 North and Longitude 60331 East. However, the town has transformed from a small traditional settlement to an urban centre with modern facilities and amenities. The State is largely agrarian (Ministry of Lands and Housing Minna, 2012). According to Adedayo and Sulyman (2013), the State at the inception in 1976 had only eight Local Government Areas (LGAs), this has increased to twenty-five due to boundary adjusted and creation of additional Local Government Areas. Federal university of Technology Minna, is a federal government owned university in Nigeria, established on 1st February, 1983. The objective for its establishment is to give effect to the Nation's drive for the much-needed self-reliance in science, engineering and especially technology. It has two campuses; Bosso and Gidan Kwano Campus. The Gidan kwano campus is sited on a 10650 hectares of land located along the Minna – Kataeregi – Bida Road.

Figure 1.1**:** Political map of Nigeria with emphasis on Niger state**.**

Source: Oguh *et al.* (2019).

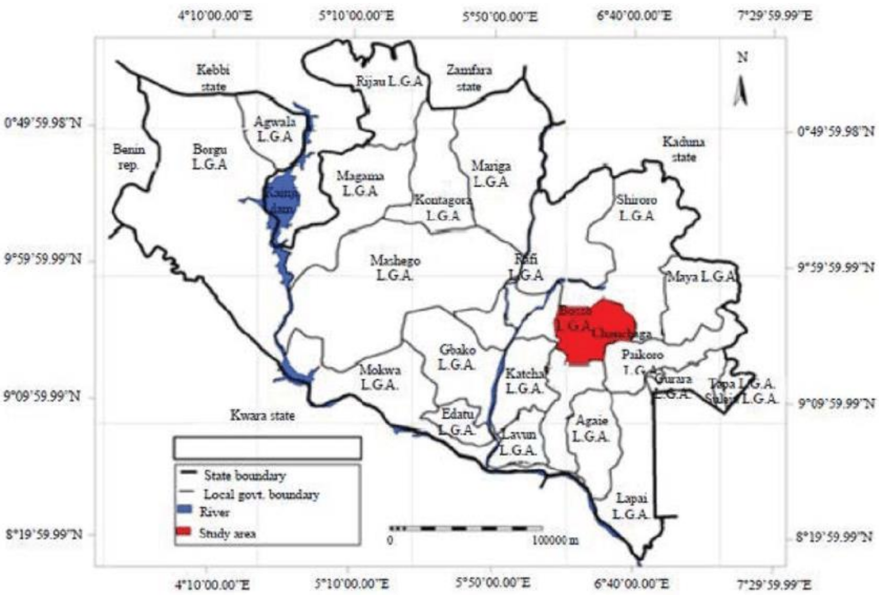


Figure 1.2: Map Niger State with emphasis on Bosso Local Government Area where the university is resided.

Source: Oguh *et al.* (2019).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Hostel

2.1.1 Definition of hostel

Kolawole and Boluwatife, (2016), identifies the hostel as an essential aspect of the tertiary institution as its availability is an attraction to a large number of students from different backgrounds to study in the tertiary institution. Nimako and Bondinuba, (2013), further stated that hostels in tertiary institutions are so important that its adequacy is highly needed in any tertiary institution to enable students make most use of the educational opportunity. This agrees with (Muhammad *et al.,* 2014) said about hostel. Gichere *et al.* (2019), defines hostel as a place that a student lives while studying a particular programme at an institution which comprises of the immediate environment, health, economic, sporting and social activities that are sympathetic to academic work. Owolabi, (2015), defines student housing as a place where students reside within or outside the campus or school.

Ekejiuba and Emetarom (2014) also defined a hostel as a building that houses students under the leadership of hostel administrators. On the other hand, Edgar and Meert (2006), define a hostel as a legal space for temporary dwelling. With these stated definitions, a consensual definition is opined by Sawyerr and Yusof (2013) who defined student housing as a set of accommodation provided by the school authority within the campus to house the students with rules and obligations put in place to monitor the behaviors of the said students and chargeable fees paid by them to have access to the use of these accommodations. Dabo *et al.* (2013) categorized students' accommodation into four, these include; Traditional on campus accommodation (TOC), Off campuses leased (OCL), On-campus school managed (OSM) and Off-campus private (OP). The type of hostel that is adopted in the Federal University of Technology (FUT) Minna is the traditional on campus accommodation. From the table 2.1, it shows the characteristics of TOC and as such maintenance is highly needed and is best suited for a university system.

Table 2.1. Types of Accommodations and their characteristics

	Academic Proximity	**Students Discipline**	**Maintenance Cost**	**Security**
Traditional On campus	Student can easily reach academic facilities and services	Can be controlled by the school	High maintenance cost	Security to the students may be guaranteed
Off-campus school managed	Students may not be easily assessable to academic facilities and services	May be control by the school	Very high maintenance cost	Security to the students may somehow be guaranteed
Off campus leased	Students cannot be assessable to academic facilities and service	May be control by the school	Very low, maintenance cost	Security to the students may be guaranteed
Off-campus Private	Students cannot be assessable to academic facilities and service	Cannot be control by the school	No maintenance cost	Student security cannot be guaranteed

Source: Dabo *et al.* (2013)

2.1.2 Types of hostel

Shady *et al.* (2020) stated that irrespective of the categories of accommodation described by (Dabo *et al.*, 2013), there exists several types of hostels worldwide, each having its benefits. They include;

i. Dorm room student housing

ii. Residence halls

iii. Private apartment

iv. Kot

v. Room in a private house

vi. Studio

i. Dorm room student housing:

Dorms or dormitories within or close to a university campus, which is convenient for students and can have shared or independent services. Dorm rooms can have individual or multiple student occupants.

ii. Residence halls:

Dorms or dormitories that are within or close to a university campus that is convenient to students. In residence halls, students have individual rooms and can have shared services or independent services in each room.

iii. Private apartment/house:

Regular apartments or houses that can be shared by students.

iv. Kot:

Lodging apartments that are refurbished study rooms. They are privately rented to cater to students with shared amenities. Kots are used in Belgium and mean a small shelter, which most of the time has a common kitchen and bathroom.

v. Room in a private house:

Private rooms that are leased by a house owner who lives in the same house.

vi. Studio:

Have larger spaces than dorm rooms and can be shared by one or two persons. A studio has its own kitchen and sanitary services.

2.1.3 Demand for hostel

The demand for student housing is consistently surpassing supply across Europe and Worldwide (Ong *et al.,* 2013). In 2018, the total number of international students worldwide reached 6.3 million, up from 4.1 million in 2014, and expectations of student accommodation have increased (Emilio, 2018). Nigeria has the biggest tertiary education system in Sub-Saharan Africa with 129 accredited universities, 78 Polytechnics and 63 Colleges of education (Adewunmi, 2012). More than 50% of the universities have over 20,000 students each (Dabo *et al.,* 2013). While the universities have continued to experience an average of 12% rise in student enrolments over the past decades, the surge in students has not been matched by a corresponding growth in student accommodation. Figures from the National Universities Commission (NUC) have shown that, the provision of student housing is less than 30% of demand (NUC, 2000).

The number of students admitted to universities usually surpasses the available accommodation available in those institutions. FUT Minna for instance can only accommodate 1930 students out of the approximately 18000 students admitted in the Gidan Kwano Campus (Adama *et al.,* 2019). The limited accommodation leads to off-campus residence for majority of the students (Gichere *et al.*, 2019).

2.1.4 Choice of hostels

Several studies have been conducted on the factors that influenced the choice of hostels by students. Oyetunji and Abidoye (2016) evaluated the factors influencing the choice of housing among students of Federal University of Technology Akure and discovered that proximity to campus the rental value of property, and type of dwelling are the main factors that influence students' choice. While Adebiyi *et al.* (2017) assessed the factors influencing the choice of housing among first-year students of the University of Benin and discovered that income of parents or sponsors, price of accommodation, gender of other occupants, proximity to classrooms and other places of interest, security, the age of the student, privacy, availability and frequency of supply of utilities, size of the accommodation and the conduciveness of the environment were the most important factors that students considered in choosing student housing in the University of Benin.

Table 2.2: Factors influencing the choice of housing among students

Factor	Mean	Rank
Availability of hostel	4.65	1
Security	4.63	2
Proximity to school activities	4.57	3
Quality of the hostel	4.43	4
Income of sponsors	4.35	5
Personal privacy	4.29	6
Hostel fees	4.26	7
Availability of off-campus housing	3.74	8

Source: Adilieme (2019)

Adilieme (2019), conducted a research on the student housing satisfaction among students of the university of Lagos and discovered that irrespective of the hostel fees, students are ready to pay if the hostels are available. They placed the quality of the hostels above their personal privacy and as such indoor air quality is a factor to be considered to raise the quality standard of any hostel.

2.2 Environmental Health

The first line of thought when the phrase environmental health is mentioned is towards hygiene and sanitation. Lukkumanul (2019), explained vividly the term environmental health been broader than hygiene and sanitation as it comprises of hygiene, sanitation and every other environmental factor that influences health. The World Health Organization (WHO) defined environmental health as all the physical, chemical and biological factors external to a person, and all the related factors impacting behaviours. It encompasses the assessment and control of those environmental factors that can potentially affect health. There exists both indoor environment and outdoor environment (Darçin and Balanli, 2020)

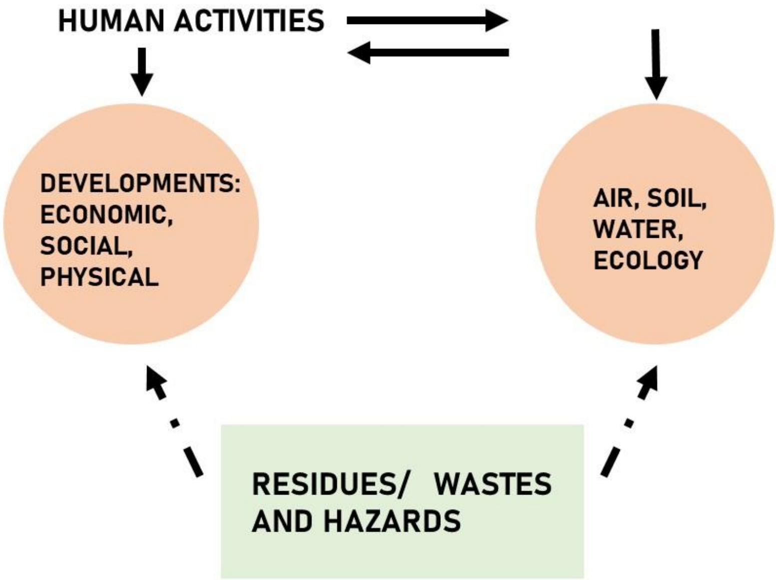


Figure 2.1: Human–environment interaction model.

Source: (Lukkumanul, 2019)

2.2.1 Air pollution

The presence of harmful substances such as gases, particulates or biological molecules in the Earth’s atmosphere is known as air pollution (Loomis *et al.*, 2013). Human exposure to air pollution has serious implications for health: Short term exposure may exacerbate asthma and be responsible for hospital admissions (Zheng *et al.*, 2015). These exposures as earlier established by Lauren *et al*. (2020) is experienced at the outdoor and indoor level.

For the purpose of this research, indoor exposure is critically examined. However, there exists a connection between the indoor air and outdoor air as the flow of air comes from outdoor to indoor as shown in figure 2.2. Therefore, exposure to outdoor air pollution will be discussed briefly.

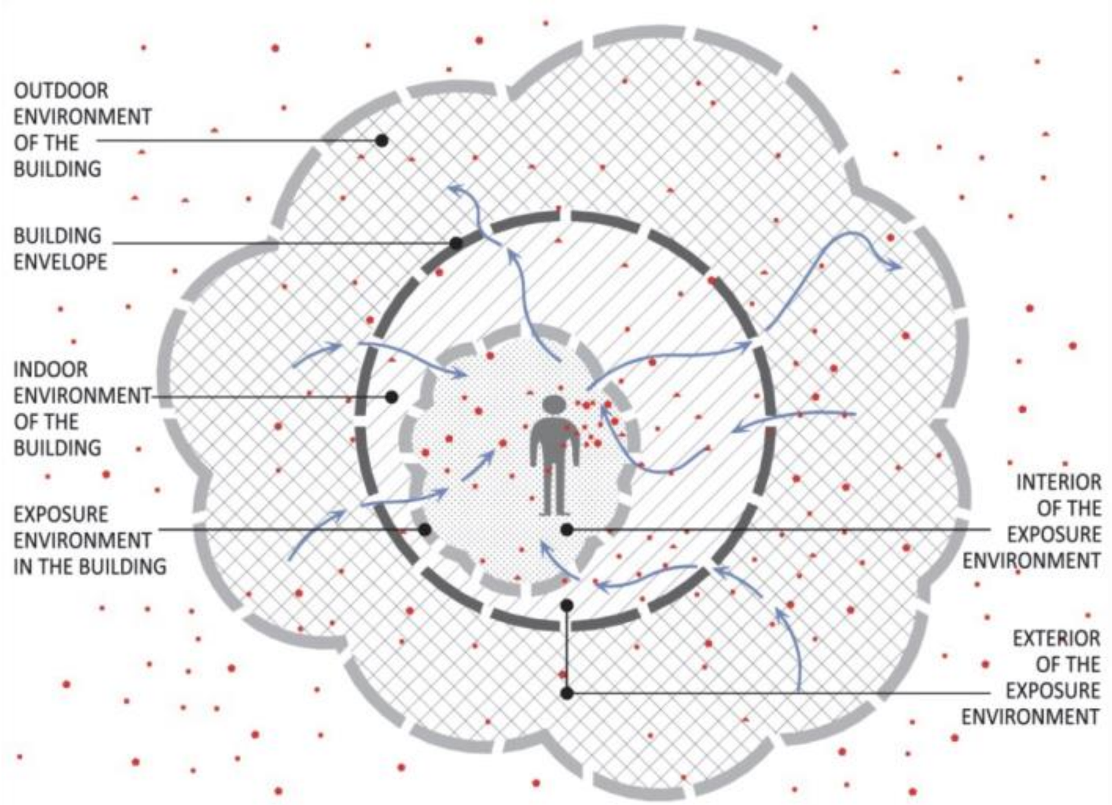


Figure 2.2: Building and its environments.

Source: Darçin and Balanli (2020).

2.2.1.1 *Outdoor air pollution*

Ambient air refers to the outdoor air in a neighborhood or community, as opposed to the air inside buildings such as homes and schools (Hiricko, 2009).The American Thoracic

Society define outdoor pollution as a mixture of tiny particles and gases that affect the health of children and adults. long term exposure to ambient air pollution is repeatedly associated with a higher incidence of cardiovascular and respiratory diseases (Pope *et al.,* 2011; Atkinson *et al.,* 2016; COMEAP, 2018), birth defects (Padula *et al.,* 2013) and neuro-degenerative disorders (Moulton and Yang, 2012).

Indoor air pollution from outdoor sources may occur due to infiltration of pollution from anthropogenic activities, such as vehicular traffic, a common source of particulate matter (PM) and nitrogen dioxide (NO_2) (COMEAP, 2018), or natural sources, such as radon from radioactive decay in the ground (Turk *et al.,* 1990). The airtightness of the dwelling, the number of external façades and their exposure to wind, and window-opening behaviour by the occupants will impact the amount of pollution that passively enters (Hänninen *et al.,* 2004).

2.2.2 Indoor air pollution

The problems associated with the air we breathe indoors have become one of the greatest challenges we face in recent time (Ehsanul *et al.,* 2012). Air pollution in closed spaces of built environments is quite often a mixture of many different pollutants (Ferro and Hildemann, 2007) that may emerge from a vast number of sources and mostly prone to undergo hard to predict transformations (Milner *et al.,* 2011). Hawaii's Pollution Prevention Information (HAPPI), stated that there are four major sources of indoor air pollution which are; combustion byproducts, such as smoke and carbon monoxide, building materials, including carpets, wood products, and paints, household products and chemicals, such as cleaning solvents, adhesives, and paint strippers and biological contaminants such as mildew, animal dander, and dust mites as shown in figure 2.3 below.

A building, basically created by separating a part of the nature with an envelope to be re-organized as a living area for their users (İzgi, 1999), comprises many interwoven sub-systems with numerous different participants. On account of this, a certain closed space or a definite part of it, which gathers users and pollutants together, can be defined as an exposure environment (Darçin and Balanli, 2020). They further stated that the architectural organization of the spaces affects the exposure due to determining specific properties related to users.

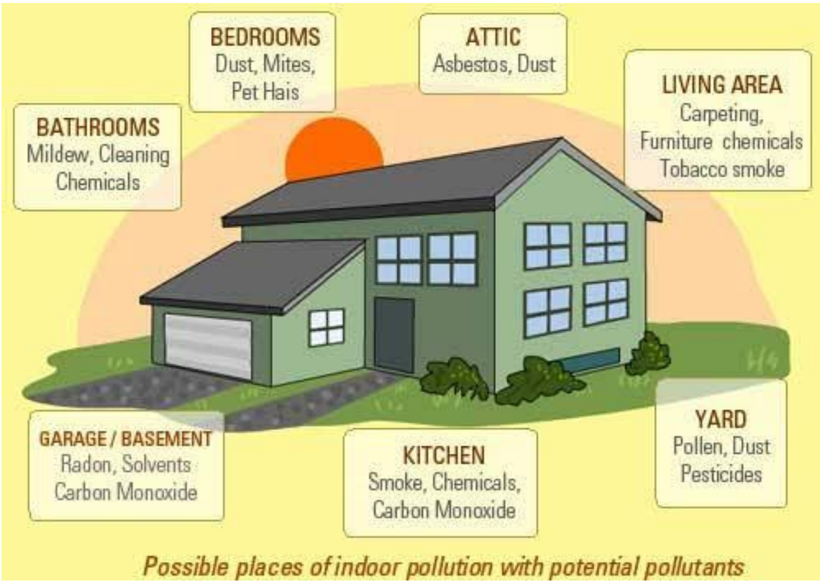


Figure 2.3: Common indoor air pollutants and their sources.
Source: Adopted from Tran *et al.* (2020).

2.2.2.1 Volume of the exposure environment on the exposure process

As the air pollutants emerge into the building, they disperse in the indoor air filling the volume of the closed space depending on their physical properties and air conditions to develop a certain level of concentration. Under proper circumstances, molecules of the pollutants in the gas / vapor state can homogeneously mix into indoor air (Kephalopoulos *et al.*, 2006) and reveal a constant concentration level throughout the space (Repace, 2007). Subsequently, the volume of the space is inversely proportional to concentration level of gas and vapor pollutants as shown in Figure 2.4. On the other hand, particulate matter pollutants may present a heterogeneous dispersion according to their size, weight, form, surface properties, etc. as they become airborne for a certain period of time and almost always sink.

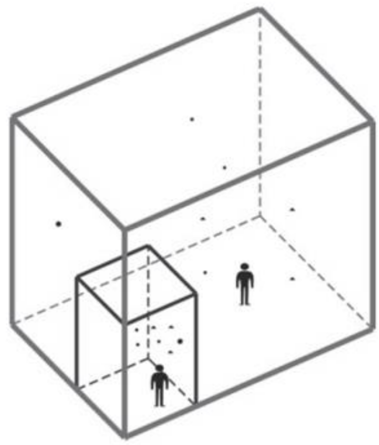


Figure 2.4: Relationship between Volume of the Space and Concentration Level.
Source: Darçin and Balanli (2020)

2.2.2.2 Air movements in and around the exposure environment

The fundamental physical phenomenon affecting the properties of indoor air pollution is the movement of air molecules which is caused by the driving effect created by the differentiation among air pressures which can occur naturally or by force between different parts of a closed space Source: (Darçin and Balanli, 2020). Chen and Glicksman (2001), highlighted that Geometric properties of the space (Chen and Glicksman, 2001) and its interior organization (such as the positions of furniture or separators) (Spengler *et al.,* 2001) are the other constituents that determine the speed, direction, behaviour and form of the airflow (Darçın & Balanlı, 2012). Replacement of indoor air of a closed space with outdoor air is defined as air exchange and the ratio between the incoming air flow

(m^3/h) and the volume of the space (m^3) determines the air exchange rate (h^{-1}) (Salthammer and Bahadir, 2009).

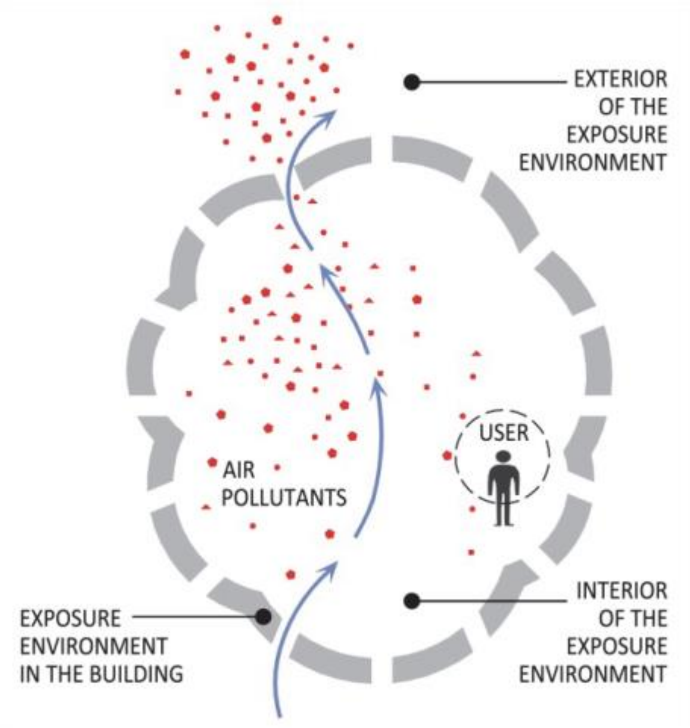


Figure 2.5: Effects of Air Movements in and around the exposure environment.
Source: Darçin and Balanli (2020).

Along with the moving molecules of air in and between interior and exterior environments of the space all other airborne substances are replaced and transported (Demokritou, 2001) therefore the position, duration and concentration levels of pollutants can be affected (Figure 2.5).

2.3 Indoor Environmental Quality (IEQ)

Indoor environmental quality (IEQ) as one of the features of green buildings and the sustainable environment has been drawing much attention, due to its high impact on the behaviour of the building users (Alfa and Öztürk, 2019). A growing body of knowledge recognizes the need for satisfactory indoor environmental quality (IEQ) in the built environment. According to Zuhaib *et al.* (2018) and Tang *et al.* (2020), acceptable IEQ is a vital factor in achieving a productive and healthy building environment, reduces sick building syndrome (SBS), and minimizes short-term absence. The authors viewed IEQ as an acceptable level of thermal, visual, and acoustic comfort in addition to indoor air quality (IAQ).

The university's hall of residence is one of the most important facilities provided on any conventional university campus to serve students' housing needs (Valiyappurakkal, 2021). The hostel facilities accommodate students who would daily spend an average of 8–12 hours within the facility outside other learning facilities (Busch-Geertsema and Sahlin, 2007). A hostel facility that is well designed, constructed, and maintained provides students with a quality and productive indoor environment that would sustain them, attract better-qualified students' enrolment into the university and achieve the institutional goals (Najib *et al.*, 2012; Valiyappurakkal, 2021). The poor indoor environment is a significant problem in the built environment and the leading cause of SBS symptoms (Wong *et al.*, 2008).

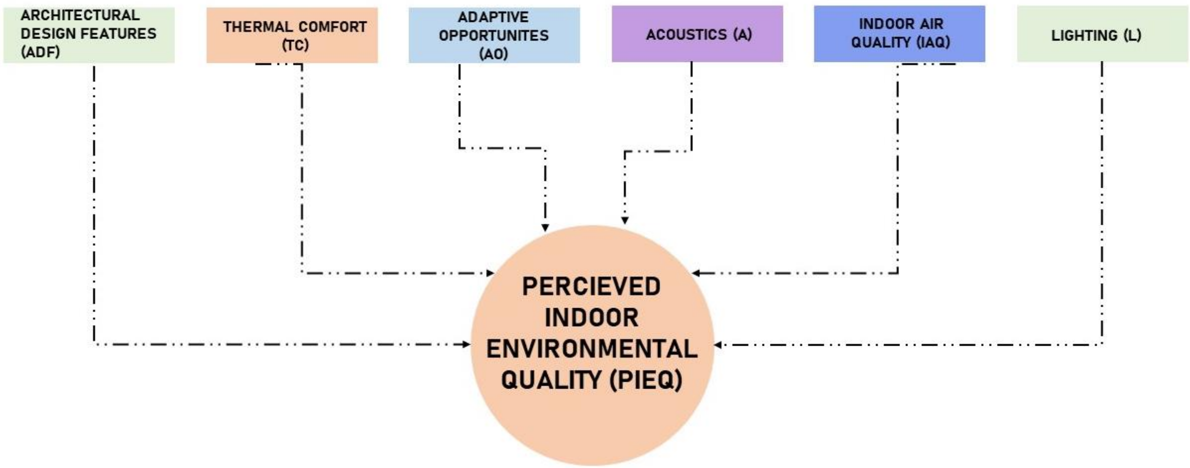


Figure 2.6: Various aspects of IEQ.
Source: Alfa and Öztürk (2019).

Figure 2.6 illustrates the various aspects of indoor environmental quality. Thermal comfort describes the condition of the mind in terms of temperature satisfaction in a defined environment (ASHRAE, 2004). Adaptive opportunities as defined by Nicol *et al.* (2012) are 'the chances created by structures for occupants to provide adequate comfort themselves such as windows, blinds, fans. For the purpose of this research, the aspect of indoor air quality will be further explained.

2.4 Indoor Air Quality (IAQ)

Buildings are becoming increasingly airtight in developed countries (Chan *et al.,* 2005), under moves designed to provide thermal comfort and to reduce energy consumption. Indoor environments are fundamental environmental factors capable of impacting health (Gocgeldi *et al.,* 2011). The quality of air in homes, offices, schools, day care centres, public buildings, health care facilities and other private and public buildings where people spend over 80% (Hoskins, 2007) of their time daily is crucial for healthy living and people's well-being (WHO, 2010). Air quality of indoor environments is one of the main factors affecting the health, well-being and productivity of people (Morakinyo *et al.,* 2015).

The National Health and Medical Research Council (NHMRC) Australia, defines indoor air as the air within a building occupied for at least one hour by people of varying states of health. Poor IAQ can profoundly impact the health, comfort and productivity of building occupants (Nnadozie, 2017). In the time past, the study of indoor air pollution was completely ignored because outdoor air problems such as acid rain, smokestack emissions (Jones, 1999) but in recent times, increasing research interests and reports on indoor environmental matters have certainly heightened the awareness of the risks which threaten our indoor environments (Ezzati *et al.,* 2001).

Poor indoor air quality has been linked with a wide range of effects on respiratory health such as asthma development and exacerbation, respiratory infections and upper respiratory tract symptoms. Emmanuel (2006), has reported that over 1.6 million lives have been lost with over 38.5 million disabled persons in the year 2000 due to IAQ problems. Hostels are part of public buildings in Nigeria, and so far, there are few studies that focused on the air quality in this complex environment. Recently, Nigeria Government has recognized the potential risk and problems related to indoor air pollution in public buildings and it's striving to establish IAQ guidelines for different types of indoor environments (Nnadozie, 2017).

2.4.1 Factors affecting indoor air quality (IAQ) in buildings

The quality of indoor air can either be good or bad due to certain factors that play in the indoor and outdoor environment. However, the quality of air in the enclosed space, there is an impact on the occupants of that space, either positive or negative impacts.

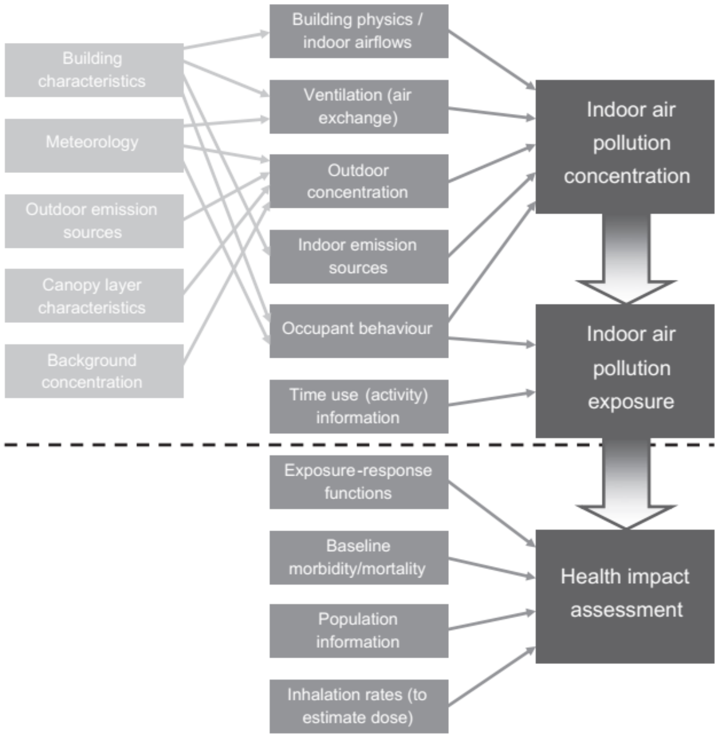


Figure 2.7: Factors affecting indoor air pollution concentrations and exposures (IAQ), and inputs to health impact assessment.
Source: Milner *et al.* (2011).

Deductions from figure 2.7 categorizes factors affecting indoor air quality; these range from the factors in the enclosed spaces even to the factors of the environment. Enclosed factors include; space configuration and requirement, number of occupants in the space, ventilation, users' behavior, materials used and pollution level. The environmental factor includes; the building orientation, the outdoor air pollution level, vegetation cover and landscape design, air flow.

2.4.1.1 Effect of space configuration on indoor air quality

The concept of a space relates to a series of objects and how they come together within a specific area (Hasgul, 2015). A lot of thinking and rethinking goes into designing a space and architects are saddled with the responsibility of configuring the space through the thinking and rethinking process. Pearson and Richards (1994) explains this as “We build in order to think and act. The relationship is essentially dynamic and reflexive. Winston Churchill said that -first we shape our buildings and afterwards our buildings shape us’’.

Hasgul (2015) then defined spatial configuration as a process which is progressive in nature that connects the human’s spatial experience and behaviour with the built environment. This connection can influence IAQ. Marc *et al.* (2017) explained that different kitchen types as well as they type of cooker used impacts IAQ at different levels. Relating this to the hostel design, some spatial configuration has both kitchen and sanitary spaces within the students living area. Some designed a general kitchen and laundry spaces and are placed at a relatively equidistant location from the combined living areas. These two different space configuration impact IAQ differently.

2.4.1.2 Effect of ventilation on indoor air quality

The type of ventilation used in an indoor space influences the exchange of outdoor air and indoor air. Tropical regions are particular about cooling than heating and this affects their choice in the type of ventilation adopted, be it mechanical or natural. For the nature of this project, natural ventilation types will be reviewed. Tjelflaat and Rodahl (1997) defined natural ventilation as an energy efficient alternative that is thermally comfortable and has the potential of enhancing IAQ of spaces within buildings. An argument was placed by Monby *et al.* (1998) that ill-health, irritation, and discomfort to occupants are caused by polluted gases within that living space. Natural ventilation ensures that these gases are replaced by fresh air from the outdoor environment. Kleiven (2003) opined that within the indoor spaces of a building envelope, natural ventilation can only the achieved when the natural wind (driving forces) within the outdoor environment is harnessed.

The harnessing of these natural driving forces within the indoor space improves the IAQ. Givoni (1994), stated that a process that subjects building structures to wind induced pressure variations is termed wind driven ventilation. He further stated that these pressure variations could be negative or positive depending on the situation as shown in figure 2.8.

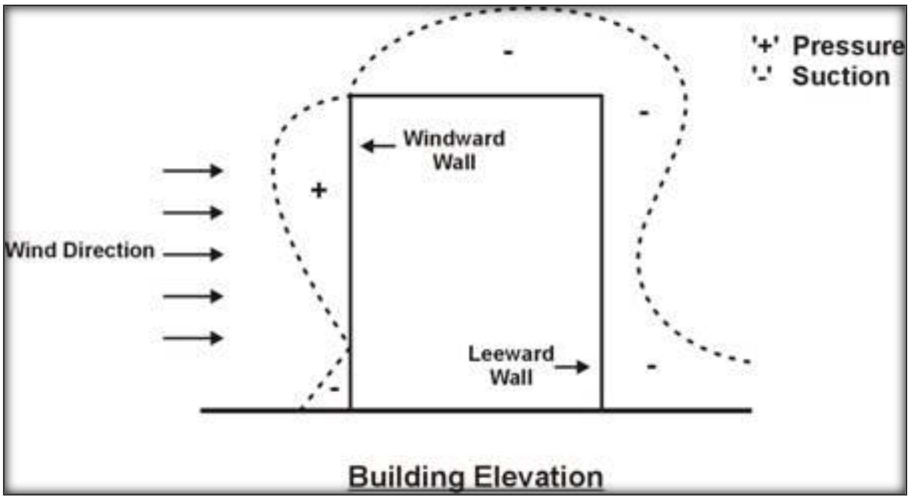


Figure 2.8: Positive and Negative air pressures on buildings.
Source: Givoni (1994)

There is a formation of a positive pressure when the driving wind hits the building on the windward side; a negative pressure is created on the leeward side through the suction effect when the wind moves around the building. Kleiven (2003) explained that fresh air enters the building envelope when the fenestrations are located on the windward side and used air diffuses through the fenestrations on the leeward side. Andrew (2014), then gave a classification of the wind driven ventilation namely;

i. Single-sided Ventilation
ii. Cross ventilation
iii. Stack ventilation

Single-sided uses one side of the wall for both inflow of fresh air and outflow of used air as shown in figure 2.9. This ventilation type results in low ventilation rates and not advisable for tropical regions as an additional ventilation system will be required which is energy intensive. However, this technique can be efficient if the width of the space is 2.5 times the height (Andrew, 2014).

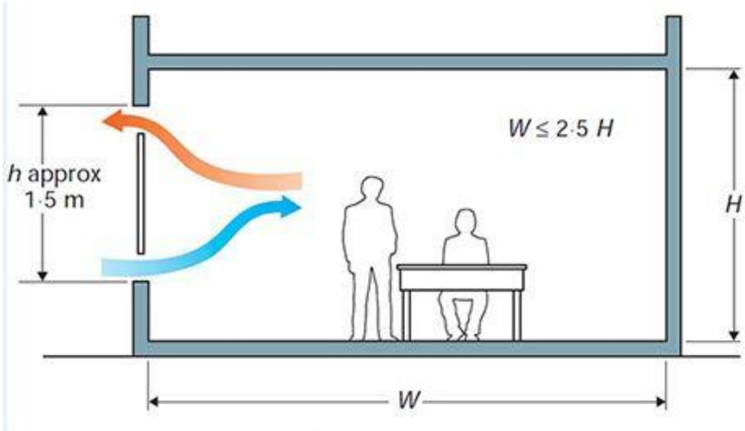


Figure 2.9: Illustration of the single-sided ventilation.
Source: Andrew (2014).

Cross ventilation is more efficient for tropical regions. It involves having fenestrations at the opposite sides or adjacent sides within the living space (figure 2.10). This allows inflow of fresh air from one side and outflow through the other. It is more efficient if one side faces the wind to create positive pressure variations and allow fresh air to flow in while the used air flows through the leeward side (Andrew, 2014)

Stack ventilation or thermal buoyancy driven ventilation operates on the principle of temperature and density changes. Hot and used air is less dense compared to cold and fresh air. The denser fresh air is introduced into the living space through fenestrations at a lower height while the less dense used air flows vertically and is exhausted (figure 2.11). An atrium design or courtyard design anchors on this principle.

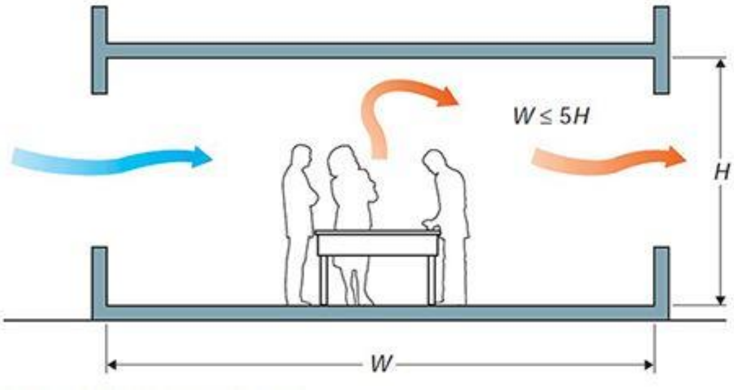


Figure 2.10: Illustration of the cross ventilation.

Source: Andrew (2014).

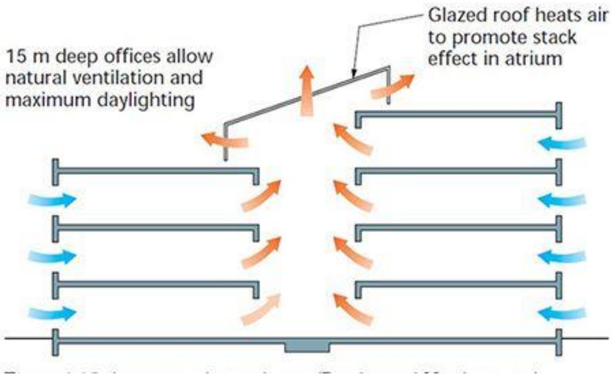


Figure 2.11: Illustration of the stack ventilation technique.

Source: Andrew (2014).

2.4.1.3 Effect of occupants' behaviour on indoor air quality

Occupants' behaviour is the primary mechanism determining indoor particulate concentrations. Various indoor human activities generate particulate matter. Human-building interactions, such as window opening behavior, change the number of outdoor particulate matter introduced into the building as seen in figure 2.12 (Chai *et al.*, 2022). The results of their research indicate that indoor air quality can be severely degraded by opening windows without considering the level of outdoor particle concentration.

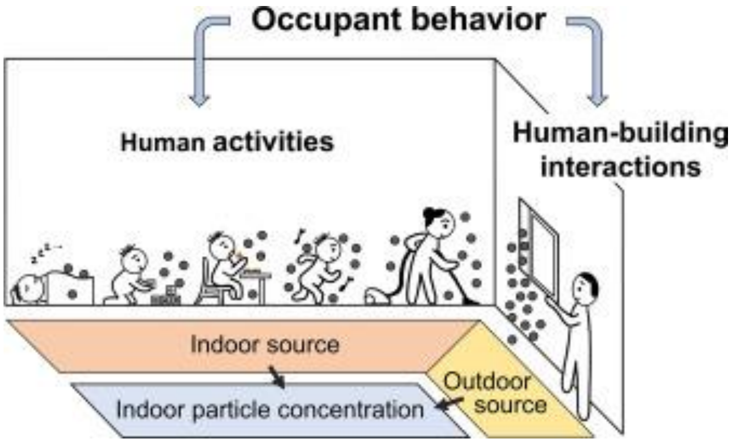


Figure 2.12: Image showing how occupants behaviour increases indoor particulate concentrations.
Source: Chai *et al.* (2022).

Schlink *et al.* (2016), opined that various forms of human activities in residential areas such as cooking, washing, cleaning, waste management and disposal influence the type and quantity of xenobiotics contained in indoor air. Hameed *et al.* (2004) and D'Souza *et al.* (2009) further stated that socioeconomic status of the occupants as well as the intensity and type of performed renovations and restoration actions are the major determinants of the extent in which these factors (xenobiotics) impact the IAQ. These can be seen in the systems and design of a kitchen (Marc *et al.*, 2017).

2.4.1.4 Effect of building materials and equipment on indoor air quality

A range of spaces and activities in different building types make use of a range of equipment (Alefu *et al.*, 2017). They further stated that these equipment have IAQ problems which emanated from inadequate exhaust ventilation and improper equipment operation. Volatile Organic Compound which have health effects on occupants are usually emitted from different building materials. The building materials known to cause IAQ problems are those that absorb moisture. Asbestos when moisten, damaged or disturbed, release asbestos fibres which when inhaled pose an increased risk of respiratory illnesses such as lung cancer and asbestosis (IAQMP. 2012). The effect of building materials and equipment on IAQ are usually related to Sick Building Syndrome (SBS) and Building Related Illnesses (BRI).

2.4.1.5 Effect of building orientation and air flow on indoor air quality

Proper orientation of a building gives that building an advantage as it harnesses the solar radiation and the prevailing winds. Aiman *et al.* (2015) and Blanc (2018) advised that for a good flow of air in the internal space, the fenestrations should have an orientation facing the prevailing wind. In this context geographically, prevailing winds are the NE trade winds and the SW trade winds.

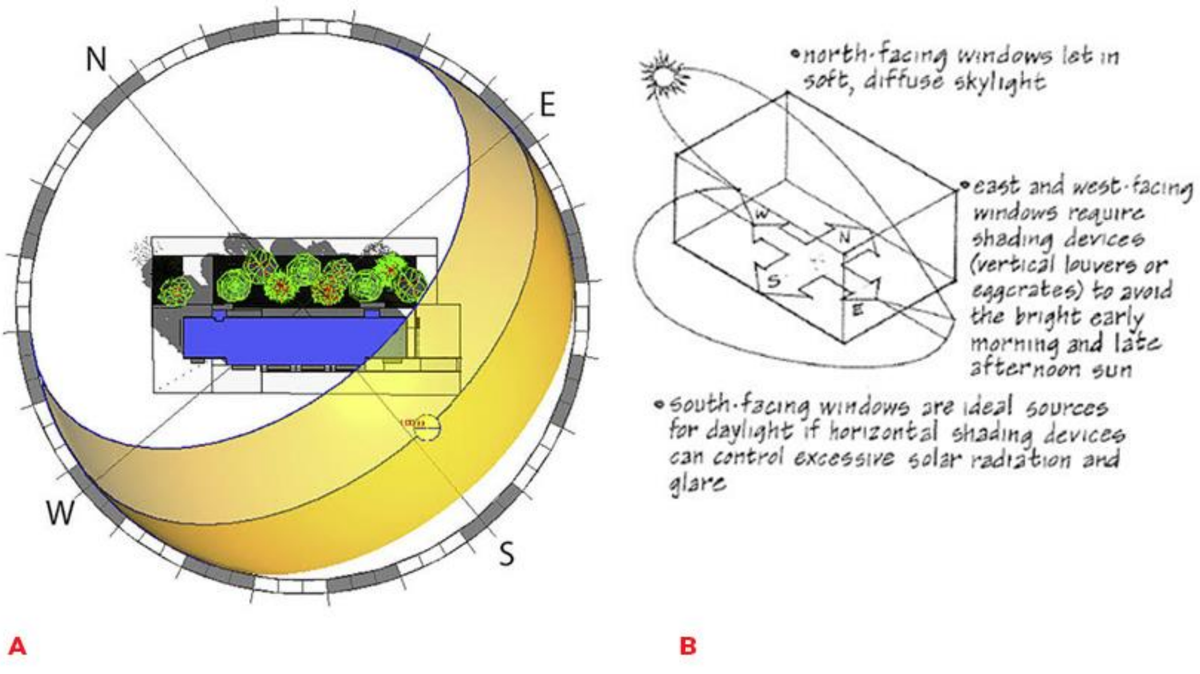


Figure 2.13: Orientation of building for optimal harnessing of solar gain and air flow. Source: Ching (2008).

2.4.1.6 Effect of landscape design on indoor air quality

This is not a direct effect however; it influences the outdoor air that comes into the indoor space. Asiedu (2012) and Aiman *et al.* (2015) acknowledged that trees and proper landscaping are beneficial as they save energy, reduce noise and pollution, moderate temperature and relative humidity, break winds and are psychologically beneficial to the occupants. The trees purify the air by introducing oxygen and using the CO_2 that humans breathe out for the process of photosynthesis. This makes the air that enters the indoor space fresh and pure. The trees and vegetation can be adopted directly in the indoor spaces through interior potted plants.

2.4.2 Indoor air purification

Beyond introduction of oxygen and usage of CO_2 from the indoor spaces, plants can purify the air by filtering toxins from the indoor air. Table 2.3 shows a plethora of indoor plants used in cleaning the indoor spaces of various institutional buildings. Among all mentioned, Swanchhindia (2018), recommended five plants to be grown indoors namely bamboo Palm, Aloe vera, Snake plant, *Warneck Dracena* and Spider plant, all of which have been proven to be good purifiers and can filter VOCs and some incomplete combustion by- products. Singh (2018), further stated that plants like Money plant, Mother in Law's tongue, Golden Pothos Areca Palm and Chrysanthemum are good remediators of air borne volatile pollutants.

Table 2.3: List of some common indoor air purifying plants

Botanical Name	**Common Name**	**Targeted Pollutants**	**Toxicity**	**Special requirements**
Aloe barbadensis	Aloe Vera	Benzene, Formaldehyde, CO_2 and CO	No	Requires a lot of sunlight and little water
Chamaedorea seifrizii	Bamboo palm	Benzene, Formaldehyde, Xylene, Chloroform and CO	No	Keep the soil moist. where air circulates freely, and mist occasionally to prevent spider mites

Chlorophytum comosum	Spider plant	Benzene, Formaldehyde, Xylene, and CO	No	Bright sunlight keeps them growing best
Dracaena deremensis	Janet Craig	Formaldehyde, Toluene, Xylene and trichloroethylene	Mildly toxic to house pets who may vomit or suffer from excessive salivation and dilated pupils upon ingestion	Keep the soil damp but not soggy
Dracaena marginata	Dragon tree	Toluene, Xylene and trichloroethylene	Causes moderate toxicity to pets on ingestion as it contains saponins	Flourishes in semi shade and top soil
Dypsis Lutescens	Areca palm, Bamboo palm, Golden cane palm, Yellow palm or butterfly Palm.	Xylene and Toluene	No	Bright, indirect light
Epipermnum aureum	Golden pothos, money plant	Benzene, Formaldehyde, Xylene, Toluene and CO	Moderate toxicity to pets on consumption is reported	Water when the soil is dry
Sansevieria trifasciata	Mother-in-law tongue, Snake plant, Viper's bowstring hemp		Causes low ton swallowing, resulting into a minor	Tolerant to low light levels and irregular watering.
Ficus robusta	Rubber plants	CO, Formaldehyde and trichloroethylene	Causes mild toxicity to pests	Water moderately to keep the soil moist, especially in the winter.
Rhapis excelsa	Lady Palm	CO, Formaldehyde, Benzene and Toluene	Causes low toxicity on swallowing, resulting into minor skin irritation.	Tolerant to low light levels and irregular watering

Source: Dharitri *et al.* (2019)

2.4.3 Indoor air extraction

Aside the process of purification, used and polluted air need to be extracted even before the diffuse into other living spaces. Kitchens and sanitary spaces are the indoor spaces highly in need of air extraction systems in hostel designs. Xu *et al.* (2022), stated that fresh kitchen air quality is a pivotal constituent of an indoor environment that is comfortable and healthy. Range hoods are good pollutant absorbs and can absorb most pollutants from the source. However, Chen *et al.* (2018), argued that well mounted range hood is 75% efficient and could be worse if the generally ventilation of the space is poorly designed. Air extraction involves the use of extractor fans to remove air pollutants from source regions of indoor spaces (figure 2.14) and it could be wall mounted of fixed to the roof.

The fresh air enters through e_1 and flows through a fan M_e into the hood which flows into the indoor space as e_2. The hood extracts used or polluted air as i_1 and this extracted air diffuses with e_1 to form i_2. A suction effect is experienced and a fan sucks i_2 and let it out through a vent in the roof. This mechanism regulates the polluted air and heated air in the kitchen space. The wall mounted extractor fan is more ideal for the sanitary spaces. This is shown in figure 2.15.

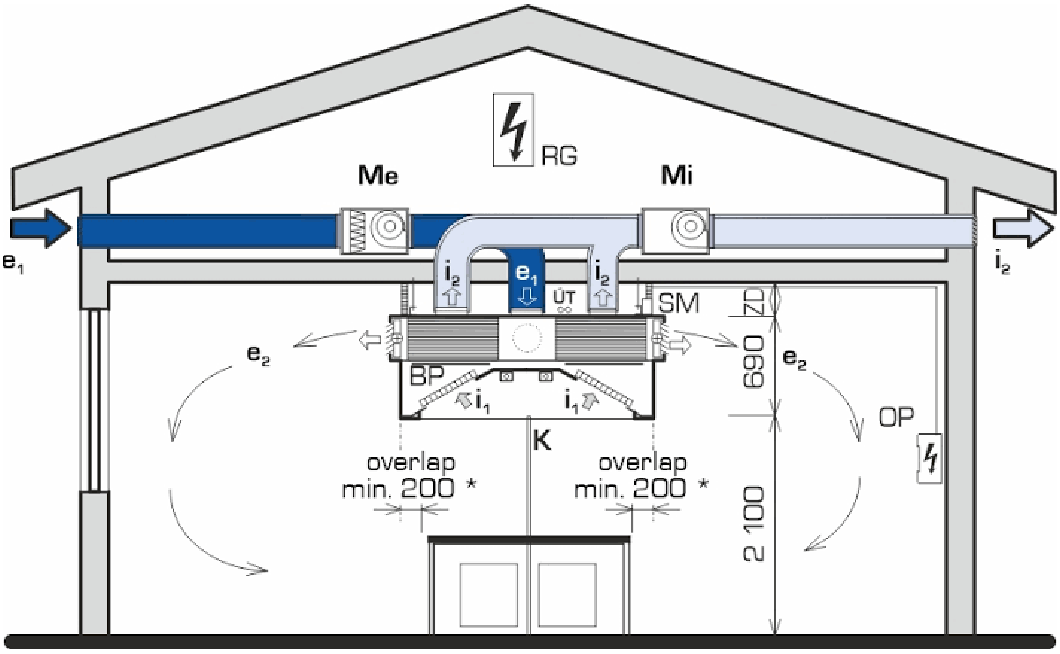


Figure 2.14: Air extraction mechanism for ceiling mounted extractors.

Source: Xpelair (2021)

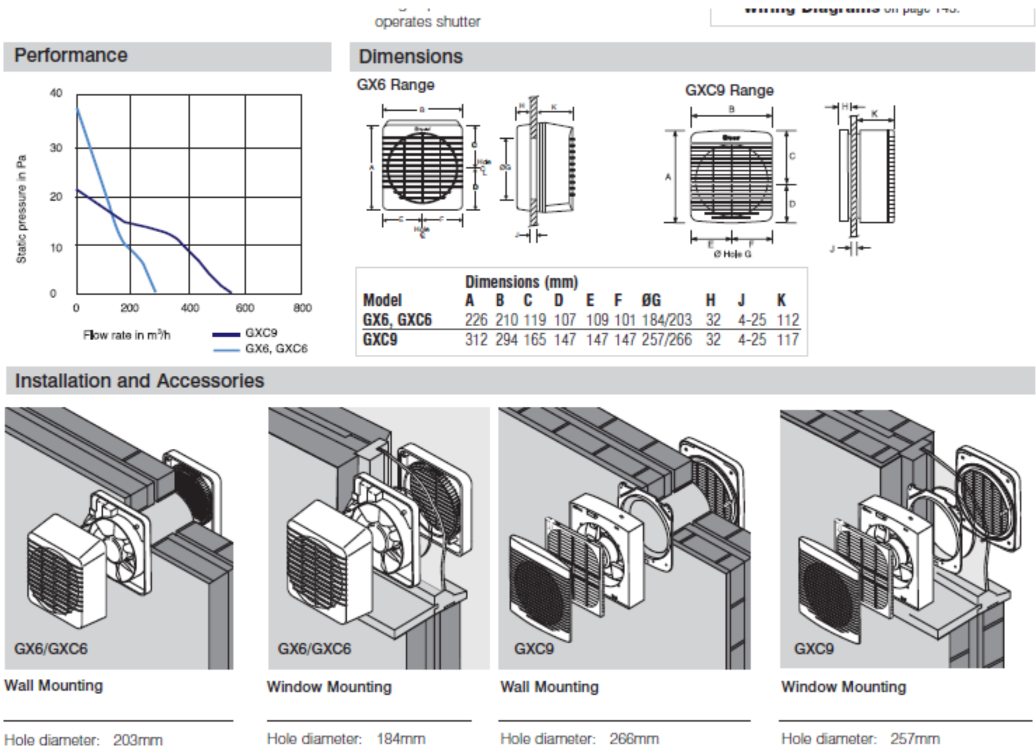


Figure 2.15: Air extraction mechanism for wall and window mounted extractors.

Source: Xpelair (2021)

2.5 Indoor Air Quality Pollution Effect

Over the past decades, various symptoms and illnesses have been linked to diminished IAQ in buildings and houses. Indoor exposure to inorganic, organic, physical, and biological contaminants, though often at low levels, is common, ubiquitous, and sustained (Tran *et al.*, 2020). Therefore, the harmful effects of IAP on human health have always attracted great attention and concern. According to the WHO, building-associated illness refers to any illness caused by indoor environmental factors, which commonly are divided into two categories: Sick building syndrome (SBS) and building-related illness (BRI). Their associated symptoms are shown in Figure 2.15.

SBS often refers to a group of symptoms that are linked to the physical environments of specific buildings; acute health and comfort effects of SBS will appear when patients spend a certain amount or duration of time in a building, but they and their causes are difficult to clearly identify (Marmot *et al.*, 2006). BRI describes illnesses and symptoms with an identified causative agent directly related to exposure to poor air quality in buildings. It is known that causative agents can be chemicals, such as formaldehyde, xylene, pesticides, and benzene, but biological agents are more widespread (Tran *et al.*, 2020).

Kamaruzzaman and Sabrani (2011), discovered that a high proportion (30%) of SBS occur to occupants in specific building precisely those with air conditioned spaces having illnesses without any clearly identified cause. Raw (1992), further classified SBS into different types as they affect various parts of the human body (table 2.4). Ho *et al.* (2004), then defined a healthy building as a building which offers the occupants a complete state of mental, physical and social well-being and not just the absence of diseases.

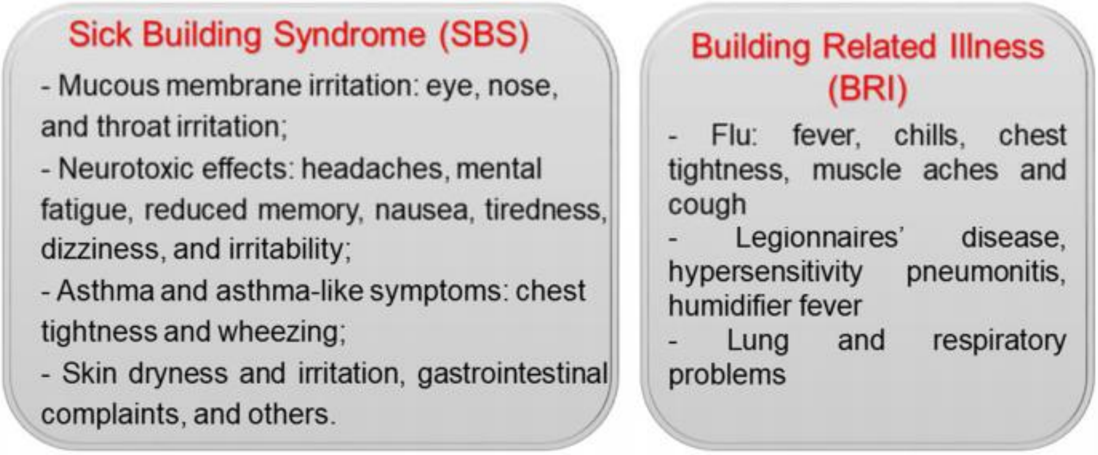


Figure 2.16: The common symptoms of sick building syndrome (SBS) and building related illness (BRI).

Source: Tran *et al.* (2020).

Table 2.4. Symptoms and effects due to SBS

S/N	Body part	Symptoms	Effects
1	Eyes	Irritated, dry/watering	Itching, tiredness, smarting, redness, burning, or has difficulty in wearing contact lenses.
2	Nose	Irritated, runny/blocked	Congestion, nosebleeds, itchy or stuffy nose.
3	Throat	Dry or sore	Irritation, or pharyngeal symptoms, upper airway irritation or difficulty swallowing.
4	Skin	Dryness, itching or irritation	Rash or specific clinical terms such as erythema, rosacea, urticaria, pruritis, xerodermia
5	Others	Headache, irritability, lethargy, and poor concentration.	

Source: Raw (1992)

2.5.1 Health conditions affiliated with poor IAQ

Dubos (1969), discovered that the toxic elements contained in poor IAQ has the potential of prohibiting human adaptation; of which could be biological or psychological. Table 2.5 gives in detail the biological effects of the toxins in a polluted air.

Table 2.5. Indoor air contaminants list and related health impacts

Contaminants	Sources	Possible consequences	References
Biological Contaminants			
Allergens	Furry pets, dust mites	Asthma	Dales *et al.* (2008)
Endotoxins	Presence of cats and dogs, contaminated humidifiers, storage of food waste, lower ventilation rate, increased amount of unsettled dust	Asthma, reduced lung function	Park *et al.* (2001)
Dampness and mold	Unattended plumbing leaks, leaks in building fabric, hidden food spills, standing water	Upper respiratory symptoms, cough, wheeze and asthma	Fisk *et al.* (2007)
Chemical Contaminants			
Smoke	Tobacco smoke	Premature mortality, lung cancer, coronary artery disease, childhood cough and wheeze, respiratory illness, infant death syndrome	U.S. Department of Health and Human Services, 2006
Coal and biomass fuels combustion product	Cooking and heating	Combustion of solid fuels releases CO, N_2O, particulates, poly-cyclic hydrocarbons, which increases the risk of lung cancer, childhood asthma	Mehta, 2002, Zhang and Smith, 2007
Carbon oxides (CO_x)	Vehicle exhaust from attached garages, gas stoves, furnaces, wood stoves, fireplaces and cigarettes, outdoor air, other gasoline powered equipment	Headache, nausea, fatique, impaired vision, reduced brain function	USEPA, 2020, Shimer & Thomas (2005)
Nitrogen dioxide (N_2O)	Combustion of fossil fuels e.g., gas or oil furnaces and stoves	Increased risks of respiratory symptoms	Spengler *et al.* (2001)
Pesticides	Contaminated soils, stored pesticide containers	Irritation to the eye, nose and throat, damage to central nervous system	Holt *et al.* (2017), USEPA, 2020
Ozone (O_3)	Outdoor sources, photocopying, air purifying, disinfecting devices	DNA damage, lung damage, asthma, decreased respiratory functions	Salonen *et al.* (2018), Huang *et al.* (2019)
Sulphur dioxide (SO_2)	Cooking stoves, fireplaces, outdoor air	Impairment of respiratory	Seow *et al.* (2016)

		Function, Asthma, chronic obstructive pulmonary disease (COPD), and cardiovascular diseases	
Off Gassing Emissions (Gases released from indoor materials)			
Volatile Organic Compounds (VOCs)	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, building materials and furnishings	Eye, nose and throat irritation, headaches, loss of coordination and nausea, damage to liver, kidney and central nervous system, some organics can cause cancer	Tang *et al.* (2015)
Plastic Compounds	Polyvinyl chloride for flooring, plastic wall material	Bronchial obstruction, Asthma, wheeze, cough and phlegm	Jaakkola *et al.* (2000)
Formaldehyde (HCHO)	Wood based products assembled using urea-formaldehyde resins, cigarette smoke, paints, vanishes, floor finishes	Eye, nose, throat irritation, asthma, bronchitis, and possible carcinogen	WHO, 2010, USEPA, 2016.
Carcinogens			
Radon	Natural decay of Uranium	Lung cancer, Leukemia	WHO, 2010
Heavy metals	Pb, Cd, Zn, Cu, Cr, As, Ni, Hg, Mn, Fe, Outdoor sources, fuel-consumption products, incense burning, smoking and building materials	Cancers, brain damage, Mutagenic and carcinogenic effects: respiratory illnesses, cardiovascular deaths	Komarnicki (2005), Rashed (2008)
Particulate Matter (PM)			
Ultra-fine particles	Cooking, combustion activities	Serious impact on heart and lungs	WHO, 2010, Prajakta, (2013)

Source: Tran *et al.* (2020); Mannan and Al-Ghamdi (2021)

Furthermore, Colligan (1981) stated that there are two psychological effect IAP has on the occupants. The first is a more direct effect relating certain behavioural patterns such as memory performance, mood state, motivation and interpersonal relations and the second is a feeling of anxiety and tension whenever there are in that space caused by a general arousal of the sympathetic nervous system.

2.6 Indoor Air Quality Standards

The control metrics for IAQ differ in each country as a result of differences in indoor air and outdoor air environment as well as building operations (Kim *et al.,* 2021). These differences have led to some distinct IAQ and in order to face these problems, some relevant organizations have established IAQ guidelines and standards based on an integrated building approach (Avegelis and Papadopoulos, 2004). According to WHO (2000), provision need to be made in form of a critical database that will create a reference for the prevention of the harmful effects of IAP; IAQ guidelines furnishes the world with such data base in a bid to eradicate or in the least minimize the IAP effects on the occupants. For example, ASHRAE standards has it that indoor CO_2 concentrations must be below 700 ppm to ensure human health (ASHRAE, 2013). Table 2.6 gives a summary of the IAQ guidelines for some common indoor air pollutants. It is important to note that these guidelines are non-occupational standards relating to residential houses, offices and schools and are not binding to occupational buildings such as industries (Abdul-Wahab *et al.,* 2015).

Table 2.6. Guidelines to major indoor air pollutants

S/N	Pollutants	Concentration levels (mg/m3)	Exposure time	Organization
1	CO	100	15 min	WHO
		60	30 min	
		30	1 h	
		10	8 h	
		29	1 h	USEPA
		10	8 h	
2	CO_2	1800	1 h	WHO
3	NO_2	0.4	1 h	WHO
		0.15	24 h	
		0.1	1 year	USEPA
4	PM	0.15	24 h	USEPA
		0.05	1 year	
5	O_3	0.15–0.2	1 h	WHO
		0.1–0.12	8 h	
		0.235	1 h	USEPA
6	SO_2	0.5	10 min	WHO
		0.35	1 h	
		0.365	24 h	USEPA
		0.08	1 year	
7	Pb	0.0005–0.001	1 year	WHO
		0.0015	3 months	USEPA
8	Xylene	8	24 h	WHO
9	Formaldehyde	0.1	30 min	WHO
10	Radon	100 Bq/m^3	1 year	WHO

Source: Tran *et al.* (2020)

In summary, this chapter focused on defining a hostel, stating types of hostels and reasons why students choose a hostel over another. The living condition (IEQ) is one of main the reasons. The IEQ as a broad concept is dependent on some variables which are interrelated and IAQ was focused upon. Numerous factors that influenced IAQ were discussed as well as some methods that can improve IAQ such as air extraction and purification. The latter part of the review focused on the effect of poor IAQ on its occupants and also the standards that should be maintained to prevent the effect of the exposure to these indoor air contaminants.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Philosophy

The research philosophy is a guiding block that is important in shaping how we formulate and solve research problems (Lincoln *et al.,* 2011). These philosophies as stated by Creswell (2014) and Pietrzyk (2022) has six (6) worldwide views namely positivism, post-positivism, constructivism, interpretivism, pragmatism and critical realism. The pragmatists philosophy was adopted in this research as it is highly suitable for this type of research that focuses only to achieve the goal in the best possible way and does not fit to the individually based constructivism, or the limited and scientific based view of positivism/post-positivism and critical realism which is anchored on social constructs (Haddadi *et al.,* 2017; Lawani, 2021; Dudovskiy, 2022).

Haddadi *et al.* (2017) further stated that the core idea of pragmatism epistemology focuses on the practicality, reality and nature of things and avoid abstract ideas. A vital philosophical orientation about pragmatism is it contribution of useful and actionable knowledge, driven by respondents’ experience which produces a buoyant and realistic human views (Kelly and Cordeiro, 2020). This aids the research as it guides the establishment of data from the occupants’ point of view. Pragmatism is not limited by one specific philosophy and can adopt other philosophies. The nature of this research also demands a scientific approach. This results in the merging of the positivist philosophy with pragmatism.

3.2 Research Approach

According to Dudovskiy (2022), there are three research approaches; deductive, inductive and abductive. The inductive approach develops data into theories and is the direct opposite of the deductive approach which involves the confirmation of a theory or hypothesis from existing data and the abductive approach combines both (Saunders *et al.*, 2016). This research adopts the abductive approach.

3.3 Research Method

There are three types of research methods, 'quantitative research', 'qualitative research' and 'Mixed method'- qualitative and quantitative (Naoum, 2013). The difference between these mainly due to the restrictions imposed on flexibility, structure, sequential order, depth and freedom that a researcher can use during the research process. The method adopted in this research process is the mixed research method. The mixed methods approach derives its findings using both qualitative and quantitative components (Halcomb, 2018), posing numerous advantages such as being able to collect more comprehensive data and developing a richer analysis as opposed to using one method (Shorten & Smith, 2017). However, one limitation of the method is its complexity, as the researcher may have difficulty in conducting two different research methods in the same study (Halcomb, 2018). Thus, a mixed methods approach was opted for to maximize its advantages.

3.4 Research Strategy

A research strategy is set of steps which synergizes to form a plan with the aim of getting answers to the research questions as well as the hypothesis (Saunders *et al.*, 2015). These strategies such as case study, surveys can be grouped under qualitative or quantitative method. For this research, the mixed method was adopted. The quantitative aspect of the research focused on the inhabitants of the space, using the questionnaire survey approach to determine the extent to which the indoor air affects the health status of the occupants. It also explores the common air pollution sources and the air pollutants present in the spaces using an air detecting device known as air node (instrument survey). The qualitative aspect of the research focuses on the hostel buildings using the case study approach to assess the state of the hostels using a checklist/observation guide. The point of triangulation exists by adopting the Building Assessment Survey and Evaluation Study (BASE) where the study synergizes both methods to assess the hostel blocks.

3.4.1 Building assessment survey and evaluation study (BASE)

In 1994, the U.S. Environmental Protection Agency (U.S. EPA) initiated a major cross-sectional study, the Building Assessment Survey and Evaluation study (BASE), to characterize key characteristics of IAQ, occupant health symptoms and perceptions of IAQ in public and commercial office buildings (Girman *et al.*, 1997). According to USEPA, (1994), the steps involved in BASE include;

i. Select and Recruit Buildings
ii. Initial Visit to Eligible Buildings
iii. Create a Study Team
iv. Select Study Areas and Monitoring Locations
v. Monitor Study Areas
vi. Survey Occupants of Study Areas
vii. Validation of data as specified in the Quality Assurance Project Plan

3.5 Data Collection and Sampling

For the survey, data was collected primarily with the use of the structured questionnaire as well as an air detecting device. For case studies, both primary and secondary data were collected for the case study of the existing hostel blocks. The primary data involved a visual assessment of the hostel buildings and reporting it while the secondary data involved the collection of building drawings from the Physical Planning and Development Unit (PPDU) of the study university.

3.5.1 The questionnaire survey

The survey questions were crafted in simple and straightforward English that is easy to understand to prevent the participants from giving up midway through the survey. It uses two types of closed-ended questions, namely the Checklist and Likert item/scale. The questionnaire is divided into three parts namely; the section A having the occupants' data, section B having the occupants' health and indoor environment and the section C which involves users behaviour as regards to building operation and indoor living.

Closed-ended questions are straight to the point as respondents are only required to give predetermined straight forward responses such as strongly disagree to, disagree, neutral, agree, strongly agree, yes, no, maybe and so on, making responses easy to analyse. The main disadvantage of closed ended questions is that respondents may feel forced to choose from the predetermined replies and not be able to voice out their views (Naoum, 2013). A pilot survey was conducted using 10 students to test the simplicity of the questions in the questionnaire.

Table 3.1 Summary of the questionnaire sample

Section	Subjects	Questions
Section A	Occupants data	Questions 1 - 4
Section B	Occupants health and indoor environment	Questions 5 - 7
Section C	Occupants’ behaviour as regards to building operation and indoor living	Questions 8 - 13
Section D	Building audit/survey	Questions 14 - 17

Source; Author’s field work (2023)

3.5.2 Questionnaire sampling method

The study population comprises of the entire occupants in the various blocks of the male and female hostels in F.U.T Minna, Gidan Kwano Campus. This places the population size at a numerical figure of 1930 occupants officially.

Table 3.2: Names and Capacity of Hostels

Name of hostel	Gender	No of rooms	Bed Space Per Room	No of bed spaces
Block A	Male	83	5	415
Block B	Male	83	5	415
Block C - G	Female	70	6	420
Shehu Aliyu Hostel	Female	62	4	248
New Boys Hostel	Male	72	4 and 2	216
New Girls Hostel	Female	72	4 and 2	216
Total		**442**		**1,930**

Source: Adama *et al.*, (2019)

The sample population is placed at a survey (occupant) per room which places it at 442 occupants for the questionnaire survey (22.9% of the study population). However, the occupant shall be selected randomly as it gives every member of the space an equal chance of been selected. This ensures an even spread and selection of the respondents surveyed thus generalizations can be made towards the entire population size.

3.5.3 The instrument survey

A short term monitoring was conducted in the hostel blocks, taking different rooms as the monitor locations. The instrument placed at the monitor rooms is the Air Node. It can measure temperature, Humidity, PM 2.5, PM 10, CO_2 and VOCs. The instrument was placed in each room for a period of 12 hours spanning from 6PM to 6AM. At this period all occupants of the rooms are available and most activities for the day occur. The accuracy of the device is as follows; temperature; -10 to +40°C, Humidity; 0 to 100%, CO2; 400 to 10000 ppm, PM 2.5; 0.3 to 2.5µm (0–100 µg/m^3). A total of six (6) blocks were surveyed with different monitor rooms. Table 3.3 shows the rooms surveyed. For the purpose of discretion, a pseudo identity was given to these rooms.

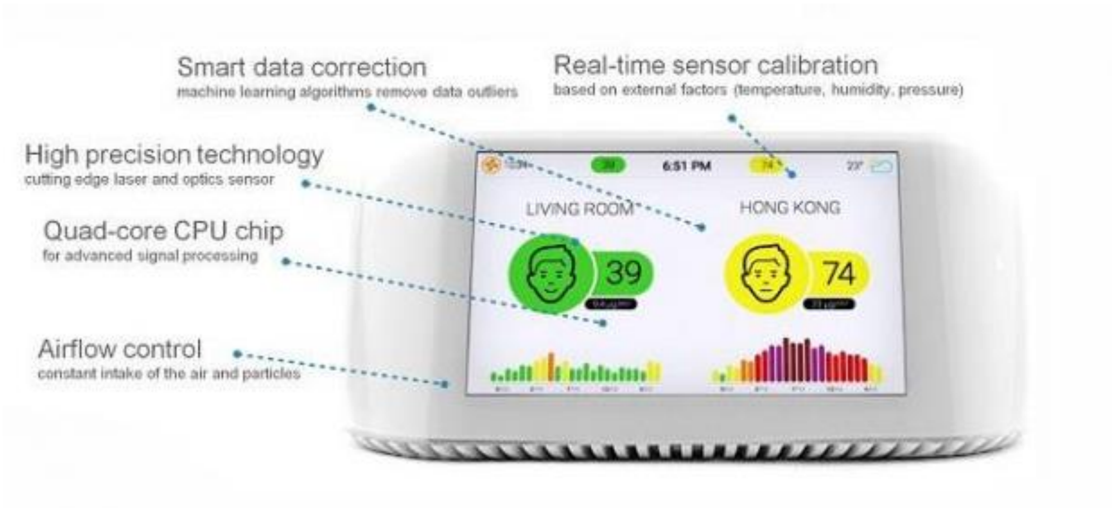


Figure 3.1 Air visual node monitoring device.
Source: https://airvisual.com/node

Table 3.3: List of rooms monitored for the instrument survey

S/N	Hostel Name	Room Identity	Location (floor)
1	Male hostel block A	Room A	Ground floor
		Room B	First floor
		Room C	Second floor
2	Male hostel block B	Room A	Second floor
		Room B	Ground floor
		Room C	First floor
3	Old Female Hostel (blocks C - G)	Room D	Ground floor (Block F)
		Room E	Ground floor (Block D)
		Room F	Ground floor (Block C)
		Room G	Ground floor (Block D)
4	Shehu Aliyu Female Hostel	Room A	Ground floor
		Room B	First floor
5	New Male Hostel	Room A	Ground floor
		Room B	First floor
		Room C	Second floor
6	New Female Hostel	Room A	Ground floor
		Room B	First floor
		Room C	Second floor

Source: Author's field work (2023)

3.5.4 Checklist/ observation schedule

The case study approach was used precisely for all the six hostel blocks in question. The parameters considered were general building characteristics that were peculiar to indoor air quality. The aspects considered include;

- Building orientation and air flow
- Ventilation and shading
- Landscaping and outdoor environment
- Indoor environment assessment

3.6 Data Analysis

The primary and secondary data obtained were analyzed. The data analysis existed at two levels namely; descriptive analysis and inferential analysis, all of which were geared towards achieving the set objectives and testing the hypothesis. A Cronbach Alpha test was conducted to determine the validity of the data set obtained from the questionnaire survey. All the analyses done were carried out using the Statistical Package for Social Sciences (SPSS) version 26 and Excel 2016.

3.6.1 Reliability and validity test

Reliability and validity are concepts used to evaluate the quality of research, they indicate how well a method, technique or test measures something; reliability is about the consistency of a measure, and validity is about the accuracy of a measure (Fiona, 2019). A reliability test using Cronbach's alpha was undertaken. Cronbach's alpha reliability, Cronbach (1951), is one of the most widely used measures of reliability in the social and organizational sciences. For multiple scales, Cronbach's alpha measures internal consistency and indicates the consistency of responses (Saunders *et al.,* 2016; Douglas and Thomas, 2014). Values of 0.7 or above are considered acceptable while Cronbach's alpha values of less than 0.7 are deemed unacceptable (Saunders *et al.,* 2016). It is mathematically represented as;

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum Vi}{Vtest}\right)$$

n = number of questions
Vi = variance of scores on each question
V test = total variance of overall scores on the entire test

3.6.2 Descriptive statistics

Descriptive statistics summarize and organize characteristics of a data set; a data set is a collection of responses or observations from a sample or entire population. (Pritha (a), 2020). She further stated that descriptive statistics is a univariate analysis. Descriptive statistics was used to establish occupants' demographics in form of charts and tables. Specifically, the weighted scores and the weighted mean of each statement were computed and ranked using the ordinal scale. For the instrument survey, air contaminants were statistically presented stating the concentration levels of the contaminants and the room atmospheric conditions recorded during the monitoring period and presented using tables and graphs. The table 3.4 below shows how the range of mean responses will be interpreted.

Table 3.4 Interpretation of Mean Scores for Individual Statements

Range of Mean	Quantitative Description	Qualitative Description
4.21 to 5.00	5	Strongly agree (very high)
3.41 to 4.20	4	Agree (high)
2.61 to 3.40	3	Neutral (moderate)
1.81 to 2.60	2	Disagree (low)
1 to 1.80	1	Strongly disagree (very low)

Source: Adopted from Arceno (2018).

3.6.3 Scaling technique

According to Kothari (2004), scaling describes the procedures of assigning numbers to various degrees of opinion, attitude and other concepts. This can be done in two ways namely,

i. making a judgement about some characteristic of an individual and then placing him directly on a scale that has been defined in terms of that characteristic

ii. constructing questionnaires in such a way that the score of individual's responses assigns him a place on a scale.

He further stated that scales of measurement can be considered in terms of their mathematical properties. The most widely used classification of measurement scales are:

a) nominal scale;
b) ordinal scale;
c) interval scale;
d) ratio scale.

For the purpose of this research, the ordinal scale was used as it is suitable for ranking. It is a type of Ranking where relationship between a set of items such that, for any two items, the first is either ranked higher than or ranked lower than or ranked equal to the second. In ordinal ranking it makes use of ordinal numbers such as 1,2,3,4, to rank a set of items based on a casual relation in an ascending or descending order.

3.6.4 Inferential statistics

Inferential statistics help you make conclusions and predictions based on your data; it enables you to understand the larger population from which the sample is taken from (Pritha (b), 2020). Allows detection of large or small differences, in variables or correlations between variables relevant to research question (Allison *et al.,* 2000; Botti & Endacott, 2008). According to Mukaka, (2012), correlation was used to derive inferences based on relationships between the variables from the sample population; a statistic representing how closely two variables co-vary; it can vary from -1 (perfect negative correlation) through 0 (no correlation) to +1 (perfect positive correlation).

Table 3.5 Example of a Conventional Approach to Interpreting a Correlation Coefficient.

Absolute Magnitude of the Observed Correlation Coefficient r)	**Interpretation**
0.00–0.10	Negligible correlation
0.10–0.39	Weak correlation
0.40–0.69	Moderate correlation
0.70–0.89	Strong correlation
0.90–1.00	Very strong correlation

Source: Schober *et al.* (2018)

The relationship between two variables is generally considered strong when their r value is larger than 0.7. (Méndez-Hernández *et al.*, 2013). According to Méndez-Hernández *et al.* (2013), Correlation coefficients have a probability (p-value), which shows the probability that the relationship between the two variables is equal to zero (null hypotheses; no relationship). Strong correlations have low p-values because the probability that they have no relationship is very low. Correlations are typically considered statistically significant if the p-value is lower than 0.05 in the social sciences, but the researcher has the liberty to decide the p-value (alpha value) for which he or she will consider the relationship to be significant. Méndez-Hernández *et al.* (2013), further stated that four things must be reported to describe a relationship:

- The strength of the relationship given by the correlation coefficient.
- The direction of the relationship, which can be positive or negative based on the sign of the correlation coefficient.
- The shape of the relationship, which must always be linear to computer a Pearson correlation coefficient.
- Whether or not the relationship is statistically significant, which is based on the p-value.

3.6.5 Evaluation metrics for indoor air contaminants

Air Quality Index (AQI), is a system for reporting the severity of air quality levels. Following the US EPA standards as published by the air visual node manual, there are categories of values for AQI. A value of 0 – 50 is deemed good, 51 – 100 moderate, 101 – 150 unhealthy for sensitive groups, 151 – 200 unhealthy, 201 – 300 very unhealthy and above 300 is hazardous. Sensitive groups comprise of people with respiratory or heart disease, children and the elderly. The adopted standard for the $PM_{2.5}$, PM_{10} and CO_2 is stated in the table 3.6 below.

Table 3.6: Evaluation metrics for indoor air contaminants

	Remark	**$PM_{2.5}$ (ug/m^3)**	**PM_{10} (ug/m^3)**	**CO_2 (ppm)**
Reference		Kim *et al.* (2021)	Kim *et al.* (2021)	Air visual node manual
Grade	Good	0 - 15	0 - 30	0 - 700
	Normal	16 - 35	31 - 80	701 - 1000
	High (bad)	36 - 75	81 - 150	1001 - 1500
	Unhealthy (very bad)	Above 75	Above 150	1501 - 2500
	Very unhealthy			2501 - 5000
	Hazardous			5001 – 10 000

Source: Adapted from Kim *et al.* (2021).

3.7 Ethical Considerations

Research must be carried out logically and coherently within the appropriate sequences to avoid research misconduct. Akaranga & Makau (2016) and Fleming and Zegwaard (2018) explained in detail, various research ethical rules to be followed to ensure thorough ethical considerations. Given that research required participants by questionnaire, they advised that sensitive and personal questions should be avoided. A brief introductory statement was made which assured the respondents that all data obtained are for research purposes alone and have the right not to answer them if it is not okay.

Furthermore, all the rooms surveyed were coded with letters and not the exact room name. according to the hostel management policies, males are not permitted into the female hostels and as such female assistants were briefed and sent to the female hostels to collect both the data for the questionnaire survey and the instrument survey. In order to obtain the building drawings from PPDU, a request letter was written to the director through the HOD architecture department.

3.8 Summary of Research Methodology

The summary of the research method is illustrated in the research onion depicted in figure 3.2. Research onion is a diagrammatic representation that gives a brief and comprehensive view of the entire research process, embodied in six layers (Saunders *et al.*, 2016).

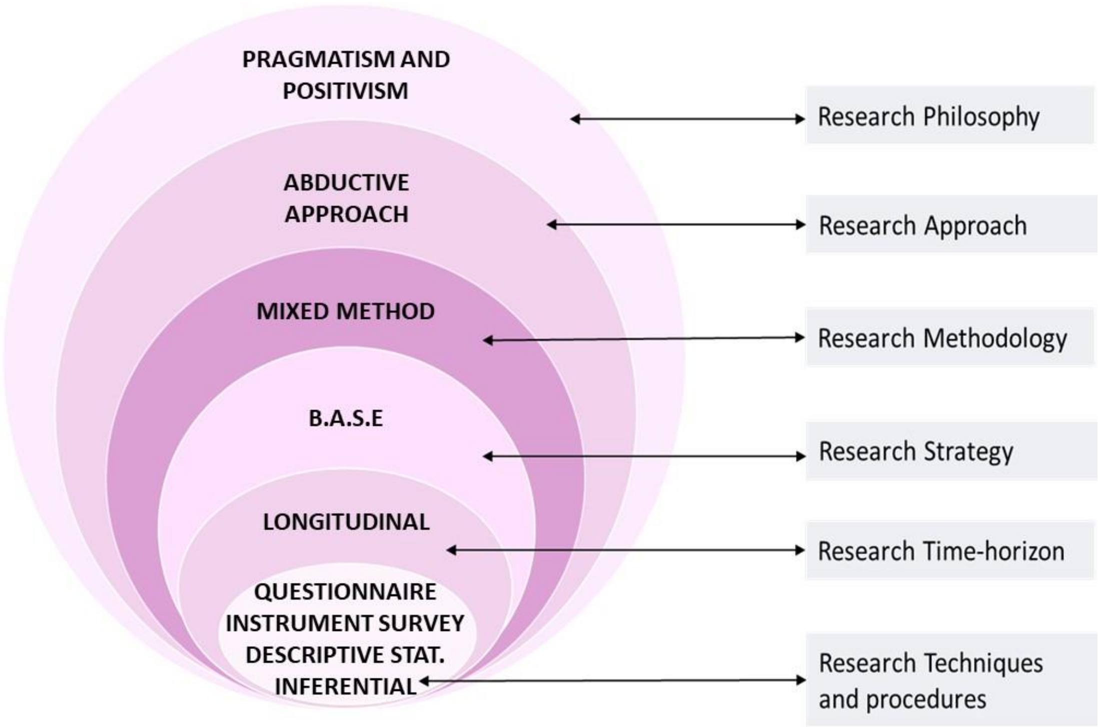


Figure 3.2 Research onion of the entire research process

Source: Author’s field work (2023)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Case Study Survey

The BASE requires a physical survey of the facility as well as an occupant survey. The existing hostels in the Federal University of Technology Minna, was surveyed and a total of six (6) blocks were surveyed as stated in the research method which cut across both the male and female hostels. The limitation faced in this stage is as a result of lack of building drawings from the Physical Planning and Development Unit (PPDU) of the university. Only the building drawings for the New Male and Female Hostels were obtained.

Figure 4.1: Google earth map of the various blocks.
Source: Author's field work (2023)

4.1.1 Case male hostel, blocks A and B

This is an accommodation space open for use only to the undergraduate males. It is building having 83 rooms, 12 kitchens, 48 toilet and bath spaces, one common room and a central courtyard all planned in 3 floors (ground, first and second floors). Each room by design has an occupancy of 5 bed spaces with a total of 415 bed spaces. However, these blocks are overcrowded. The design for both blocks A and B is typical and face similar issues.

Plate I: Approach view of the Male Hostel Block.
Source: Author's field work (2023).

4.1.1.1 Building orientation and air flow

The orientation of the buildings is such that it harnesses the prevailing winds at the NE and SW ends with the longer sides facing those directions. This gives the buildings a good positioning for air flow. Adjourning buildings are well located at a good distance that will not obstruct air flow. However, the building is subject to the harsh impact of the winds as there are no wind breakers.

4.1.1.2 *Ventilation and shading*

The Ventilation type used was the Stack ventilation and cross ventilation. The rooms are cross ventilated. There is a central courtyard which serves as an open space to achieve the cross ventilation through stack effect. The window type used is the casement windows openable on both hinges on the exterior walls and a louvre window on the walls facing the courtyard. The vertical and horizontal shading devices were used for sun shading, however, this did not form an eggcrete. The state of some of the windows are bad and need maintenance. Artificial ventilation is achieved through the use of ceiling fans in all room spaces.

Plate II: A & C. Image of the window type and the shading device. B. Image of the central courtyard.
Source: Author's field work (2023).

4.1.1.3 *Landscaping and outdoor environment.*

The land area covering the blocks were not landscaped. The outdoor environment is unkempt. The water supply area is a harbor for brooding mosquitoes and also a source of outdoor pollutants. The courtyard is also not left out. It is not landscaped and the drainages are not well maintained. In between the two hostel blocks is a refuse dump. This is not hygienic for the occupants of the space as this land pollution impacts the outdoor air invariably affecting the indoor air.

Plate III: A & C. The outdoor environment surrounding the hostels. B. Image of the clogged drainage of the central courtyard.
Source: Author’s field work (2023).

4.1.1.4 Indoor environment assessment

The state of the indoor environment is varying, considering the occupants of the space. However, one common attribute that exists is overcrowding of the space. By design, there is a kitchen space where cooking activities should occur, however, this space is redundant and seldomly used. The sanitary spaces are poorly maintained and is a strong source of indoor pollutants to the neighboring rooms. Plate IV shows the state of the indoor spaces in the Male hostel from both blocks A and B.

Plate IV: A. Water gather points in the hostel. B. The interior of the room space. C. The general kitchen space.
Source: Author’s field work (2023).

4.1.2 Case Shehu Aliyu female hostel

This is an accommodation space open for use only to the undergraduate females. It is building having 62 rooms, general kitchens, ensuite toilet and bath spaces, all planned in 2 floors (ground, and first floors). Each room by design has an occupancy of 4 bed spaces with a total of 248 bed spaces. This block also does not have the floor plans available.

4.1.2.1 Building orientation and air flow

The building has a T shaped plan with the cross longer than the tail. The cross facing the north exposing the longer length to the sunrise and sunsets in the east and west respectively as well as the radiant energy of the sun as showing in figure 4.1. This also gave the building an exposure to the prevailing winds directly. This is a good orientation if wind breakers were planted to reduce the strong winds in the summer and winter. This orientation gives the buildings a good positioning for air flow. Adjourning buildings are well located at a good distance that will not obstruct air flow.

4.1.2.2 Ventilation and shading

The Ventilation type used was the one sided ventilation. The rooms are placed at opposite sides of long lobby along the cross axis (plate V). For tropical regions, cross ventilation is the best form of natural ventilation or daylighting. The double banked lobby is always dark and narrow and depends on artificial lighting. The window type used is the casement windows openable on both hinges on the exterior walls as well as on the walls facing the lobby. There are no exterior shading devices except for the curtains which are placed internally by the occupants.

Plate V: A. The approach to the building. B. Image of the window type and absence of shading device. C. The narrow lobby separating the rooms
Source: Author’s field work (2023).

4.1.2.3 Landscaping and outdoor environment.

There is a perimeter fencing for this block and the undeveloped area was landscaped with paved areas, green areas. The outdoor environment is not polluted and can be further enhanced with proper landscaping, planting of trees and maintenance (plate VI). There is no land induced air pollution emanating from refuse dump places and clogged drainages, however the users behaviour has an impact on the indoor environment.

4.1.2.4 Indoor environment assessment

The survey showed that cooking activities are done along the narrow lobby and even at the circulation points of the hostels such as the staircase regions. The kitchen area is poorly maintained thus leading to cooking along the lobby and even inside the rooms. Plate VII shows the improper waste disposal along the lobby. There is no laundry room, so even washing is done inside rooms as occupants are reluctant to go outside and wash. The ensuite toilets also needs proper maintenance. All these activities added to the one side ventilation will eventually impact the indoor air quality in the hostel spaces.

Plate VI: A. The paved area devoid of trees. B. The use of the corridors for cooking activities

Source: Author’s field work (2023).

Plate VII: A. Dumping of refuse along the narrow lobby. B. The interior of the room space.
Source: Author's field work (2023).

4.1.3 Case new male and female hostels

This is the recently completed hostel accommodation comprising of two typical blocks which was initially planned to be for just the female students but was later shared amongst the male and female occupants. This is an accommodation space open for use only to the undergraduate males and females. It is building having 72 rooms, general kitchens, ensuite toilet and bath spaces as well as shops and common room, all planned in 3 floors (ground, and first and second floors) each. There are two space typologies, room of four with ensuite bathroom and toilet with a shared kitchen and then room of 2 with kitchen and sanitary spaces embedded within. This brings the bed spaces to a total of 216 bed spaces.

Plate VIII: A. Orientation of the hostel buildings. B & C. The exterior outlook of the buildings.
Source: Author's field work (2023).

4.1.3.1 Space planning, building orientation and air flow

The building has a L shaped floor plan, forming a right angle, with the longer axis facing North and the shorter facing west (plate VIII). The part facing the north exposes the longer length to the sunrise and sunsets in the east and west respectively as well as the radiant energy of the sun and the shorter part can harness majorly the prevailing winds. The orientation of the longer axis is more convenient compared to that of the shorter axis and occupants at that those spaces will have a balance natural ventilation and daylighting. The building was planned to have a long courtyards divided into two by walkways (plate XIII). This served as a means to achieve cross ventilation through the courtyards.

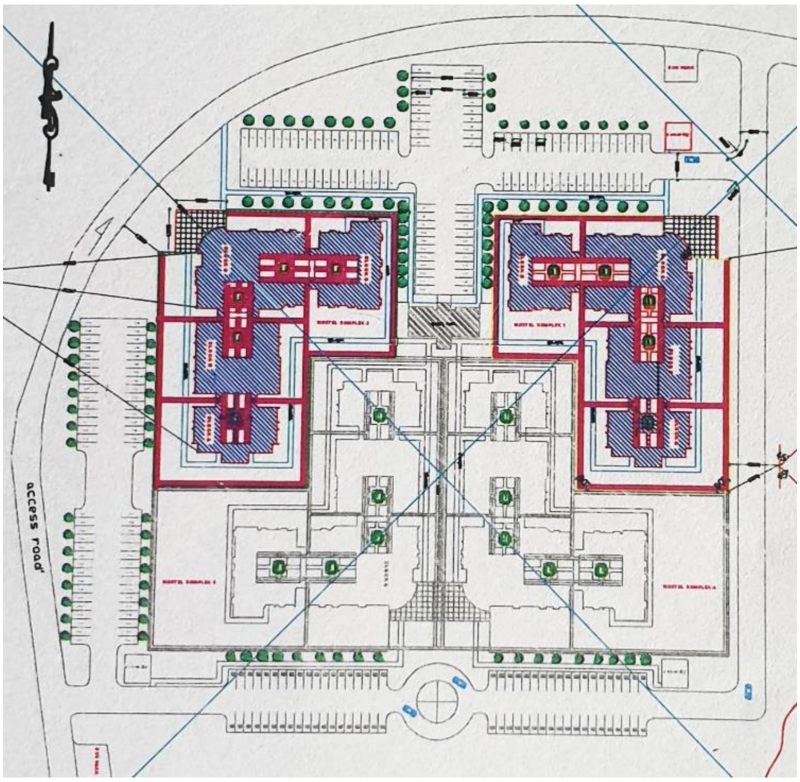


Plate IX: Image of the site plan of the two hostels.

Source: PPDU (2023).

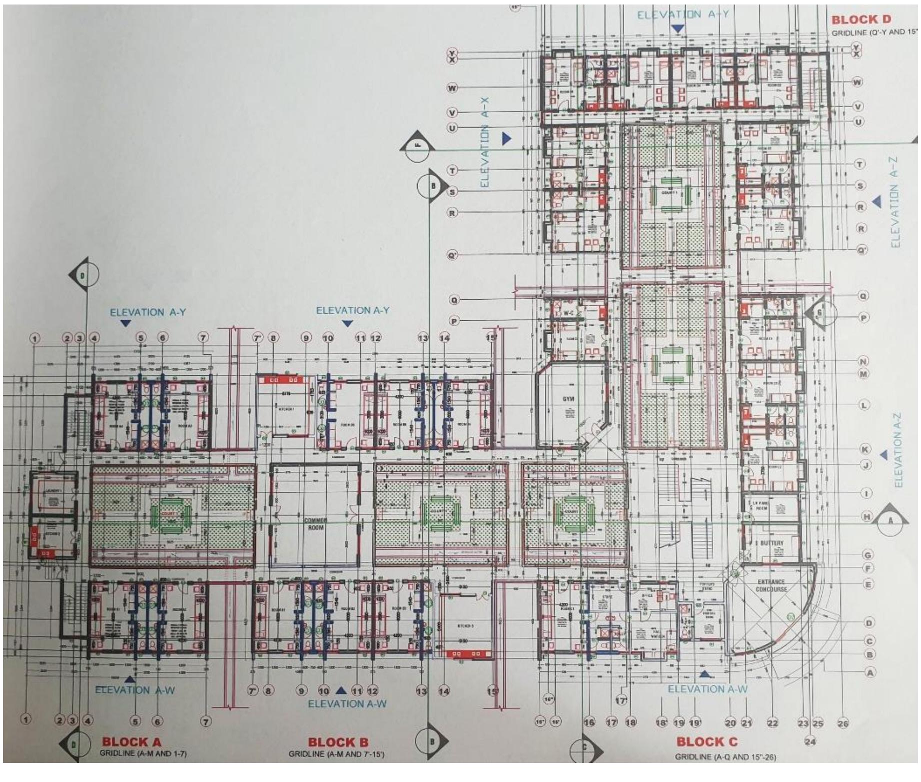


Plate X: Image of the ground floor plan of the hostel

Source: PPDU (2023).

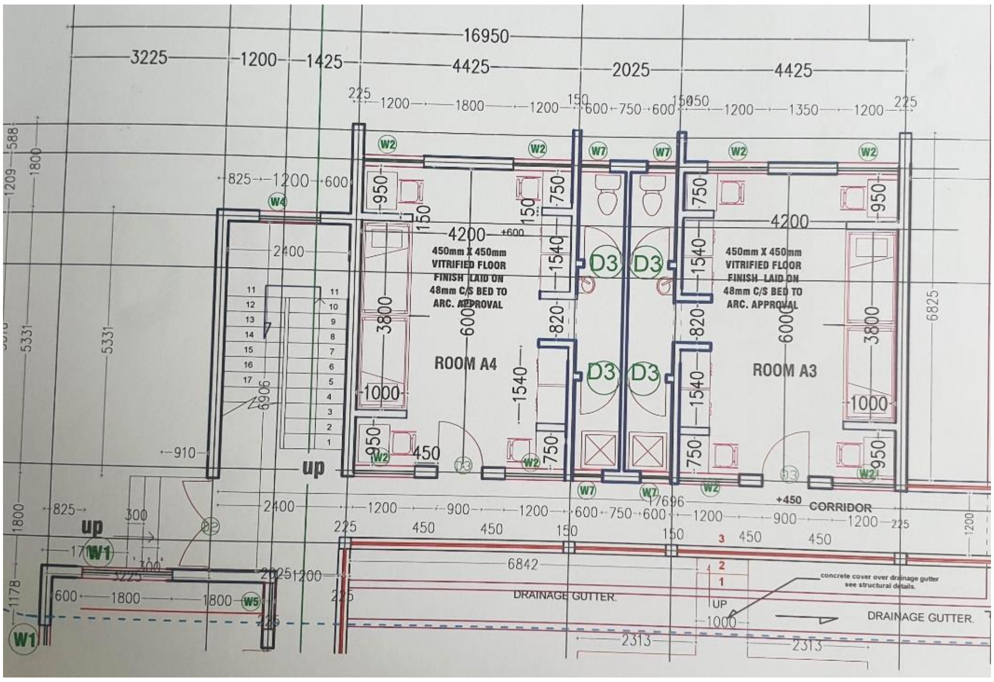


Plate XI: Image of the call out of the room of four space typology.

Source: PPDU (2023).

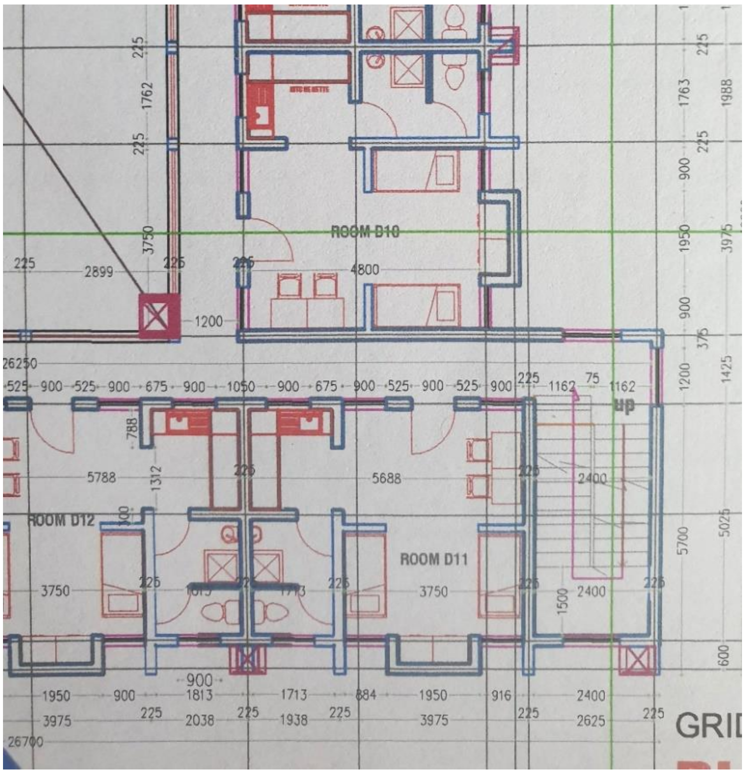


Plate XII: Image of the call out of the room of two space typology

Source: PPDU (2023).

4.1.3.2 Ventilation and shading

The Ventilation type used was the cross ventilation achieved through the courtyard stack effect. The window typed used was the sliding window with a tint glass for solar shading. The advantage a casement window has over the sliding window is in its ability to obtain a 100% air flow in and out of the space The vertical exterior shading devices was used for sun shading. Within the indoor space is an artificial ventilation system in the rooms and a wall extractor fan in the kitchen and laundry areas. The AC units can serve as an air extractor depending on the design of the AC unit. Plate XIII shows the air extractor fan in the kitchen area.

Plate XIII: A. Image of the central courtyard. B. The use of extractor fan in the kitchen space. C. The use of AC in the room spaces

Source: Author's field work (2023).

4.1.3.3 Landscaping and outdoor environment.

There is a perimeter fencing for these blocks and the undeveloped area are yet to be landscaped. The courtyards however are landscaped and designed for social seating and outdoor sporting event. The outdoor environment is not polluted and can be further enhanced with proper landscaping, planting of trees and maintenance (plate XIX). There is no land induced air pollution emanating from refuse dump places and clogged drainages, however the users behaviour has an impact on the indoor environment in such a way that urination is done in particular portion of the hostel facility and this activity pollutes the air.

Plate XIV: A. The paved area of the compound. B. The landscaping of the central courtyard. C. The use of planted trees in the outdoor environment.

Source: Author’s field work (2023).

4.1.3.4 Indoor environment assessment

The indoor environment of this hostel is still in good shape considering it was recently done. However individual spaces are defined by the hygiene of the occupants. There is a separate room for laundry and cooking which has extractors fans, however, the students still prefer cooking in their room spaces or the corridor due to the distance of some rooms to the kitchen space. This is common with the occupants inhabiting the four bed space typology. This activity impacts the room IAQ as later discussed and defeats the aim of the design strategies employed for good IAQ.

Plate XV: A & B. Image of the ensuite kitchen and general kitchen. C. Image of the interior space for the room of four.
Source: Author’s field work (2023).

4.1.4 Case C – G blocks (old female hostels)

This accommodation comprises of five standalone blocks built on just one floor each and has spaces for both undergraduate and postgraduate students. It is a group of buildings having 70 rooms, general kitchens, ensuite toilet and bath spaces as well as shops and common room, all planned in one floor each. There are two space typologies, room of six for the undergraduates and a single room for post graduates. This is the only hostel that made room for post graduate accommodation. It has a perimeter fence and a portress office which is responsible for managing the hostel.

4.1.4.1 Space planning, building orientation and air flow

The five buildings are orientated facing one direction (the NE and SW) along its longer axis. (plate VIII). This means that the shorter axis is open to the windward side and the longer axis will only harness the deflected winds. This orientation however is beneficial for natural daylighting but not efficient for adequate natural ventilation. However, the case of the orientation may be, the blocks are at planned in a rectilinear pattern with large space (open courtyards) between them that will enhance air flow. Each block has a closed courtyard which boosts the ventilation of the interior spaces through cross ventilation and stack effect.

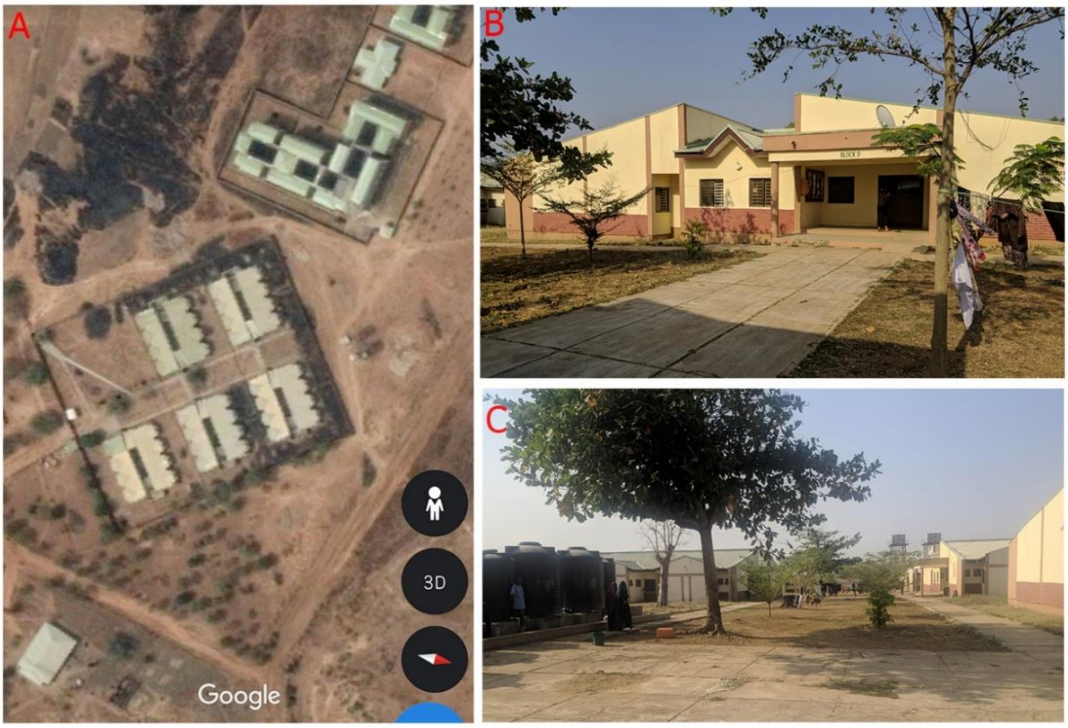


Plate XVI: A. Image of the orientation and layout of the blocks. B. Image of the approach to a typical block. C. Open courtyards and a vast space to enhance air flow. Source: Author’s field work (2023).

4.1.4.2 Ventilation and shading

The Ventilation type used was the cross ventilation achieved through the courtyard stack effect. The window typed used was the sliding window with a tint glass for solar shading. The rooms are shaded from the sun with the use of overhangs and recessed walls. The courtyard separated the linearly arranged cellular rooms, ensuring that each room is cross ventilated.

4.1.4.3 Landscaping and outdoor environment.

There is a perimeter fencing for these blocks and the undeveloped area is landscaped with green areas, trees, shrubs and paved walkways. The courtyards are not landscaped used for social seating, clothes drying. The outdoor environment is not polluted due to the landscaping and tree elements (plate XIX). There is no land induced air pollution emanating from refuse dump places and clogged drainages.

Plate XVII: A. Image of the paved areas and trees. B. Image of window type and the shading technique. C. Image of the central courtyard.
Source: Author's field work (2023).

4.1.3.4 *Indoor environment assessment*

The indoor environment of this hostel needs renovation. The general kitchens are in a bad condition and has caused the students to cook in their rooms. The room spaces are overcrowded as shown in plate XXI. The ceiling boards are producing moulds which are a source of indoor air pollutant. This space makes it difficult for the occupants to maintain good hygiene as the spaces are usually choked up. The hostel management needs to consider a serious renovation on this facility and ensure that a good maintenance culture is kept.

Plate XVIII: A & C. Image of the interior of the room space. B. Image of the general kitchen.

Source: Author's field work (2023).

4.2 Questionnaire and Instrument Survey

The method in which the data were collected, involved an occupant survey using a questionnaire and an instrument survey (air visual node) as stated in the research methods.

For the occupant survey, a Cronbach alpha test was conducted to test for internal consistency (reliability). The values obtained as shown in table 4.1 is above 0.7 which is the acceptable value for reliability. This means that the data presented in this research work is valid and reliable.

4.1 Table of Reliability Statistics

Hostel Name	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Male Hostel Block A	0.705	0.730	59
Male Hostel Block B	0.829	0.818	59
New Male Hostel	0.680	0.680	59
Block C – G (female)	0.76	0.788	59
Shehu Aliyu	0.854	0.849	59
New Female Hostel	0.819	0.815	59

Source: Author's field work (2023)

4.2.1 General characteristics of the respondents.

4.2.1.1 Male hostel A

The demographics of the respondents in Male Hostel A are shown in table 4.2. There exists an underlining issue of overcrowded spaces as 83.1% of the respondents stay in a room of 5 – 12 occupants against the allocated 5 persons. Overcrowding of space impacts the indoor air quality. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (96.8%). This implies that a good number of respondents have stayed in the hostel environment for a good period of time as against the 100 level respondents. Staying in an indoor space for 6 months is enough for the nature of the air to affect the occupant. 71.1% of the respondents have stayed a period of 4 – 6 months in these hostel rooms. This means that deductions drawn in the later stages of this chapter is abiding to the respondents.

Table 4.2: Demographics of respondents of Male Hostel A

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
100 Level	6	7.2
200 Level	18	21.7
300 Level	29	34.9
400 Level	19	22.9
500 Level	11	13.3
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	14	16.9
5 - 8 Persons	41	49.4
9 - 12 Persons	28	33.7
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
1 - 3 Months	20	24.1
4 - 6 Months	59	71.1
7 - 9 Months	02	2.4
10 - 12 Months	02	2.4
Total	83	100

Source: Author's field work (2023)

4.2.1.2 Female hostel C – G

The demographics of the respondents in Female Hostel C - G are shown in table 4.3. There exists an underlining issue of overcrowded spaces as 80.6% of the respondents stay in a room of 5 – 12 occupants against the allocated 6 persons. Overcrowding of space impacts the indoor air quality. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (87.1%) and even at post graduate level of 12. 9%. This implies that a good number of respondents have stayed in the hostel environment for a good period of time as against the 100 level respondents. Staying in an indoor space for six (6) or more months is enough for the nature of the air to affect the occupant. 56.5% of the respondents have stayed a period of 4 – 6 months in these hostel rooms. This means that deductions drawn in the later stages of this chapter regarding these blocks is abiding to the respondents.

Table 4.3: Demographics of respondents of Female Hostel C - G

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
Postgraduate	08	12.9
200 Level	11	17.7
300 Level	11	17.7
400 Level	08	12.9
500 Level	24	38.7
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	12	19.4
5 - 8 Persons	48	77.4
9 - 12 Persons	02	3.2
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
Less than a month	04	6.5
1 - 3 Months	22	35.5
4 - 6 Months	35	56.5
7 - 9 Months	01	1.6
Total	62	100

Source: Author’s field work (2023)

4.2.1.3 Male hostel B

The demographics of the respondents in Male Hostel B are shown in table 4.4. the issue of overcrowding of space is minimized as 66.3% of the respondents stay in a room of 5 – 8 occupants against the allocated 5 persons. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (71.2%) and even at post graduate level of 6. 0%. This implies that a good number of respondents have stayed in the hostel environment for a good period of time. A significant number of respondents are in the 100 level (22.9%) and this will only imply that possible symptoms noticed in such students might be prevalent even before they were admitted. 74.7% of the respondents have stayed a period of 4 – 6 months in these hostel rooms. This means that deductions drawn in the later stages of this chapter regarding this block is abiding to the respondents.

Table 4.4: Demographics of respondents of Male Hostel B

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
100 Level	19	22.9
200 Level	12	14.5
300 Level	18	21.7
400 Level	12	14.5
500 Level	17	20.5
Postgraduate	05	6.0
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	28	33.7
5 - 8 Persons	55	66.3
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
1 - 3 Months	14	16.9
4 - 6 Months	62	74.7
7 - 9 Months	01	1.2
10 - 12 Months	03	3.6
Over a year	03	3.6
Total	83	100

Source: Author’s field work (2023)

4.2.1.4 Shehu Aliyu female hostel

The demographics of the respondents in Shehu Aliyu female hostel are shown in table 4.5. there issue of overcrowding of space is almost not occurring in this block as 82.7% of the respondents stay in a room of 1– 4 occupants against the allocated 4 persons. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (92.0%) and even at post graduate level of 4.8%. This implies that a good number of respondents have stayed in the hostel environment for a good period of time. A greater percentage of respondents (99.4%) in this block stayed at least 3 months in the space, with 45.2% spending at least 4 months in the hostel space. The outcome of this survey is binding to the occupants of the hostel block.

Table 4.5: Demographics of respondents of Shehu Aliyu Hostel

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
100 Level	02	3.2
200 Level	07	11.3
300 Level	24	38.7
400 Level	02	3.2
500 Level	24	38.7
Postgraduate	03	4.8
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	51	82.7
5 - 8 Persons	11	17.7
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
Less than a month	01	1.6
1 - 3 Months	33	53.2
4 - 6 Months	28	45.2
Total	62	100

Source: Author’s field work (2023)

4.2.1.5 New male hostel

The demographics of the respondents in New male hostel are shown in table 4.6. There is a strict adherence to maximum space allocated for a room as 94.4% of the respondents stay in a room of 1– 4 occupants against the allocated 4 persons. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (83.3%). This implies that a good number of respondents have stayed in the hostel environment for a good period of time. A greater percentage of respondents

(77.8%) in this block stayed at least 4 months in the space, with 19.4% spending at least 3 months in the hostel space. The outcome of this survey is binding to the occupants of the hostel block.

Table 4.6: Demographics of respondents of New Male Hostel

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
100 Level	12	16.7
200 Level	24	33.3
300 Level	16	22.2
400 Level	08	11.1
500 Level	12	16.7
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	68	94.4
5 - 8 Persons	04	5.6
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
Less than a month	02	2.8
1 - 3 Months	14	19.4
4 - 6 Months	56	77.8
Total	72	100

Source: Author's field work (2023)

4.2.1.6 New female hostel

The demographics of the respondents in New female hostel are shown in table 4.7. There is no overcrowding as 100% of the respondents reside in rooms within the design capacity of 1 – 4 persons. The distribution of the respondents across the various levels is such that majority of them are between 200 level and 500 level (94.4%). This implies that a good number of respondents have stayed in the hostel environment for a good period of time. A greater percentage of respondents (83.3%) in this block stayed at least 4 months in the space, with 16.7% spending at least 3 months in the hostel space. The outcome of this survey is binding to the occupants of the hostel block.

Table 4.7: Demographics of respondents of New Female Hostel

Respondents based on Education Year		
Education Year	**Frequency**	**Percentage %**
100 Level	04	5.6
200 Level	36	50.0
300 Level	24	33.3
400 Level	04	5.6
500 Level	04	5.6
Respondents based on Number of Persons sharing a Room		
Number	**Frequency**	**Percentage %**
1 - 4 Persons	72	100.0
Respondents based on Duration of Stay		
Number	**Frequency**	**Percentage %**
1 - 3 Months	12	16.7
4 - 6 Months	60	83.3
Total	72	100

Source: Author's field work (2023)

In summary, the new hostels showed positive signs regarding overcrowding of space as there were record the least percentage of overcrowded space. Generally, the distribution of the respondents is such that the 100 level students only took a small fraction of the population sample as there just enrolled in the institution, whereas higher level who must have stayed in the hostel spaces for at least a session dominated the sample population.

4.2.2 Occupant behavior and indoor air particulate concentrations

4.2.2.1 Male hostel A

As established in the literature review, occupants behaviour affect indoor air particulate concentrations through various activities. From the occupants' survey, the activities relating to the indoor environment are presented in table 4.8. it is important to note that occupants behaviours that influence indoor air particulate concentrations are in two categories namely; activities within the indoor space that increases indoor air particulate concentrations such as indoor cooking, laundry and cleaning, and activities that creates an interaction between the indoor air and outdoor air such as opening of fenestrations.

Table 4.8: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	30	36.1
Kerosene	51	61.4
Charcoal	02	02.4
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	37	44.6
Along the Corridor of the Room	27	32.5
Separate room in the Hostel (i.e. kitchen)	19	22.9
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	6	7.2
No	77	92.8
Total	83	100

Source: Author’s field work (2023)

It is seen from table 4.8 that indoor air particulate concentrations will naturally increase due to the occupants behaviours. 61.4% of them use kerosene to cook. Kerosene stove is a combustion stove which produces CO_2 whenever there is complete combustion and CO when combustion is incomplete. 44.6% of the occupants, cook inside their rooms. This will increase the CO_2 content of the rooms from the already existing ones created as a result of an overcrowded room. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Three rooms were surveyed using the air node device namely; rooms A, B and C all in the dry season. The statistical observations are presented in table 4.9. It was observed that Room B has the worst conditions of all three rooms. Room A has daily temperature and humidity averages of 28^{o}C and 21% respectively. The room has temperatures as high as

30^{o}C and humidity as high as 25%. The air is too dry for breathing and too hot for a comfortable environment. Room B also had high temperatures with an average of 27^{o}C a little bit above the normal room temperature of 25^{o}C. The average humidity was recorded at 27%, with a maximum of 44% which is abnormal in the dry season. This means that some activity within the room must have influenced it. Room C located at the second floor had an average temperature of 28^{o}C and a maximum of 30^{o}C. This means the temperature is generally high which will require a good ventilation system and cooling system if possible. Average humidity recorded is 27% with a maximum value of 30%. This indoor conditions affects occupants behaviour which influences indoor air particulate concentrations.

Table 4.9: Statistical observation of indoor air contaminants (Male Hostel A)

Indoor Air Variables (Room A)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	68.47	97.56	676.68	28.12	21.11	134.94
SD	38.848	60.388	28.333	1.635	.675	43.956
Min	11	12	641	25	20	46
Max	147	213	832	30	25	198
Indoor Air Variables (Room B)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	72.2326	99.3609	757.6502	27.7760	27.3863	158.9581
SD	15.78244	22.11439	157.07922	2.30154	5.26154	9.50847
Min	45.00	53.00	633.00	24.30	22.00	124.00
Max	174.20	232.00	1283.00	31.10	44.00	224.00
Indoor Air Variables (Room C)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	50.939	67.105	827.326	28.588	27.347	130.306
SD	15.2324	21.9751	166.0399	2.0596	3.1171	26.1547
Min	34.281	42.392	708.71	25	20	46
Max	75.233	101.572	1136.51	30	30	198

Source: Author’s field work (2023)

The air contaminants that the device could measure include PM 2.5, PM 10 and CO_2. For the Room A, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 68 ug/m^3, 98 ug/m^3, and 677 ppm. Room B had 72 ug/m^3, 99 ug/m^3, and 757 ppm. Room C had 51 ug/m^3, 67 ug/m^3, and 827 ppm. Generally, the AQI for the three rooms are above 100. This is unhealthy for sensitive cases. Room B had an average AQI of 159, a minimum value of 124 and a maximum value of 224. This is very unhealthy.

H_{01a} Occupant behavior is the primary mechanism determining indoor particulate concentrations

When placed in indoor spaces with similar properties in terms of ventilation, room size and room population, it becomes a need to understand why these indoor spaces have varying indoor particulate concentrations. Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. As shown in table 4.8, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

Table 4.10 The hourly average of air contaminants in the various rooms

Hourly avg.	Room A			Room B			Room C		
	$PM_{2.5}$	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**
Hr. 1	19.90	25.64	717.18	57.61	78.28	1119.77	54.591	72.939	1136.51
Hr. 2	32.33	39.90	711.99	63.17	86.71	913.63	61.264	82.050	1081.67
Hr. 3	35.68	43.61	703.15	67.42	90.39	826.34	65.554	88.519	1088.04
Hr. 4	27.98	34.79	686.23	80.32	105.79	908.01	64.331	87.317	823.91
Hr. 5	33.71	43.72	668.83	82.33	111.72	707.54	75.233	101.572	726.88
Hr. 6	45.35	61.54	664.95	71.55	95.76	675.48	65.436	87.047	722.20
Hr. 7	77.54	111.74	677.03	65.90	87.97	667.04	44.830	57.708	728.06
Hr. 8	102.14	149.54	667.37	68.14	94.21	650.85	38.558	49.661	708.71
Hr. 9	111.77	164.48	660.63	80.04	114.59	648.38	34.281	42.392	741.99
Hr. 10	114.81	170.76	652.45	75.63	107.55	656.91	34.983	43.008	736.98
Hr. 11	115.75	170.87	648.54	77.41	110.19	666.40	34.569	43.572	722.93
Hr. 12	116.78	172.99	656.65	77.27	109.17	651.45	37.636	49.469	710.04

Source: Author's field work (2023)

The period in which the survey was conducted was from 6:00 PM to 6:00 AM (12 hours). This period was chosen as it was a time were most members of the rooms are presented due to day to day activities. It is also the period when most chores take place. The cooking activities spans from 7pm to 11pm sometimes even early hours of the morning considering it is the male hostel and they do not have a restriction to the time of cooking. Occupants of Rooms B and C cook inside the room as against occupants of room A who cook along the corridor. This activity is as a result of the distance from the kitchen to their rooms. It is observed that the CO_2 content of the indoor air for room A is normal (moderate) having the highest hourly average to be 717 ppm (the cooking period in which CO_2 gases could have diffused into the room from the corridor or other outdoor sources). This room also is not overcrowded (6 persons against the standard 5). Rooms B and C have high values of CO_2 with the highest average been 1120 ppm and 1136 ppm respectively. This is not healthy. The high CO_2 contents of these room is as a result of the cooking activities in the rooms.

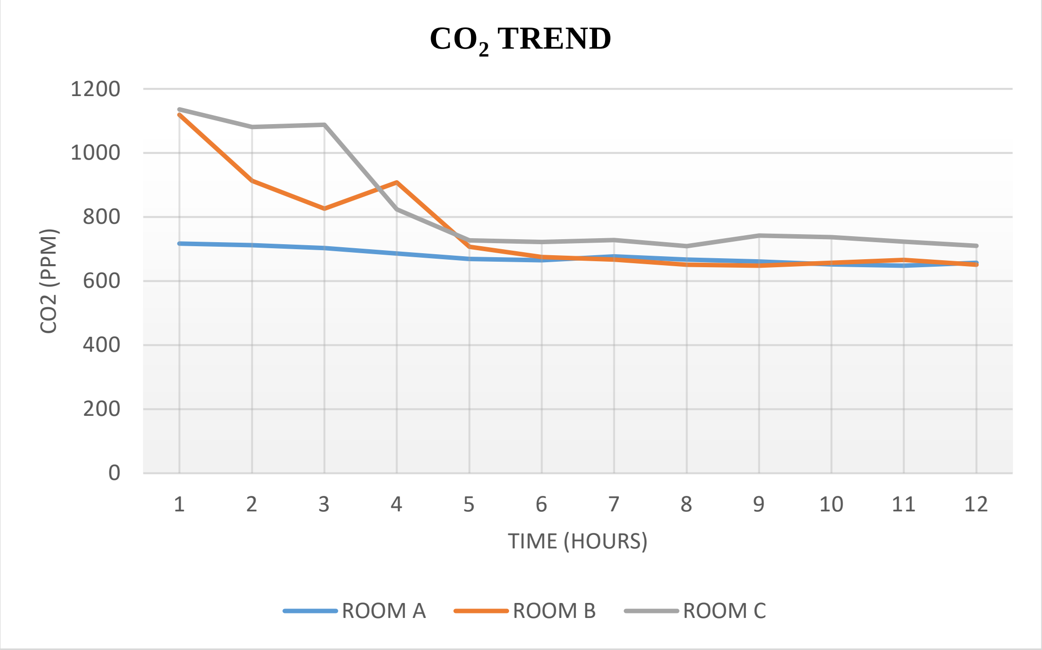


Figure 4.1: Trend chart of CO_2 in the monitor rooms (Male Hostel A).
Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking (Tran *et al.*, 2020). $PM_{0.1}$ is obtained majorly from fossil fuel (this cannot be detected by the device), $PM_{2.5}$ and PM_{10} are obtained indoors majorly from cooking and smoking. Room A had normal values for both even during the cooking period. This further proves the absence of cooking activities going on in the room. However, the values went high so much that it became unhealthy (117 ug/m^3). This is possible only if the windows of the rooms were open considering the dry season and the outdoor air has influenced the indoor air. Table 4.6 shows that occupants frequently open windows during dry season. It is expected that the PM values of rooms B and C to be high considering the cooking activities in the rooms, which was so. However, there was a decline during the early hours of the day for both PM $_{2.5}$ and PM $_{10}$ for room C after cooking where as that of Room B increased.

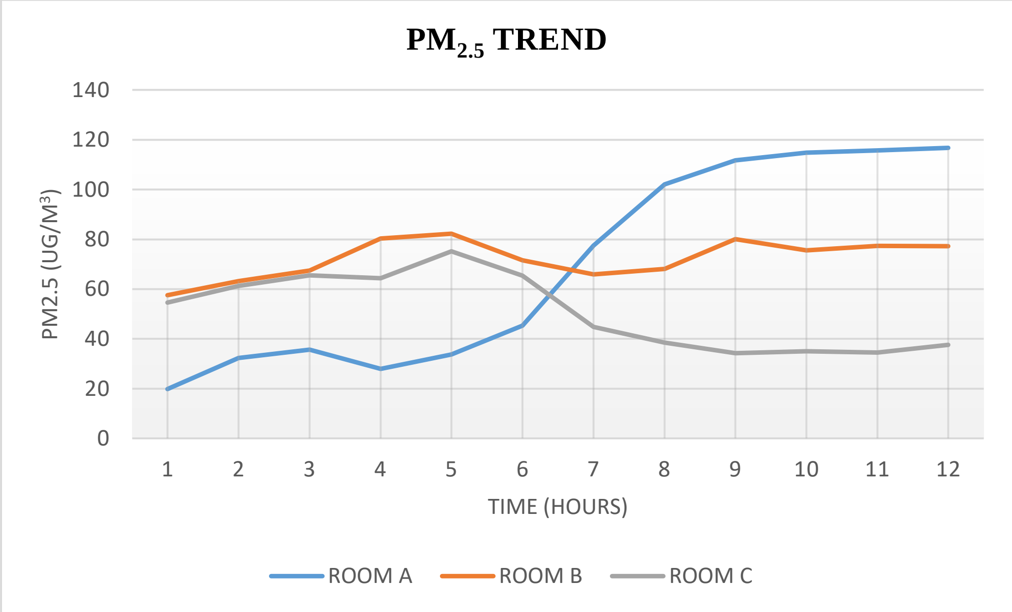


Figure 4.2: Trend chart of $PM_{2.5}$ in the monitor rooms.

Source: Author's field work (2023)

This is possible because after cooking hours there was a general drop in the PM values for about 2 hours averagely before the different changes as a result of outdoor influencing indoor concentrations. room C had their windows closed while room B had theirs open. This further proves that occupants behaviours influence indoor air particulate concentrations. Activities relating to the interactions between the indoor and outdoor concentrations as obtained from the occupants' survey is shown in table 4.11

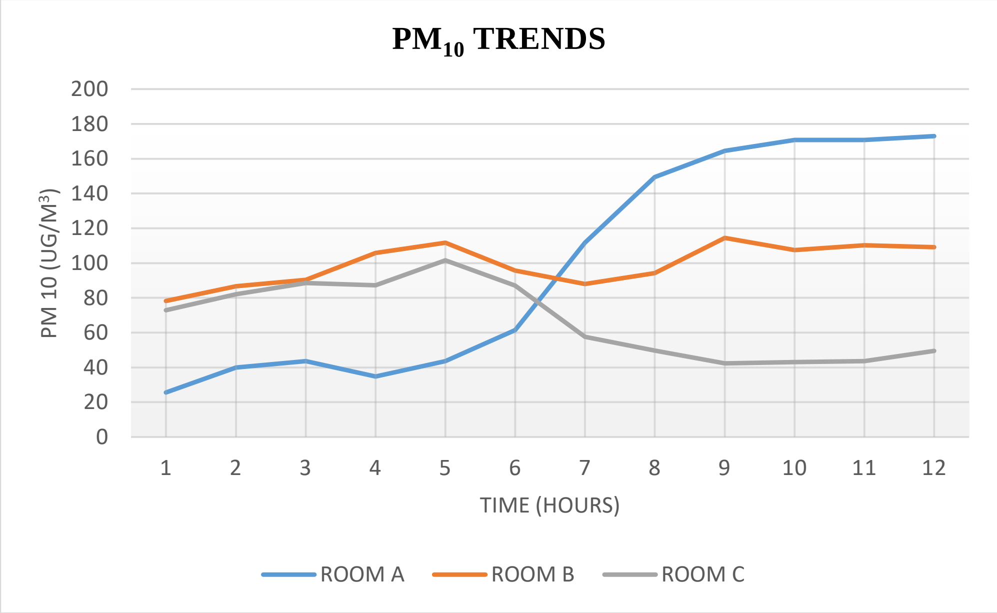


Figure 4.3: Trend chart of PM_{10} in the monitor rooms.

Source: Author's field work (2023)

Table 4.11 Occupants activities that results in indoor outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	315	3.80
Raining Season	270	3.25
Number of respondents = 83; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it's windy outdoor	57	30
When it's dusty outdoor	61	32
When it's raining	72	38
Total	190	100
Multiple responses by 83 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	40	48.2
Louvres	37	44.6
Window blinds (i.e.	20	24.1
curtains)	97	100
Total		

Multiple responses by 83 respondents

Source: Author's field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. This particle migration can be reduced with the use of window blinds and curtains whereas shutters and louvres have to be open for effective ventilation. The reason for high PM in rooms with who open the windows are as a result of the need for good ventilation. Rooms B and C faced the wind direction. This means that an opened window without curtains or blinds will allow an influx of PMs. Only few rooms have curtains in them.

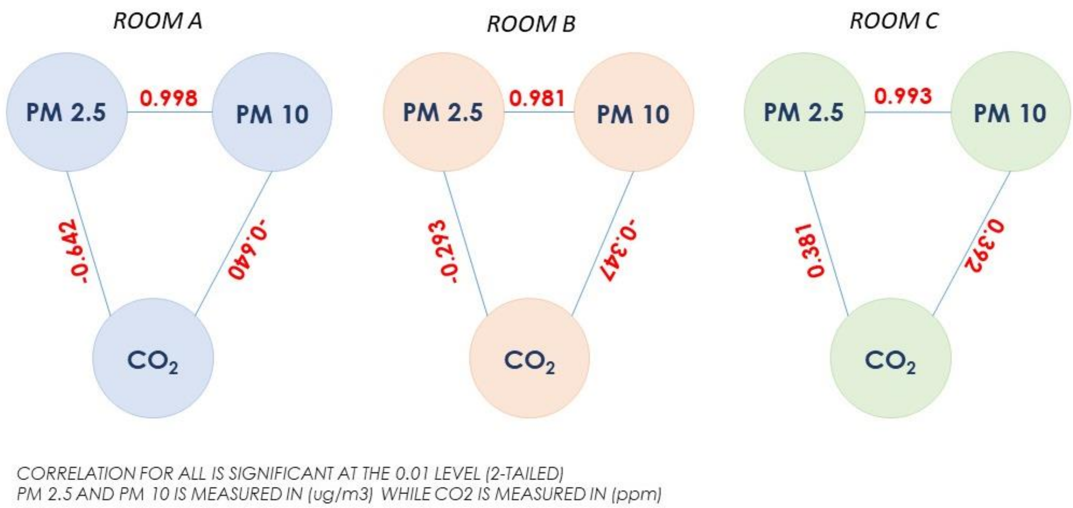


Figure 4.4: Correlation of Indoor Air Contaminants as obtained from SPSS 26.
Source: Author’s field work (2023)

According to Kim *et al.* (2021), indoor air contaminants are correlated and as much as correlation are used to the quantify the existent relationship between two variables, these two variables can be correlated with other variables. In this case, two indoor contaminants are correlated with each other as well as other contaminants especially if their source is similar. They are also correlated to outdoor contaminants if there is a significant interaction. $PM_{2.5}$ and PM_{10} showed a strong positive relationship in the three rooms.

There is a moderate negative relationship between CO2 and the PMs in room A. This negative relationship exists as a result of outdoor interactions from opening of windows as seen also in room B with a weak negative interaction between CO2 and the PMs. Room C however had a positive correlation with the PMs as there was little or no outdoor interactions with the indoor space resulting from open windows. This means that for room A and B there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas room C had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.2.2 Female hostel C - G

Table 4.12: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	08	12.9
Kerosene	53	85.5
Charcoal	01	1.6
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	22	35.5
Along the Corridor of the Room	26	41.9
Separate room in the Hostel (i.e. kitchen)	14	22.6
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	02	3.2
No	60	96.8
Total	62	100

Source: Author’s field work (2023)

It is seen from table 4.12 that indoor air particulate concentrations will naturally increase due to the occupants behaviours. 85.5% of them use kerosene to cook. Kerosene stove is a combustion stove which produces CO_2 and CO at different stages of combustion. 35.5%

of the occupants, cook inside their rooms and 41.9% cook. This will increase the CO_2 content of the rooms through direct and indirect diffusion from within the room and along the corridor respectively. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Four rooms were surveyed using the air node device namely; rooms D, E, F and G all in the dry season. The statistical observations are presented in table 4.13. It was observed that Room E has the worst conditions of all four rooms. Room D has daily temperature and humidity averages of 26.8^oC and 54.95% respectively. The room has temperatures as high as 30^oC and humidity as high as 71%. The air is too dry for breathing and too hot for a comfortable environment. Considering the winter season, the RH should not be this high except for an indoor variable induced by the occupants.

Room E also had high temperatures with an average of 27.83^oC a little bit above the normal room temperature of 25^oC. The average humidity was recorded at 47.84%, with a maximum of 61% which is abnormal in the dry season. This means that some activity within the room must have influenced it. Room F had an average temperature of 28.22^oC and a maximum of 29^oC. This means the temperature is generally high which will require a good ventilation system and cooling system if possible. Average humidity recorded is 47.46% with a maximum value of 59%. Room G result did not deviate from the trend with high RH and temperature values. These indoor conditions affects occupants behaviour which influences indoor air particulate concentrations.

Table 4.13: Statistical observation of indoor air contaminants

Indoor Air Variables (Room D)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	32.28	37.49	973.30	26.80	54.95	93.90
SD	5.043	7.452	254.211	1.462	9.955	11.297
Min	22	24	0	24	22	72
Max	113	164	1735	29	71	181
Indoor Air Variables (Room E)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	43.98	53.03	1063.79	27.83	47.84	115.76
SD	17.944	23.052	127.627	.791	5.389	22.128
Min	24	28	667	27	36	76
Max	175	225	1326	29	61	225
Indoor Air Variables (Room F)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	37.12	44.88	1035.05	28.22	47.46	102.49
SD	15.240	18.722	106.180	.569	3.979	24.816
Min	17	18	785	27	37	61
Max	128	158	1380	29	59	188
Indoor Air Variables (Room G)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	43.9577	53.5528	948.8259	27.9319	51.1083	117.8792
SD	12.54789	15.56874	130.75605	.66451	2.26734	21.16658
Min	26.00	31.00	732.00	26.50	44.00	80.00
Max	107.90	202.00	2409.00	28.90	57.00	178.00

Source: Author’s field work (2023)

The air contaminants that the device could measure include PM $_{2.5}$, PM $_{10}$ and CO_2. For the Room D, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 32.28 ug/m^3, 37.49 ug/m^3, and 973.30 ppm. Room E had 43.98 ug/m^3, 53.03 ug/m^3, and 1063.79 ppm. Room F had 37.12 ug/m^3, 44.88 ug/m^3, and 1035.05 ppm. Room G had 43.9 ug/m^3, 53.5 ug/m^3, and 948.8 ppm. Generally, the average AQI for the four rooms are above 100, except for Room D with a value of 93.9. This is unhealthy for sensitive cases. Room E had an average AQI of 115.76, a minimum value of 76 and a maximum value of 225. This is the highest value recorded and it is very unhealthy.

H_{01b} Occupant behavior is the primary mechanism determining indoor particulate concentrations

Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. The occurrence of these activities is dependent on the occupants behaviour. As shown in table 4.12, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

As shown in table 4.14, The CO_2 content of this block is generally high. Occupants of Rooms D and G experienced the highest CO_2 concentrations within the first five hours (cooking hours) and reduced during the sleeping hours. Occupants of room D cook inside the room as against occupants of room G who cook along the corridor. This activity is as a result of the distance from the kitchen to their rooms also as a result of the unkempt condition of the kitchens. It is observed that the CO_2 content of the indoor air for room E and F was high throughout the monitoring period. This is a due to carbon emissions from the overcrowded space added to that from cooking activities. Rooms E and F have high values of CO_2 with the highest average been 1243 ppm and 1152 ppm respectively. This is not healthy.

Table 4.14 The hourly average of air contaminants in the various rooms

Hourly average	**ROOM D**			**ROOM E**			**ROOM F**			**ROOM G**		
	PM 2.5	**PM 10**	**CO_2**	**PM 2.5**	**PM 10**	**CO_2**	**PM 2.5**	**PM 10**	**CO_2**	**PM 2.5**	**PM 10**	**CO_2**
Hr. 1	31.78	39.13	1008.70	30.52	35.76	807.33	28.46	32.97	1043.05	34.68	44.05	1039.08
Hr. 2	33.05	39.63	1383.94	47.80	56.63	1063.90	33.05	39.84	1040.33	38.04	47.78	999.64
Hr. 3	37.93	45.37	1483.61	53.82	63.09	1013.59	57.05	68.67	1115.86	34.32	42.61	1042.75
Hr. 4	38.63	47.25	990.26	76.32	92.83	1151.09	62.53	75.64	1133.61	35.29	43.48	1066.86
Hr. 5	34.41	40.96	1064.45	34.44	39.01	1243.16	41.02	50.57	1152.46	60.77	74.81	837.51
Hr. 6	30.22	34.56	868.30	36.16	41.77	1111.79	36.63	45.03	1083.17	65.69	79.43	1001.99
Hr. 7	28.89	32.73	810.66	35.46	42.96	1107.55	40.32	49.05	1029.03	51.84	62.66	899.19
Hr. 8	30.10	33.90	765.52	38.41	47.82	1097.29	38.61	47.19	1010.82	40.28	48.28	913.01
Hr. 9	30.59	34.17	772.14	45.69	57.47	1012.85	33.26	40.73	1036.11	43.87	52.26	873.87
Hr. 10	31.76	35.29	786.27	44.38	54.69	1086.22	27.60	33.22	994.44	41.89	49.63	896.51
Hr. 11	30.70	34.18	856.99	42.97	52.60	1039.93	23.51	27.80	921.98	38.10	45.49	922.09
Hr. 12	29.30	32.77	888.83	41.78	51.70	1030.79	23.40	27.80	859.77	42.72	52.16	893.41

Source: Author’s field work (2023)

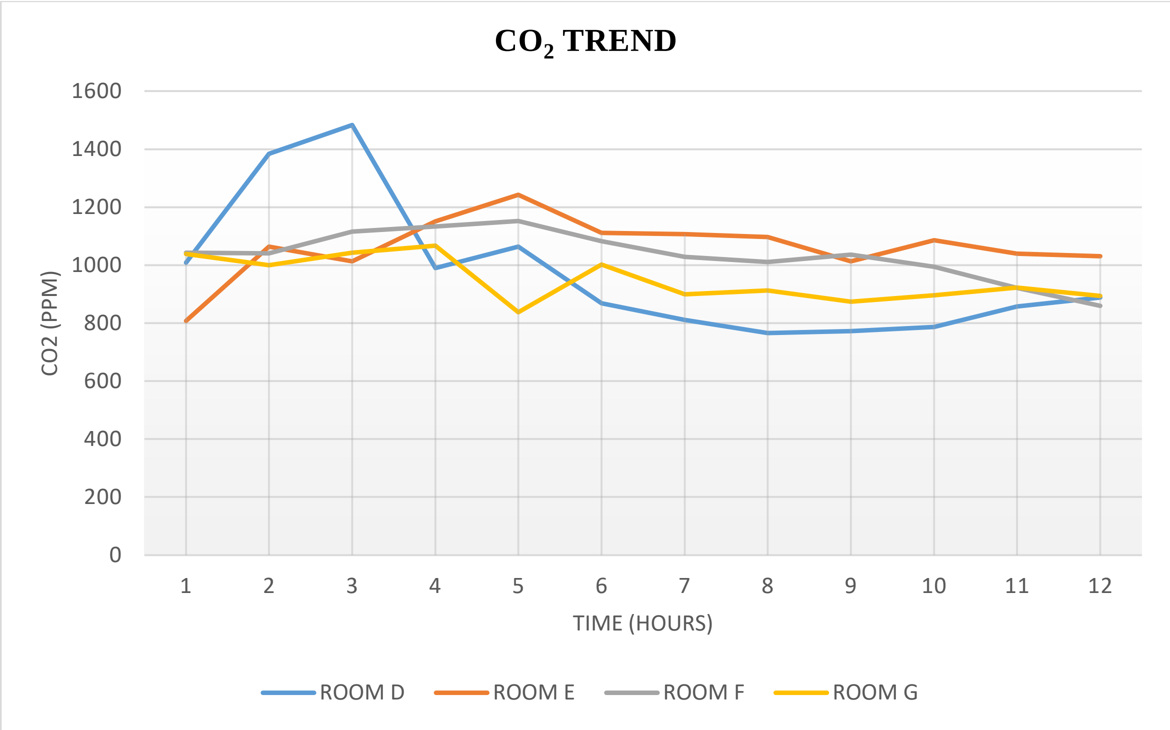


Figure 4.5: Trend chart of CO_2 in the monitor rooms.

Source: Author's field work (2023)

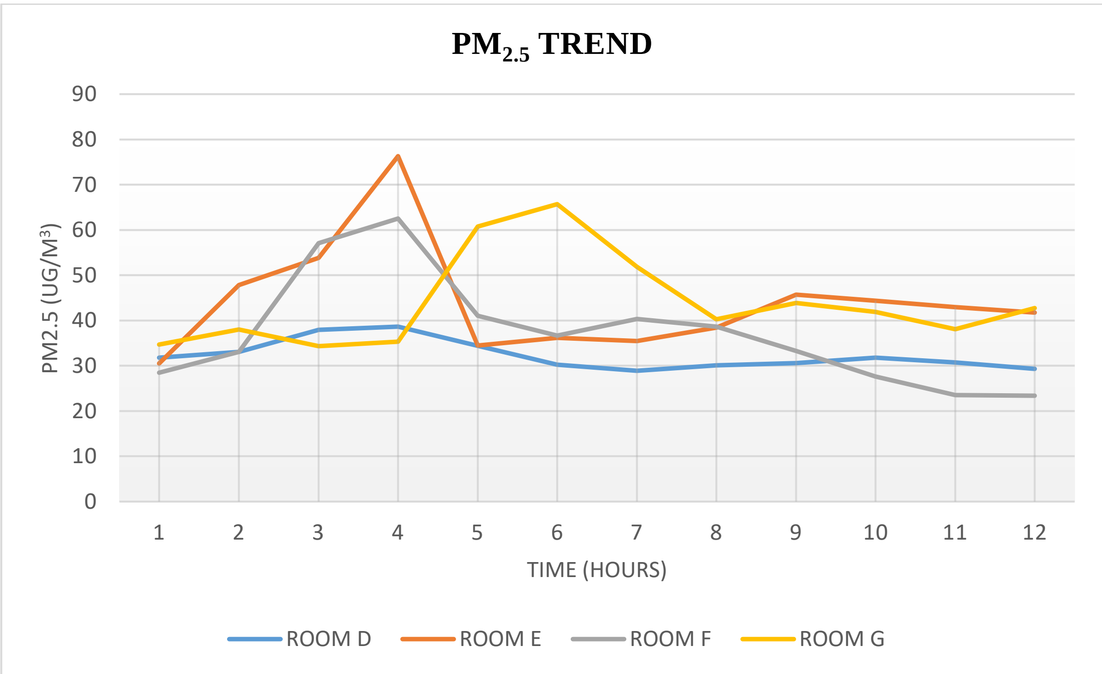


Figure 4.6: Trend chart of $PM_{2.5}$ in the monitor rooms.

Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking (Tran *et al.*, 2020). The PM_{10} values for this block is generally low. All the rooms monitored had low PM_{10} values all within the accepted standard of 80 ug/m^3, however the PM2.5 values were above the accepted value of 35 ug/m^3.

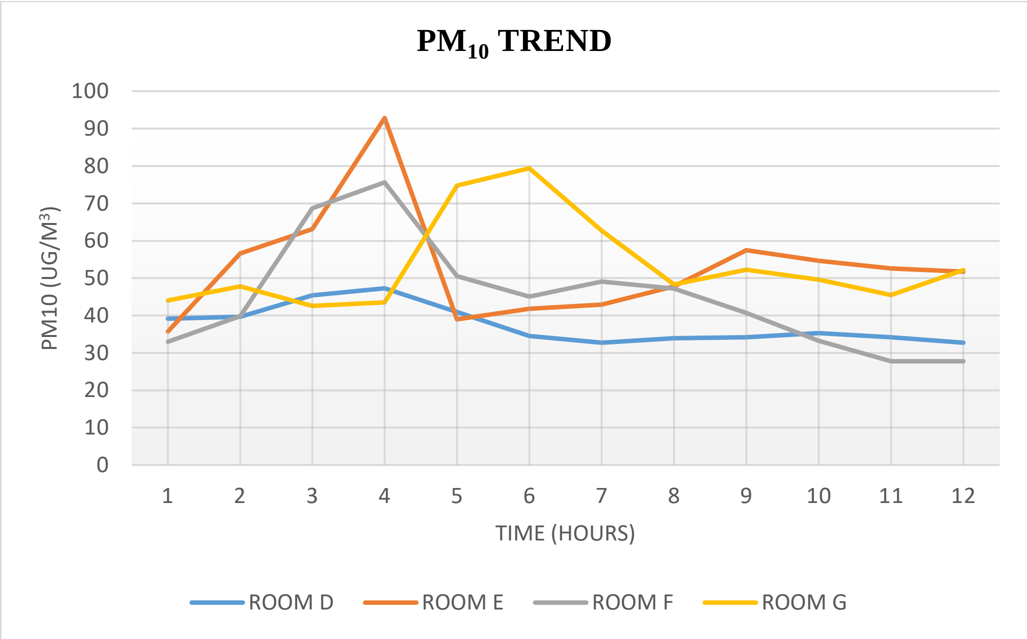


Figure 4.7: Trend chart of PM_{10} in the monitor rooms.
Source: Author's field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. PMs are sourced from heating sources as well as from unpaved areas. Considering the time, the monitoring occurred (the dry season) PM is abundant in the air and got into the room spaces through window and door openings. This was regulated with the use of curtains in the spaces such that the impact of the opened window was mild.

Table 4.15 Occupants activities that results in indoor outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	233	3.76
Raining Season	204	3.29
Number of respondents = 62; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it’s windy outdoor	38	34.2
When it’s dusty outdoor	32	28.8
When it’s raining	41	40
Total	111	100
Multiple responses by 62 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	05	8.1
Louvres	11	17.7
Window blinds (i.e. curtains)	51	82.3
Total	67	100

Multiple responses by 62 respondents

Source: Author’s field work (2023)

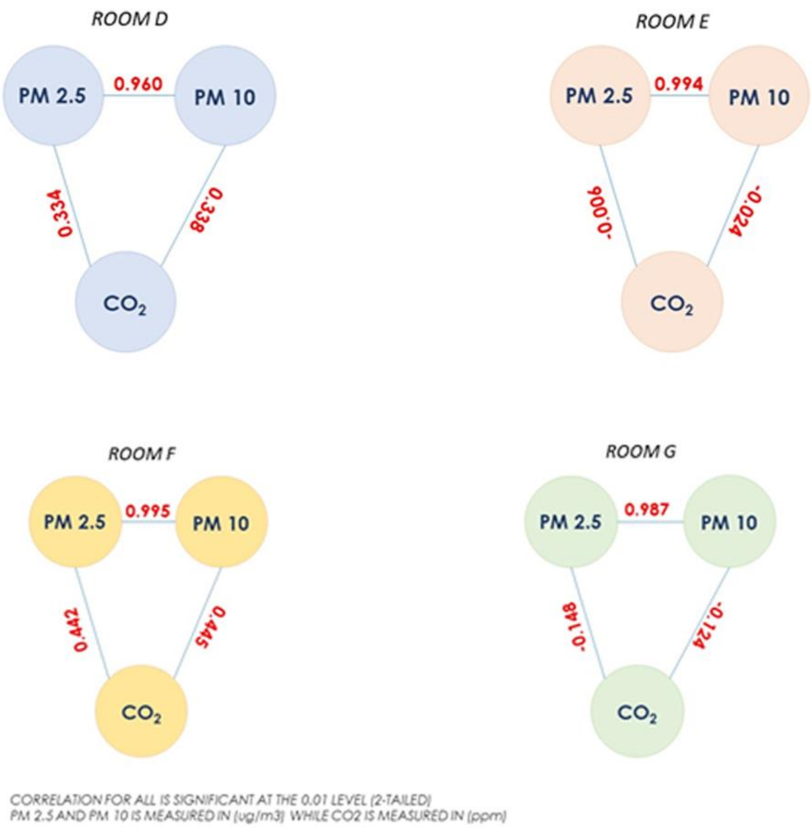


Figure 4.8: Correlation of Indoor Air Contaminants as obtained from SPSS 26.

Source: Author’s field work (2023)

According to Kim *et al.* (2021), indoor air contaminants are correlated and as much as correlation are used to the quantify the existent relationship between two variables, these two variables can be correlated with other variables. PM $_{2.5}$ and PM $_{10}$ showed a strong positive relationship in the Four rooms. There is a weak negative relationship between CO_2 and the PMs in room E. This negative relationship exists as a result of outdoor interactions from opening of windows as seen also in room G with a weak negative interaction between CO_2 and the PMs. Room F and D however had a moderate positive correlation with the PMs as there was little or no outdoor interactions with the indoor space resulting from open windows. This means that for room E and G there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas room D and F had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.2.3 Male hostel B

It is seen from table 4.16 just like in other hostels that indoor air particulate concentrations will naturally increase due to the occupants behaviours as 77.1% of them use kerosene to cook. Kerosene stove produces CO_2 and CO at different stages of combustion. 50.6% of the occupants, cook inside their rooms and 19.3% cook along the corridor. This will increase the CO_2 content of the rooms through direct and indirect diffusion from within the room and along the corridor respectively. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Table 4.16: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	17	20.5
Gas/Propane	01	1.2
Kerosene	64	77.1
Charcoal	01	1.2
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	42	50.6
Along the Corridor of the Room	16	19.3
Separate room in the Hostel (i.e. kitchen)	25	30.1
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	50	60.2
No	33	39.8
Total	83	100

Source: Author's field work (2023)

Three rooms were surveyed using the air node device namely; rooms A, B and C all in the dry season. The statistical observations are presented in table 4.17. It was observed that Room A has the worst conditions of all three rooms. Room A has daily temperature and humidity averages of 27.7^{o}C and 37.28% respectively. The air is too dry for breathing and too hot for a comfortable environment. Room B also had high temperatures with an average of 28.47^{o}C a little bit above the normal room temperature of 25^{o}C. The average humidity was recorded at 45.85%, with a maximum of 58% which is abnormal in the dry season. This means that some activity within the room must have influenced it. Room C had an average temperature of 27.59^{o}C and a maximum of 30^{o}C. This means the temperature is generally high which will require a good ventilation system and cooling system if possible. Average humidity recorded is 33.38% with a maximum value of 41%, this is normal considering the current season (winter). These indoor conditions affects occupants behaviour which influences indoor air particulate concentrations.

Table 4.17: Statistical observation of indoor air contaminants

Indoor Air Variables (Room A)						
Parameters	**PM 2.5 (ug/m³)**	**PM 10 (ug/m³)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	180.09	271.78	720.79	27.72	37.28	237.69
SD	103.541	160.878	56.005	1.573	3.246	89.894
Min	21	24	670	25	34	70
Max	1244	1866	900	31	47	991
Indoor Air Variables (Room B)						
Parameters	**PM 2.5 (ug/m³)**	**PM 10 (ug/m³)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	108.06	151.45	807.75	28.47	45.85	176.94
SD	106.021	141.441	88.281	.827	4.750	77.589
Min	34	42	716	27	37	97
Max	1799	2000	1114	30	58	1358
Indoor Air Variables (Room C)						
Parameters	**PM 2.5 (ug/m³)**	**PM 10 (ug/m³)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	34.33	43.76	787.58	27.59	33.38	98.99
SD	6.920	9.258	42.894	1.584	1.486	15.734
Min	15	19	708	25	30	57
Max	53	93	926	30	41	144

Source: Author’s field work (2023)

The air contaminants that the device could measure include PM 2.5, PM 10 and CO_2. For the Room A, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 180.09 ug/m^3, 271.78 ug/m^3, and 720.79 ppm. Room B had 108.06 ug/m^3, 151.45 ug/m^3, and 807.75 ppm. Room C had 34.33 ug/m^3, 43.76 ug/m^3, and 787.58 ppm. Generally, the average AQI for the three rooms are above 100, except for Room C with a value of 98.99. This is unhealthy for sensitive cases. Room A had an average AQI of 237.69, a minimum value of 70 and a maximum value of 991. This is the highest value recorded and it is very unhealthy.

H_{01c} Occupant behavior is the primary mechanism determining indoor particulate concentrations

Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. As shown in table 4.16, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

Table 4.18 The hourly average of air contaminants in the various rooms

Hourly average	**Room A**			**Room B**			**Room C**		
	$PM_{2.5}$	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**
Hr. 1	34.28	44.04	819.16	105.24	153.95	843.73	21.28	27.09	775.56
Hr. 2	59.93	82.77	809.06	115.56	166.36	906.63	32.60	39.82	732.09
Hr. 3	39.86	50.59	781.66	143.36	204.54	822.25	38.13	47.61	804.36
Hr. 4	106.97	147.08	757.23	114.55	165.57	943.72	37.66	45.93	760.19
Hr. 5	153.78	230.98	702.95	274.71	379.07	873.27	40.54	49.55	783.60
Hr. 6	202.00	309.00	689.00	119.96	172.80	805.23	39.77	51.75	835.43
Hr. 7	225.09	345.04	686.38	101.88	145.00	775.56	40.16	53.61	821.34
Hr. 8	244.71	376.33	683.72	100.58	142.98	773.43	38.86	51.59	819.81
Hr. 9	252.40	388.37	681.33	82.30	113.66	754.59	37.07	48.67	810.01
Hr. 10	304.81	465.08	686.97	52.75	67.74	735.04	33.33	43.24	788.08
Hr. 11	269.84	414.26	677.13	45.52	56.22	724.49	27.45	34.68	756.39
Hr. 12	267.69	408.73	675.09	40.36	49.48	735.13	25.07	31.57	764.07

Source: Author's field work (2023)

Occupants of Rooms A, B and C cook inside the room. These rooms however are not overcrowded, having 5, 4, and 5 persons respectively. Rooms B and C have the occupants washing in the rooms. It was observed that the CO_2 content of the indoor air for room A is normal (moderate) having the highest hourly average to be 819 ppm. The trend line suggests that even with the low CO_2 values, the cooking periods had the highest values but not dangerous owning to the fact that gas and kerosene stoves were not used instead electric stoves were used. Rooms B and C also have similar context with room A. This shows that in an ideal setting where the room is not overcrowded and CO_2 is not introduced through the occupants behaviour, the concentration will be normal.

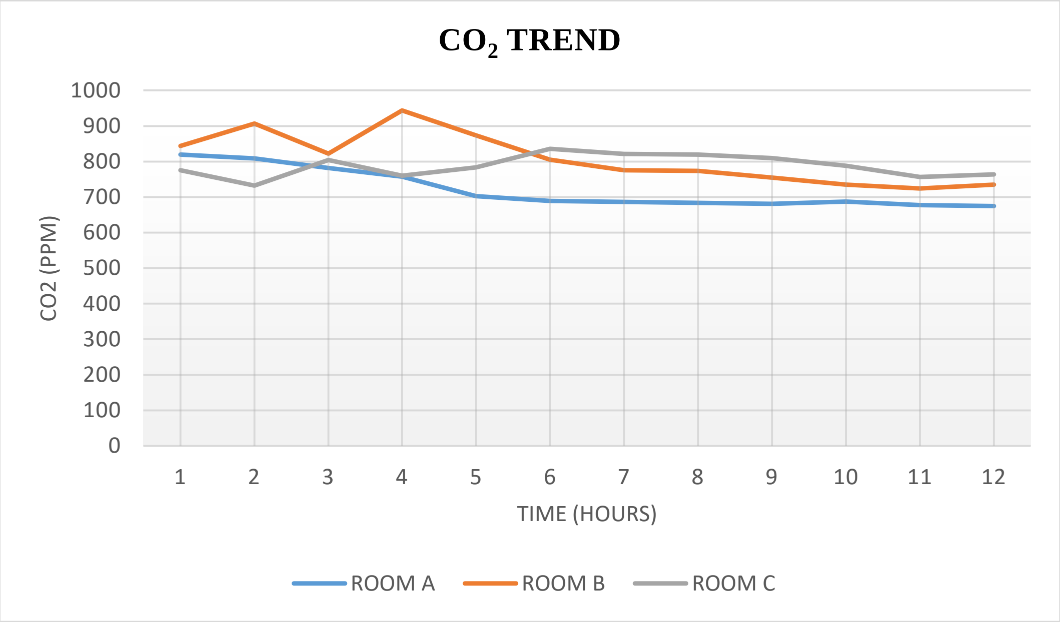


Figure 4.9: Trend chart of CO_2 in the monitor rooms (block B).

Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking (Tran *et al.*, 2020). The PM_{10} and $PM_{2.5}$ values for room A and B is very high. This possibly was triggered by the cooking process as well as the washing, although washing activities brings high values for VOCs. The trend line established the high PM contents in rooms A and B. however room C had moderate values which are not harmful.

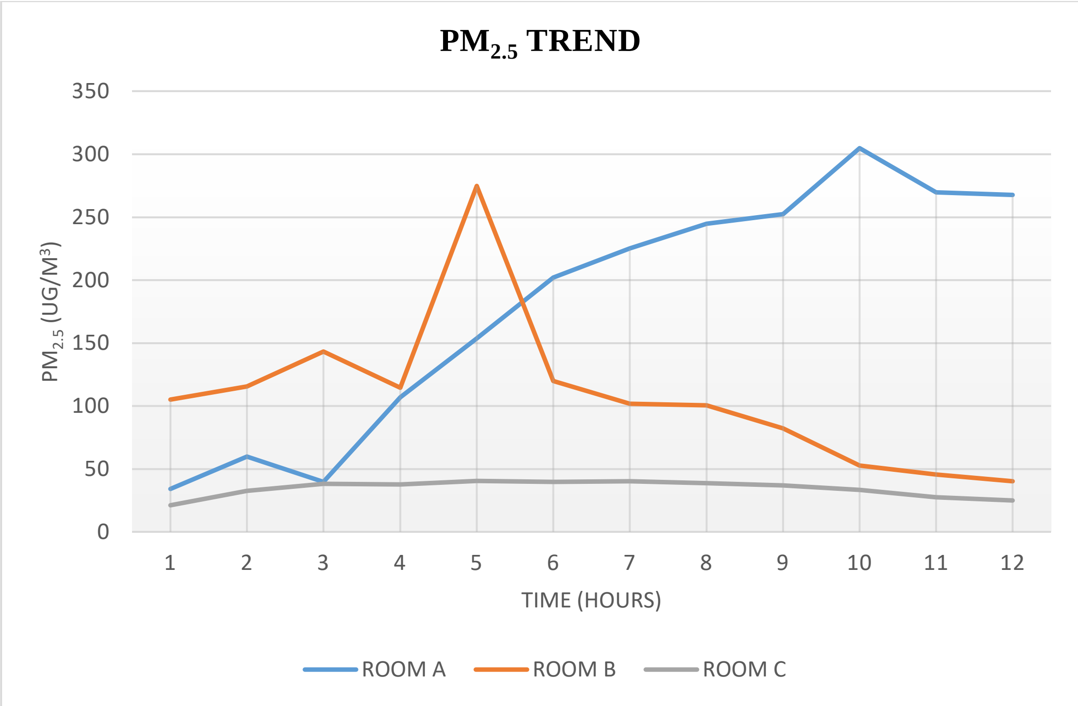


Figure 4.10: Trend chart of $PM_{2.5}$ in the monitor rooms (block B).

Source: Author’s field work (2023)

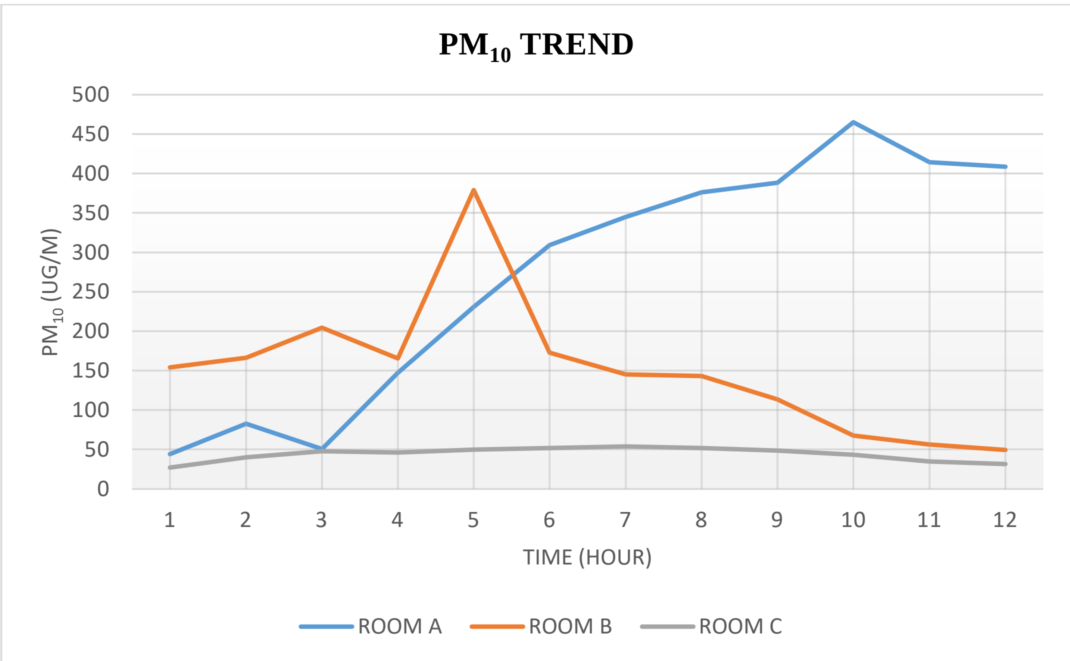


Figure 4.11: Trend chart of PM_{10} in the monitor rooms (block B).

Source: Author’s field work (2023)

Table 4.19 Occupants activities that results in indoor outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	314	3.78
Raining Season	243	2.92
Number of respondents = 83; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it’s windy outdoor	48	30.6
When it’s dusty outdoor	52	33.1
When it’s raining	57	36.3
Total	157	100
Multiple responses by 83 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	05	8.1
Louvers	43	51.8
Window blinds (i.e. Curtains)	33	39.8
Total	81	100

Multiple responses by 83 respondents

Source: Author’s field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. Considering the time, the monitoring occurred (the dry season) PM is abundant in the air and got into the room spaces through window and door openings. This was regulated with the use of curtains in the spaces such that the impact of the opened window was mild. The trend lines showed that the peak of the PM concentration was during the early hours of the day.

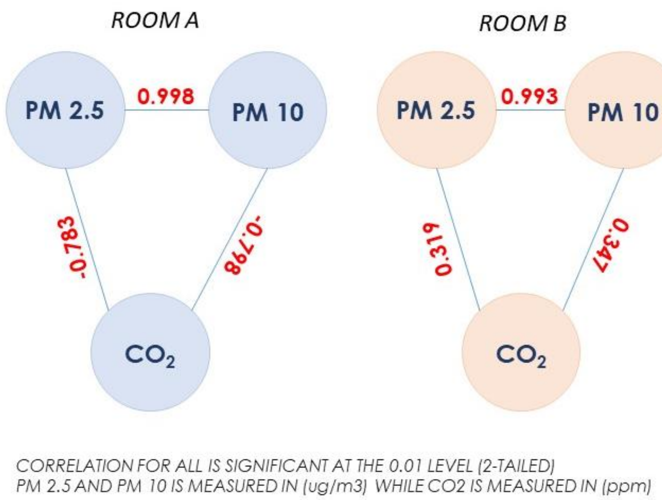


Figure 4.12: Correlation of indoor air contaminants, obtained from SPSS 26 (block B). Source: Author’s field work (2023)

PM $_{2.5}$ and PM $_{10}$ showed a strong positive relationship in the three rooms. This is why the trend line for $PM_{2.5}$ and PM_{10} are similar for the same room. There is a strong negative relationship between CO_2 and the PMs in room A. This negative relationship exists as a result of the linear outdoor interactions from opening of windows. Rooms B and C, however had a moderate positive correlation between CO_2 and the PMs as there was little or no outdoor interactions with the indoor space resulting from open windows. This means that for room A, there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas rooms B and C had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.2.4 Shehu Aliyu female hostel

It is seen from table 4.20 just like in other hostels that indoor air particulate concentrations will naturally increase due to the occupants behaviours as 79.0% of them use kerosene to cook. Kerosene stove produces CO_2 and CO at different stages of combustion. 16.1% of the occupants, cook inside their rooms and 40.3% cook along the corridor. This will increase the CO_2 content of the rooms through direct and indirect diffusion from within the room and along the corridor respectively. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Table 4.20: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	06	9.7
Gas/Propane	06	9.7
Kerosene	49	79.0
Charcoal	01	1.6
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	10	16.1
Along the Corridor of the Room	25	40.3
Separate room in the Hostel (i.e. kitchen)	27	43.5
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	05	8.1
No	57	91.9
Total	83	100

Source: Author's field work (2023)

Two rooms were surveyed using the air node device namely; rooms A, and B, all in the dry season. The statistical observations are presented in table 4.21. It was observed that Room B has the worst conditions of the two rooms. Room A has daily temperature and humidity averages of 27.98^{o}C and 53.52% respectively. Room B also had high temperatures with an average of 29.83^{o}C, the average humidity was recorded at 51.97%, with a maximum of 68% which is abnormal in the dry season. This means that some activity within the room must have influenced it. These indoor conditions affects occupants behaviour which influences indoor air particulate concentrations.

Table 4.21: Statistical observation of indoor air contaminants

Indoor Air Variables (Room A)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	46.85	56.49	839.49	27.98	53.52	128.43
SD	6.562	8.769	79.713	.736	2.029	15.133
Min	30	34	758	27	47	89
Max	70	83	1183	29	57	159
Indoor Air Variables (Room B)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	38.38	47.41	1219.89	29.83	51.97	98.72
SD	30.00	36.00	1181.00	30.00	51.00	89.00
Min	17	17	749	29	40	61
Max	926	1372	1703	30	68	781

Source: Author's field work (2023)

The air contaminants that the device could measure include PM $_{2.5}$, PM $_{10}$ and CO_2. For the Room A, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 46.85 ug/m^3, 56.49 ug/m^3, and 839.49 ppm. Room B had 38.38 ug/m^3, 47.41 ug/m^3, and 1219.89 ppm. Generally, the average AQI for the two rooms are 128.43 for A and 98.72 for B. values as high as 781 were recorded, this is very unhealthy.

H_{01d} Occupant behavior is the primary mechanism determining indoor particulate concentrations

Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. As shown in table 4.20, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

Table 4.22: The hourly average of air contaminants in the various rooms

Hourly average	Room A			Room B		
	$PM_{2.5}$	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**
Hr. 1	52.85	66.48	1049.04	36.36	44.53	1486.26
Hr. 2	51.22	63.10	890.82	30.99	37.66	1588.81
Hr. 3	51.88	64.49	898.30	36.36	43.54	1463.64
Hr. 4	48.28	58.38	859.24	43.79	51.36	1267.82
Hr. 5	48.09	57.91	797.22	29.67	34.52	1185.48
Hr. 6	45.90	54.55	784.71	26.38	30.44	1188.08
Hr. 7	42.82	50.68	811.19	24.96	29.20	1159.93
Hr. 8	47.68	56.36	782.64	22.34	25.75	1115.56
Hr. 9	47.79	55.65	821.55	22.93	26.95	1157.64
Hr. 10	39.18	46.41	803.08	26.31	31.28	1135.88
Hr. 11	35.44	42.51	782.71	120.21	165.83	1069.14
Hr. 12	51.07	61.37	793.34	40.23	47.92	820.39

Source: Author's field work (2023)

Occupants of Rooms A and B cook, do dish washing and laundry inside the room. These rooms however are not overcrowded, having 4 and 5 persons respectively. It was observed that the CO_2 content of the indoor air for room A is normal (moderate) having the highest hourly average to be 1049 ppm. The trend line suggests that even with the low CO_2 values, the cooking periods had the highest values but not dangerous owning to the fact that gas and kerosene stoves were not used instead electric stoves were used. Rooms B also has similar context with room A, however, the CO_2 content of room B is generally high throughout the monitor period and even higher during the cooking periods (1588.81 ppm) as seen in the trend line. This exposure is dangerous to the health of the occupants.

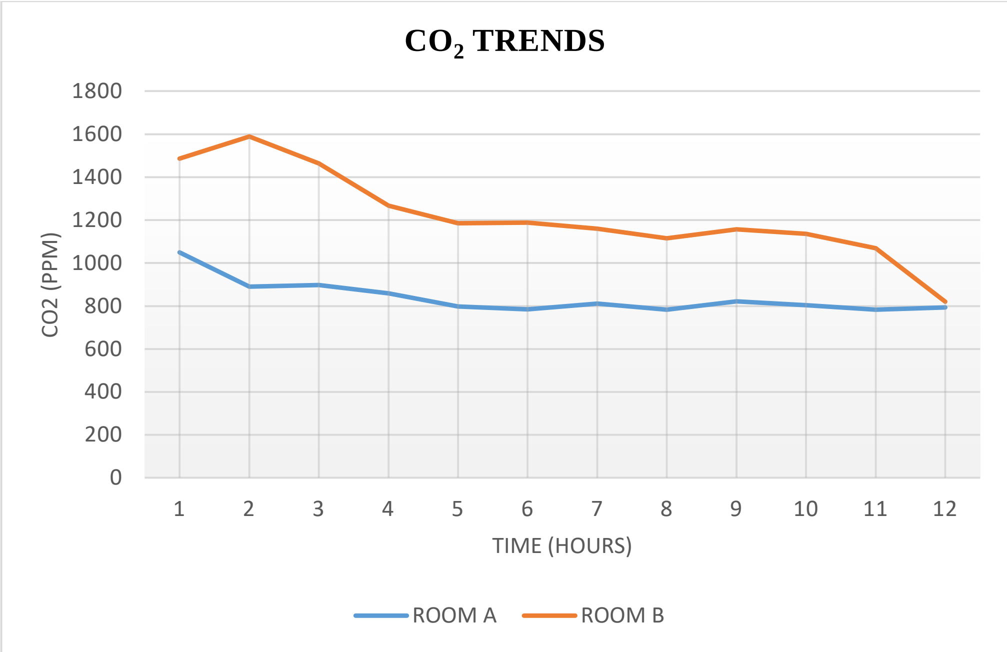


Figure 4.13: Trend chart of CO_2 in the monitor rooms (Shehu Aliyu).

Source: Author's field work (2023)

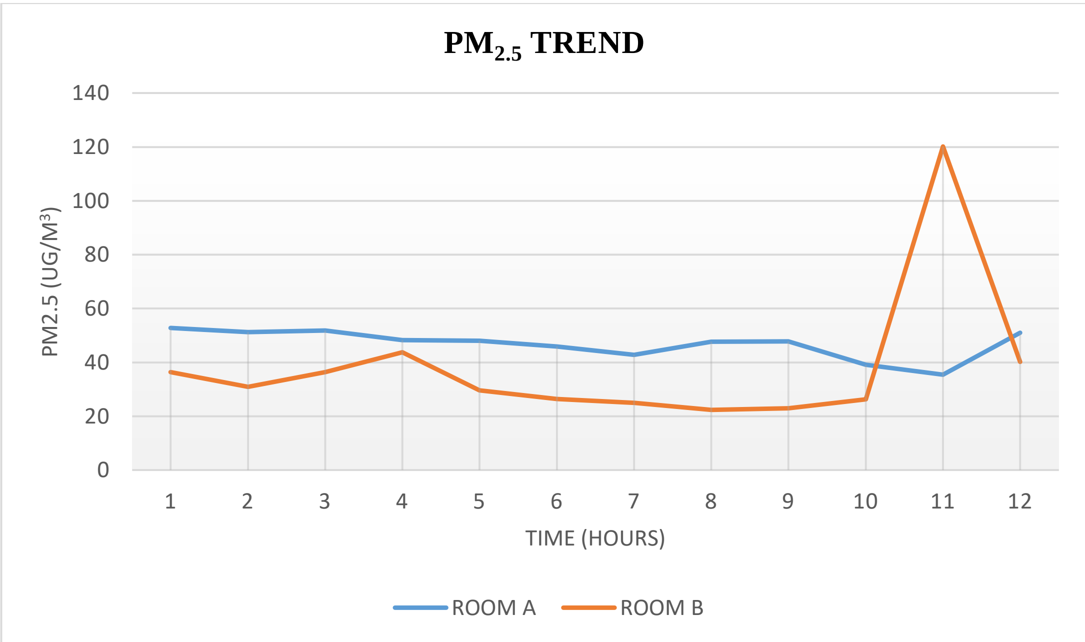


Figure 4.14: Trend chart of $PM_{2.5}$ in the monitor rooms (Shehu Aliyu).

Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking

(Tran *et al.*, 2020). The $PM_{2.5}$ values for room A is high and low in room B even though both rooms are not overcrowded and have similar activities going on within. The positioning of the two rooms are different. Room A faces the windward side and opening of windows will increase the PM concentration. Aside PMs, washing, and laundry brings high values for VOCs. The trend line established the high PM contents in rooms A and an abrupt high value in B.

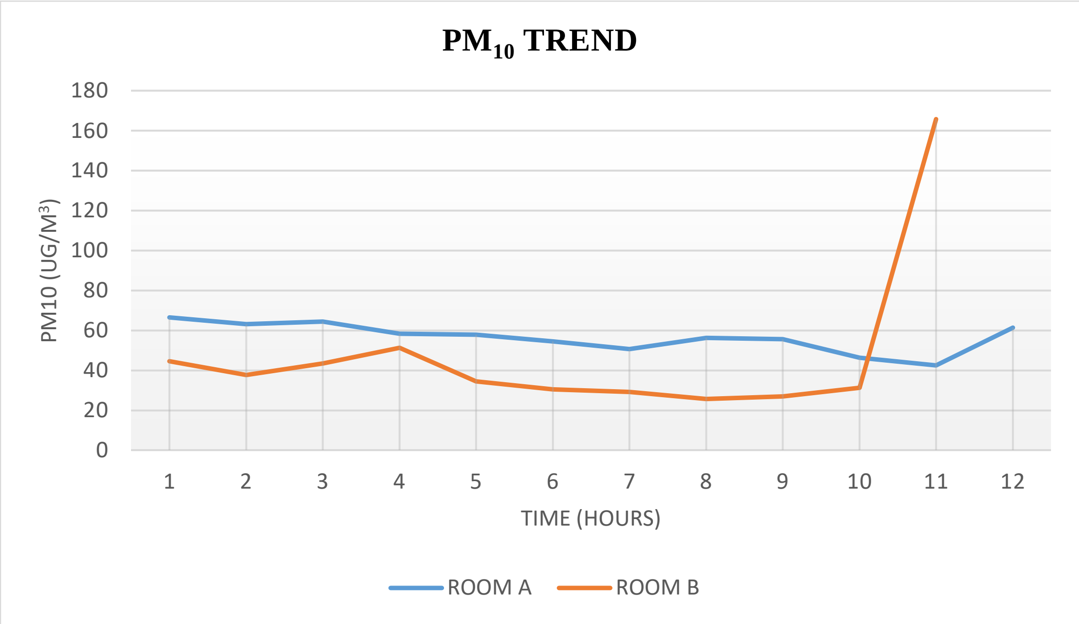


Figure 4.15: Trend chart of PM_{10} in the monitor rooms (Shehu Aliyu).
Source: Author's field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. Considering the time, the monitoring occurred (the dry season) PM is abundant in the air and got into the room spaces through window and door openings. This was regulated with the use of curtains in the spaces such that the impact of the opened window was mild. It was generally higher in room A due to its windward positioning giving it more exposure to these particles

Table 4.23: Occupants activities that results in indoor outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	224	3.61
Raining Season	160	1.93
Number of respondents = 62; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it's windy outdoor	48	30.6
When it's dusty outdoor	52	33.1
When it's raining	57	36.3
Total	157	100
Multiple responses by 62 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	05	8.1
Louvers	43	51.8
Window blinds (i.e. Curtains)	33	39.8
Total	81	100

Multiple responses by 62 respondents

Source: Author's field work (2023)

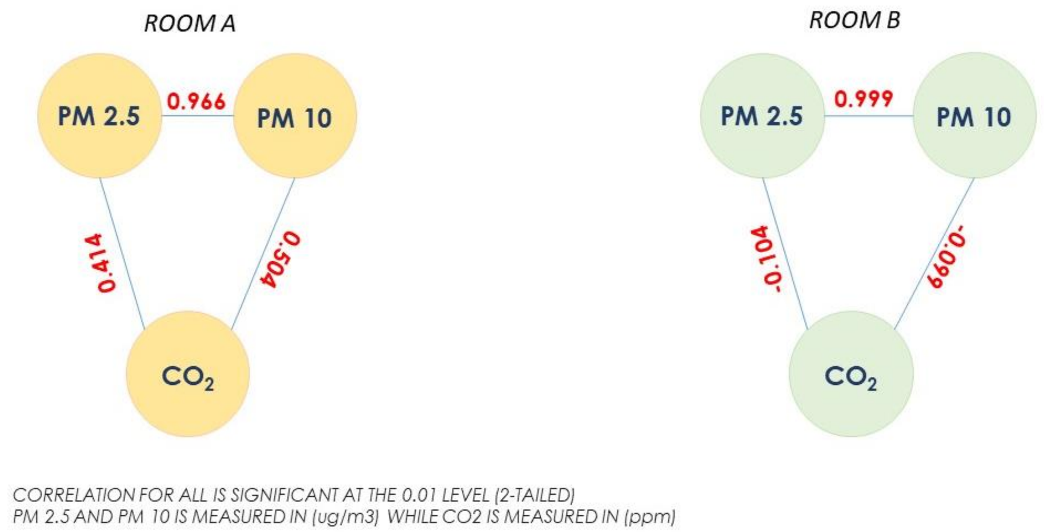


Figure 4.16: Correlation of indoor air contaminants, obtained from SPSS 26 (Shehu Aliyu).

Source: Author's field work (2023)

According to Kim *et al.* (2021), indoor air contaminants are correlated and as much as correlation are used to the quantify the existent relationship between two variables, these two variables can be correlated with other variables. $PM_{2.5}$ and PM_{10} showed a strong positive relationship in the two rooms. This is why the trend line for $PM_{2.5}$ and PM_{10} are similar for the same room. There is a moderate positive relationship between CO_2 and the PMs in room A and a weak negative relationship in room B This negative relationship exists as a result of the weak linear outdoor interactions from opening of windows and the moderate positive shows not just a moderate similarity in the source of the contaminant but also a moderate linear outdoor interaction from opening of fenestration. This means that for room A, there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas rooms B had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.2.5 New male hostel

It is seen from table 4.24 just like in other hostels that indoor air particulate concentrations will naturally increase due to the occupants behaviours as 94.4% of them use gas (propane) to cook. Gas cookers or burners produces CO_2 during combustion and in the case of leakages gives off propane which is not only dangerous to the health but also highly volatile. 41.7% of the occupants, cook inside their rooms and 58.3% cook in the kitchens designed separately. Based on this result, the CO_2 levels in rooms generally in this block should not be high, but might be distinct in various rooms. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Table 4.24: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	02	2.8
Gas/Propane	68	94.4
Kerosene	02	2.8
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	30	41.7
Separate room in the Hostel (i.e. kitchen)	42	58.3
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	Yes	00
No	No	72
Total	72	100

Source: Author's field work (2023)

Three rooms were surveyed using the air node device namely; rooms A, B and C all in the dry season. The statistical observations are presented in table 4.25. Room A has daily temperature and humidity averages of 24.6^{o}C and 36.68% respectively. This is a low temperature compared to other blocks surveyed. Room B had high temperatures with an average of 27.91^{o}C a little bit above the normal room temperature of 25^{o}C. The average humidity was recorded at 48.81%, with a maximum of 63% which is abnormal in the dry season but due to the air conditioners installed in the rooms, the humidity will be altered a bit. Room C had an average temperature of 26.62^{o}C and a maximum of 27^{o}C. Average humidity recorded is 47.99% with a maximum value of 57%. These indoor conditions affects occupants behaviour which influences indoor air particulate concentrations.

Table 4.25: Statistical observation of indoor air contaminants

Indoor Air Variables (Room A)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	61.24	77.52	505.23	24.60	36.68	136.88
SD	27.247	36.636	22.163	2.279	3.188	32.309
Min	23	29	478	21	29	74
Max	167	212	631	29	42	217
Indoor Air Variables (Room B)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	41.88	51.25	947.57	27.91	48.81	115.38
SD	9.187	11.826	338.439	.358	7.273	19.145
Min	27	31	521	27	38	82
Max	77	97	1672	29	63	162
Indoor Air Variables (Room C)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	36.35	43.79	821.66	26.22	47.99	101.93
SD	10.447	18.750	120.842	.866	4.136	17.641
Min	20	22	562	24	40	68
Max	145	294	1394	27	57	197

Source: Author's field work (2023)

The air contaminants that the device could measure include $PM_{2.5}$, PM_{10} and CO_2. For the Room A, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 61.24 ug/m^3, 77.25 ug/m^3, and 505.23 ppm. Room B had 41.88ug/m^3, 51.25 ug/m^3, and 947.75 ppm. Room C had 36.35 ug/m^3, 43.79 ug/m^3, and 821.66 ppm. Generally, the average AQI for the three rooms are above 100. This is unhealthy for sensitive cases. Room A had an average AQI of 136.88, a minimum value of 74 and a maximum value of 271. This is the highest value recorded and it is very unhealthy.

H_{01e} Occupant behavior is the primary mechanism determining indoor particulate concentrations

Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. As shown in table 4.24, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

Table 4.26: The hourly average of air contaminants in the various rooms

Hourly average	**Room A**			**Room B**			**Room C**		
	$PM_{2.5}$	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**
Hr. 1	33.60	41.59	506.64	38.94	49.21	842.29	41.54	49.04	984.60
Hr. 2	32.53	41.43	550.76	38.31	48.00	1500.05	34.38	41.61	772.86
Hr. 3	39.03	48.42	518.01	39.19	48.27	1338.13	37.66	45.88	727.72
Hr. 4	34.91	42.06	497.09	44.98	56.40	1292.46	38.11	45.32	852.44
Hr. 5	41.53	49.61	493.26	36.87	45.24	1152.65	34.62	40.17	921.27
Hr. 6	53.69	65.55	504.76	39.38	47.07	947.43	34.58	39.71	899.64
Hr. 7	64.99	79.00	508.57	41.61	50.86	1167.94	34.13	39.28	909.11
Hr. 8	62.08	76.13	498.96	63.06	77.68	603.58	54.55	77.81	848.23
Hr. 9	86.00	112.00	487.04	54.06	65.41	569.17	37.75	44.52	869.44
Hr. 10	87.69	116.70	484.17	40.76	49.30	581.69	25.07	28.53	808.91
Hr. 11	104.4	135.96	489.40	33.71	40.14	649.80	30.16	35.13	676.32
Hr. 12	94.48	121.82	524.05	31.71	37.37	725.68	36.35	43.79	821.66

Source: Author's field work (2023)

Occupants of Rooms A, B and C cook inside the room. These rooms however are not overcrowded, having 3, 4, and 2 persons respectively. Rooms A and C have the kitchens within the living space by design and room B uses a general kitchen by design. It was observed that the CO_2 content of the indoor air for room A is normal (moderate) having the highest hourly average to be 550 ppm which shows that as simple as a design is with a kitchen embedded in the living space, it produces a good living condition. This is different with room C even though it is similar with A by design. It has higher CO_2 content although not harmful which could be due to the fact that it is located on the ground floor. The trend line suggests that room B deviates from the trend as the CO2 content is generally high (1500 ppm). This is possible because the occupants cook inside the room where as by design they should cook in the general kitchen. This exposure is harmful to the occupants.

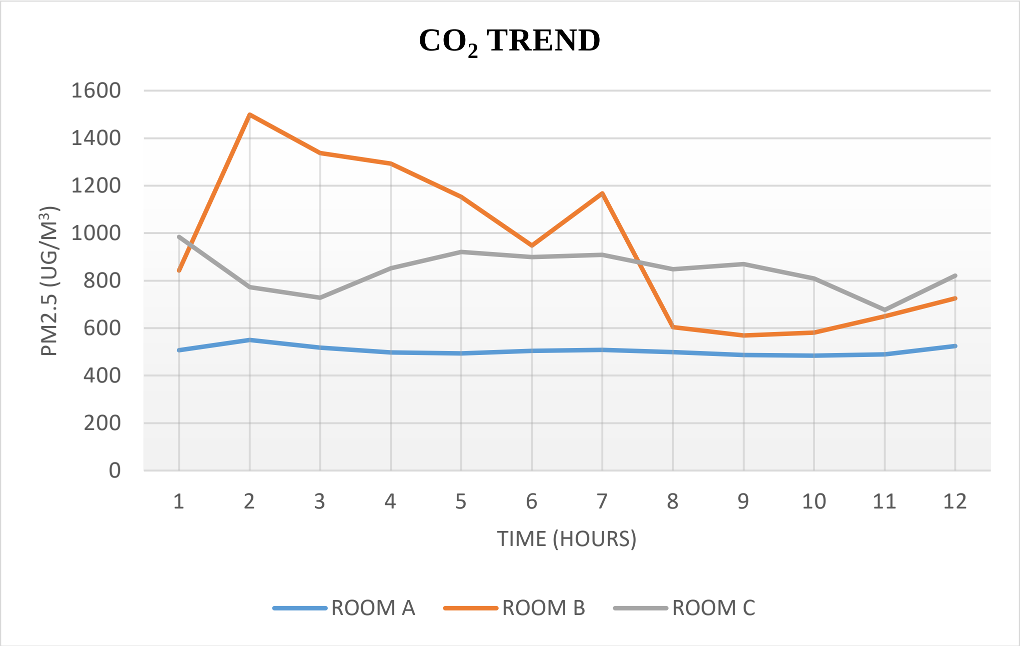


Figure 4.17: Trend chart of CO_2 in the monitor rooms (new male hostel).
Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking (Tran *et al.*, 2020). The PM_{10} and $PM_{2.5}$ values for rooms B and C had a similar pattern where there is constant value during the opening hours, an increased value around the middle and a decreased value towards the closing hours. Room A however deviates from this pattern. It had an ever increasing value for both PMs throughout the monitor period. Considering its low CO_2 content, it high PM shows that there is a slightly different condition which is the malfunctioning of the air conditioner which acts also as an extractor.

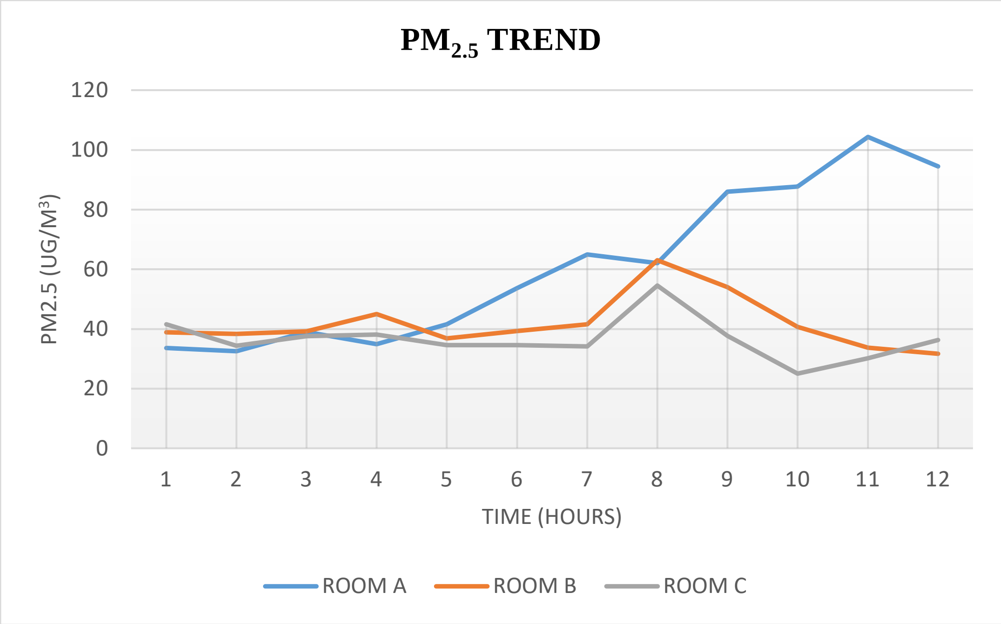


Figure 4.18: Trend chart of PM$_{2.5}$ in the monitor rooms (new male hostel).

Source: Author's field work (2023)

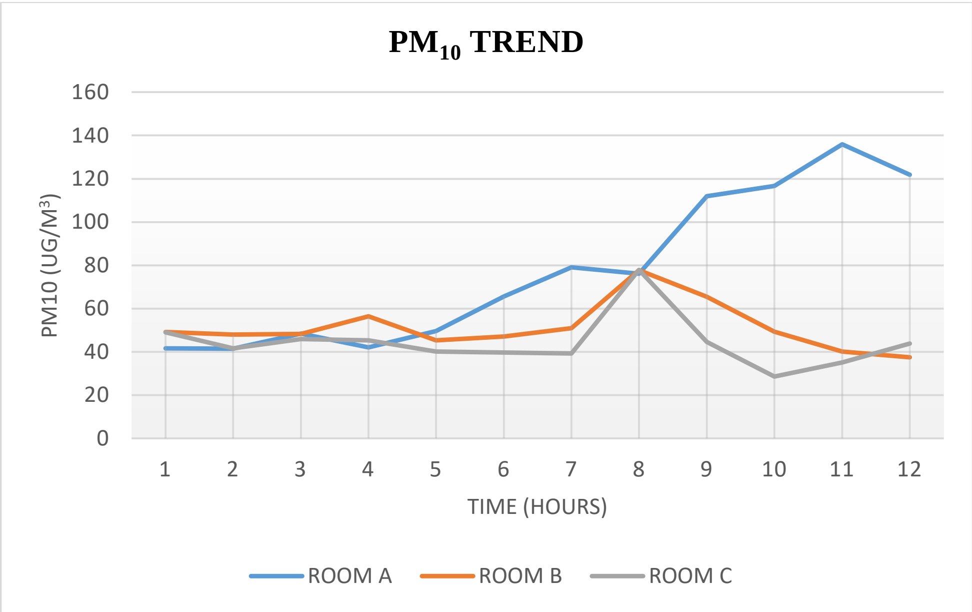


Figure 4.19: Trend chart of PM$_{10}$ in the monitor rooms (new male hostel).

Source: Author's field work (2023)

Table 4.27: Occupants activities that results in indoor outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	208	2.89
Raining Season	196	2.72
Number of respondents = 72; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it's windy outdoor	40	27.0
When it's dusty outdoor	42	28.4
When it's raining	66	44.6
Total	148	100
Multiple responses by 72 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	16	22.2
Louvers	0	0
Window blinds (i.e. Curtains)	48	66.7
Total	64	100

Multiple responses by 72 respondents

Source: Author's field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. Considering the time, the monitoring occurred (the dry season) PM is abundant in the air and got into the room spaces through window and door openings. This was regulated with the use of curtains in the spaces such that the impact of the opened window was mild. It was generally higher in room A due to its windward positioning giving it more exposure to these particles.

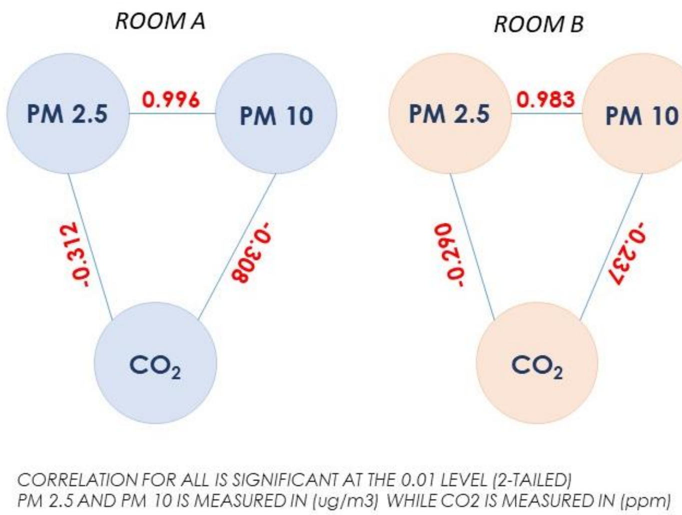


Figure 4.20: Correlation of indoor air contaminants, obtained from SPSS 26

Source: Author's field work (2023)

PM $_{2.5}$ and PM $_{10}$ showed a strong positive relationship in the three rooms. This is why the trend line for $PM_{2.5}$ and PM_{10} are similar for the same room. There is a moderate negative relationship between CO_2 and the PMs in room A and B. This negative relationship exists as a result of the linear outdoor interactions from opening of windows. Rooms C, however had a weak positive correlation between CO_2 and the PMs as there was little or no outdoor interactions with the indoor space resulting from open windows. This means that for rooms A and B, there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas room C had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.2.6 New female hostel

Table 4.28: Distribution of respondents based on activities within the indoor space

Respondents based on Cooking Tools Used		
Cooking Tools	**Frequency**	**Percentage**
Electric Cooker	00	00
Gas/Propane	72	100
Kerosene	00	00
Respondents based on Place of Cooking		
Cooking Place	**Frequency**	**Percentage**
Inside room	16	22.2
Along the corridor of the room	02	2.8
Separate room in the hostel (i.e. kitchen)	54	75.0
Respondents based on Indoor Smoking Habit		
Response	**Frequency**	**Percentage**
Yes	Yes	00
No	No	72
Total	72	100

Source: Author's field work (2023)

It is seen from table 4.28 just like in other hostels that indoor air particulate concentrations will naturally increase due to the occupants behaviours as 100% of them use gas (propane) to cook. Gas cookers or burners produces CO_2 during combustion and in the case of leakages gives off propane which is not only dangerous to the health but also highly volatile. 22.2% of the occupants, cook inside their rooms and 75% cook in the kitchens designed separately and 2% cook along the corridor. Based on this result, the CO_2 levels in rooms generally in this block should not be high, but might be distinct in various rooms. For this reason, an instrument survey was conducted to determine the exact concentration levels.

Table 4.29: Statistical observation of indoor air contaminants

Indoor Air Variables (Room A)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	34.55	39.16	1461.08	25.21	47.92	99.23
SD	34.00	39.00	1243.00	25.10	46.00	97.00
Min	21	24	940	24	41	70
Max	58	66	2386	27	57	152
Indoor Air Variables (Room B)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	32.40	36.11	1417.79	26.52	46.90	94.39
SD	32.00	36.00	1437.00	26.40	47.00	93.00
Min	14	16	1201	26	41	55
Max	47	53	1886	28	54	129
Indoor Air Variables (Room C)						
Parameters	**PM 2.5 (ug/m^3)**	**PM 10 (ug/m^3)**	**CO_2 (ppm)**	**Temperature °C**	**Humidity (%RH)**	**AQI (US)**
Mean	53.93	63.32	754.25	28.92	53.43	135.28
SD	16.936	21.366	96.006	.821	2.165	21.772
Min	32	37	694	27	50	93
Max	157	189	3278	30	62	208

Source: Author's field work (2023)

The air contaminants that the device could measure include $PM_{2.5}$, PM_{10} and CO_2. For the Room A, the average values of PM $_{2.5}$, PM $_{10}$ and CO_2 respectively are 34.55 ug/m^3, 39.16 ug/m^3, and 1461.08 ppm. Room B had 32.40ug/m^3, 36.11 ug/m^3, and 1417.79 ppm. Room C had 53.93 ug/m^3, 63.32 ug/m^3, and 754.25 ppm. Generally, the average AQI for the three rooms are above 100. This is unhealthy for sensitive cases. Room A had an average AQI of 136.88, a minimum value of 74 and a maximum value of 271. This is the highest value recorded and it is very unhealthy.

H_{01f} Occupant behavior is the primary mechanism determining indoor particulate concentrations

Activities such as indoor cooking, smoking, keeping unhealthy plates, pots and spoilt food items all affect indoor air particulate concentrations. As shown in table 4.28, one of the major factors that affects indoor particulate concentration in the case hostel is indoor cooking.

Table 4.30: The hourly average of air contaminants in the various rooms

Hourly average	**Room A**			**Room B**			**Room C**		
	$PM_{2.5}$	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**	**$PM_{2.5}$**	**PM_{10}**	**CO_2**
Hr. 1	37.00	43.05	1519.35	19.73	22.34	1659.21	40.44	48.74	803.76
Hr. 2	44.25	50.41	2128.82	31.83	36.28	1441.06	50.96	61.09	809.65
Hr. 3	38.51	44.05	2150.30	31.59	35.46	1438.28	38.33	44.64	772.74
Hr. 4	28.21	31.61	1920.07	30.62	34.25	1445.41	39.01	45.08	709.25
Hr. 5	26.14	28.94	1826.85	30.81	34.22	1451.29	43.72	50.62	709.54
Hr. 6	33.66	38.36	1401.84	34.18	38.38	1510.19	88.36	108.24	721.94
Hr. 7	38.65	44.36	1149.48	40.30	44.87	1445.90	73.94	87.75	719.28
Hr. 8	33.48	37.88	1216.47	38.84	43.01	1475.79	60.25	70.24	733.66
Hr. 9	30.47	34.29	1118.36	38.05	42.16	1335.48	61.51	71.68	745.64
Hr. 10	35.61	40.29	985.95	34.33	37.59	1287.75	48.74	55.58	735.87
Hr. 11	34.72	38.75	1065.28	29.83	32.71	1305.38	45.94	52.32	834.86
Hr. 12	33.84	37.87	1050.21	28.74	32.08	1217.74	55.94	63.88	754.77

Source: Author's field work (2023)

Occupants of Rooms A, B and C cook inside the room. These rooms however are not overcrowded, having 4, 4, and 2 persons respectively. Room C have the kitchens within the living space by design and rooms A and B use a general kitchen by design. It was observed that the CO_2 content of the indoor air for room A is high having the highest hourly average to be 2150 ppm. The trend line shows that this extremely high values occurred during the cooking period and possible that two or more persons cooked at the same time. The pattern repeated itself in room B also however its values are not that high. Room C offered a different pattern due to the fact that by design there is a space for cooking activities in the student living space.

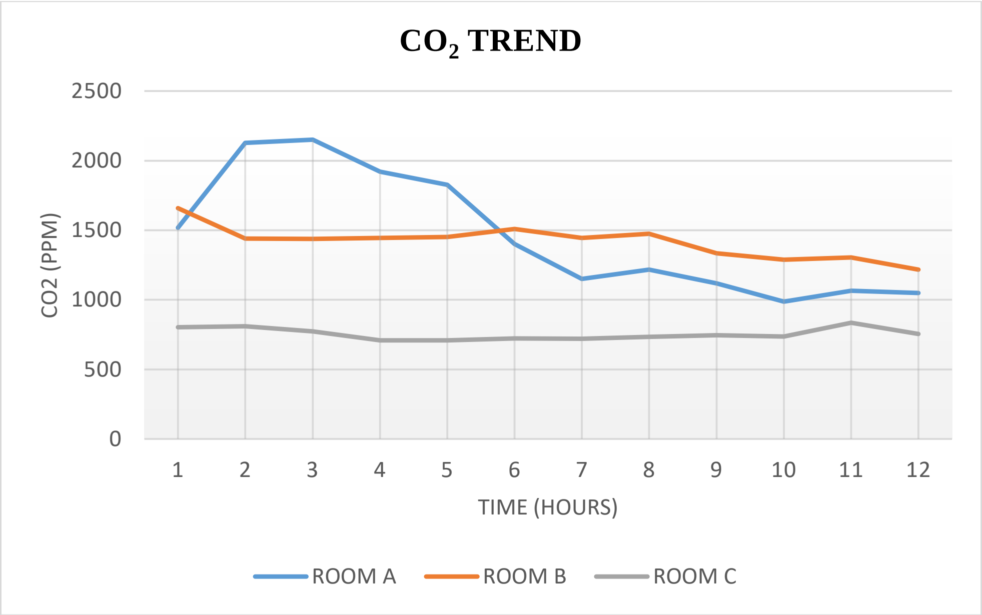


Figure 4.21: Trend chart of CO_2 in the monitor rooms (new female hostel).
Source: Author's field work (2023)

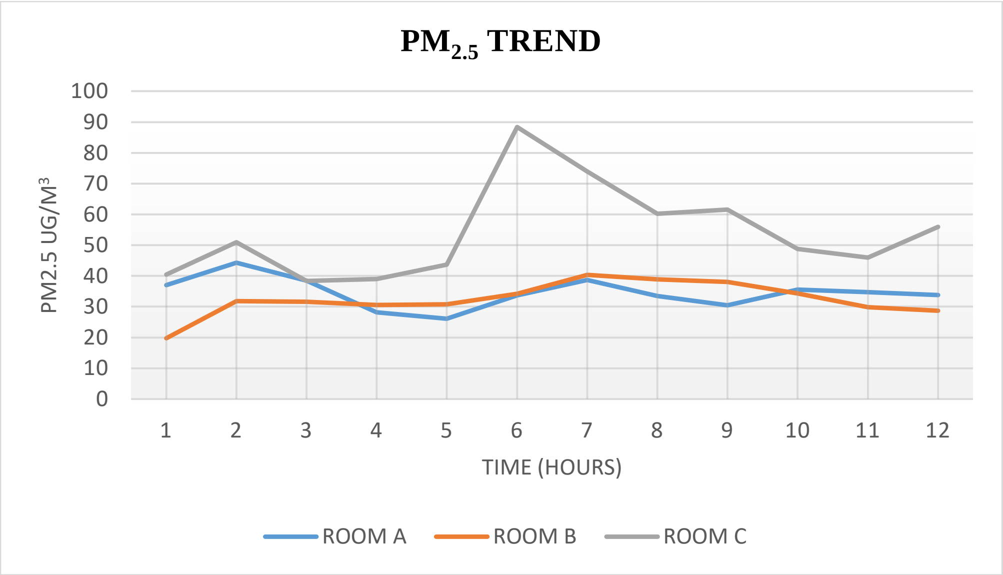


Figure 4.22: Trend of $PM_{2.5}$ in the monitor rooms (new female hostel).
Source: Author's field work (2023)

Particulate Matter PM are sourced majorly from migration of particles from outdoor environment and particles generated from indoor activities such as cooking, smoking (Tran *et al.*, 2020). The PM_{10} and $PM_{2.5}$ values for rooms A and B had a similar pattern where there are fluctuations of up and downs but became a little stable towards the closing hours. Room C however deviates from this pattern. It had an ever increasing value for both PMs throughout the monitor period.

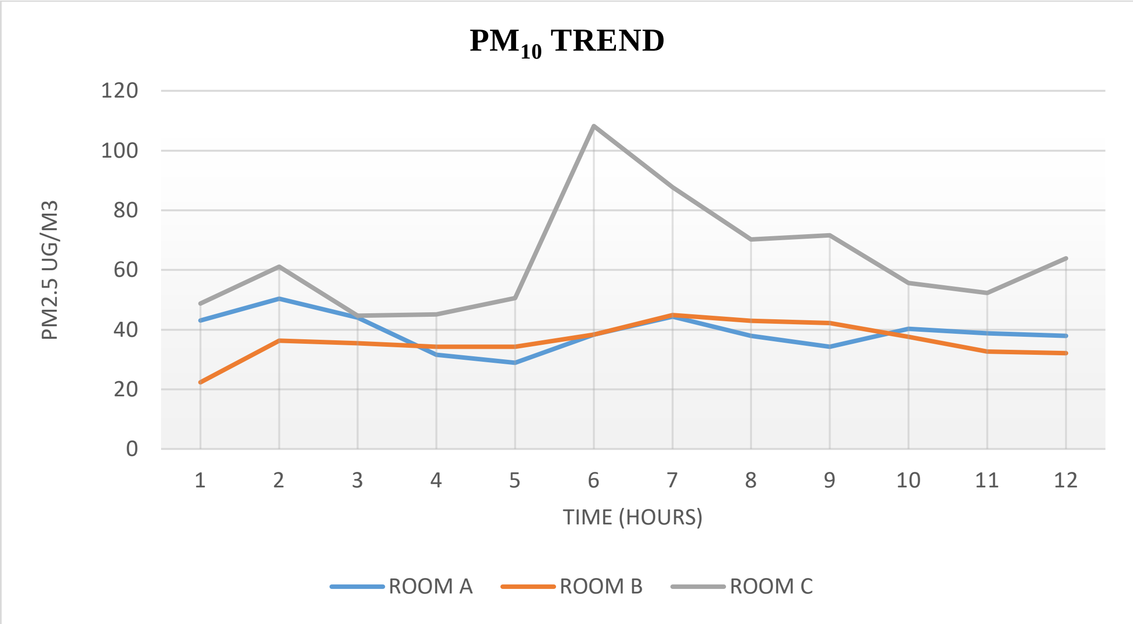


Figure 4.23: Trend chart of PM_{10} in the monitor rooms (new female hostel).
Source: Author's field work (2023)

Indoor air is not only influenced by activities of occupants that generates pollutants but also activities that allows the migration of outdoor particles indoor such as opening of windows and doors. It was observed that a most respondents open their windows more during the dry season and the reasons been for good air circulation. Considering the time, the monitoring occurred (the dry season) PM is abundant in the air and got into the room spaces through window and door openings. This was regulated with the use of curtains in the spaces such that the impact of the opened window was mild. It was generally higher in room A due to its windward positioning giving it more exposure to these particles.

Table 4.31: Occupants activities that results in indoor-outdoor air interactions.

Frequency of Opening Windows During Dry and Raining Season		
Seasons	**WS**	**WM**
Dry Season	208	2.89
Raining Season	196	2.72
Number of respondents = 72; WS = Weighted Score; WM = Weighted Mean		
Respondents based on Conditions for Window Opening		
Conditions	**Frequency**	**Percentage**
When it's windy outdoor	40	27.0
When it's dusty outdoor	42	28.4
When it's raining	66	44.6
Total	148	100
Multiple responses by 72 respondents		
Respondents based on Window Coverings Used		
Window Coverings	**Frequency**	**Percentage**
Shutters	16	22.2
Louvers	0	0
Window blinds (i.e. Curtains)	48	66.7
Total	64	100

Multiple responses by 72 respondents

Source: Author's field work (2023)

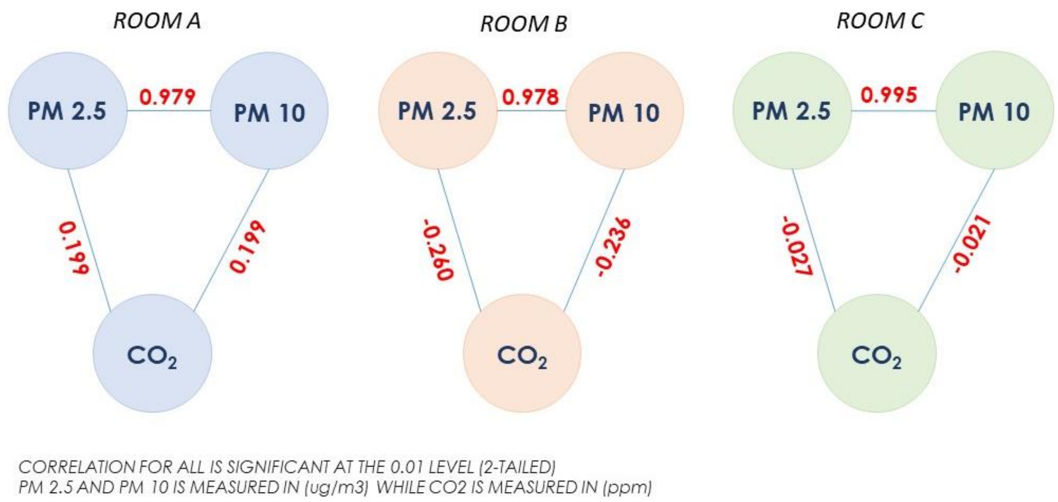


Figure 4.24: Correlation of indoor air contaminants, obtained from SPSS 26.

Source: Author's field work (2023)

$PM_{2.5}$ and PM_{10} showed a strong positive relationship in the three rooms. This is why the trend line for $PM_{2.5}$ and PM_{10} are similar for the same room. There is a weak negative relationship between CO_2 and the PMs in room B and C. This negative relationship exists as a result of the linear outdoor interactions from opening of windows. Rooms A, however had a weak positive correlation between CO_2 and the PMs as there was little or no outdoor interactions with the indoor space resulting from open windows. This means that for rooms B and C, there exists a heterogeneous relationship with outdoor concentrations greatly influencing indoor concentrations whereas room A had a homogenous relationship with outdoor concentrations having little or no influence on the indoor concentrations.

4.2.3 Indoor air quality and health status of the occupants.

4.2.3.1 Male hostel A

From table 4.2 it was established that 71% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.32 shows the exposure hours of the occupants of the various rooms surveyed. Room A had no bad exposure to CO_2 but had 6 hours and 8 hours of exposure to high $PM_{2.5}$ and PM_{10} levels respectively. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.*, 2020). Room B had 11 and 12 hours of exposure to high levels of $PM_{2.5}$ and PM_{10} respectively coupled with 1-hour exposure to high levels of CO_2. Room C had 5, 9 and 3 hours of exposure to high levels of $PM_{2.5}$, PM_{10} and CO_2 respectively. From tables 4.3 and 4.6 it is safe to say the entire hostel will experience similar period of exposure to high levels of indoor air contaminants considering similar behaviours and same outdoor air concentration. The effects through symptoms and signs is in table 4.32.

Table 4.32: Respondents duration of Exposure to different levels of indoor air contaminants (Male hostel A)

Room	Grade	Observation period	PM 10		PM 2.5		CO_2	
			Hours	%	Hours	%	Hours	%
A	Good	12 Hrs.	1	08.3	0	0	9	75.0
	Normal		5	41.7	4	33.3	3	25.0
	Bad		6	50.0	8	66.7	0	00.0
B	Good	12 Hrs.	0	0	0	0	7	58.4
	Normal		1	8.3	0	0	4	33.3
	Bad		11	91.7	12	100	1	08.3
C	Good	12 Hrs.	0	0	0	0	0	00.0
	Normal		7	58.3	3	25	9	75.0
	Bad		5	41.7	9	75	3	25.0

Source: Author's field work (2023)

Some of the symptoms observed (table 4.34) are not directly related to the air contaminants mentioned. However, other contaminants exist which were mentioned in the literature review. The diseases mentioned in table 4.33 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next two ranking diseases is respiratory related, asthma and influenza. There are other possible respiratory problems which might be inherent amongst the respondents which has not been be tested for from the symptoms mentioned such as cardiovascular diseases, Chronic Obstructive Pulmonary Disease (COPD) all resulting from cooking stoves (SO_2; Seow *et al.*, 2016)

Table 4.33: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	157	1.89	8th
Pneumonia	161	1.94	7th
Asthma	177	2.13	2nd
Meningitis	169	2.04	5th
Measles	170	2.05	4th
Chicken Pox	165	1.99	6th
Influenza	171	2.06	3rd
Malaria	262	3.16	1st

Source: Author's field work (2023)

Table 4.34: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	Frequency & (%)		
		Dry Season	Raining Season	None
1	Headaches and a stiff neck	64 (77)	19 (23)	0 (0)
2	Dizziness	54 (65.1)	27 (32.5)	02 (2.4)
3	A tingling/pins/needles feeling	45 (54.2)	17 (20.5)	21 (25.3)
4	Difficulty or fast breathing	54 (65.0)	18 (21.7)	11 (13.3)
5	Increased heart rate	31 (37.3)	25 (30.1)	27 (32.5)
6	Loss of consciousness (i.e. fainting)	31 (37.3)	18 (21.7)	34 (41.0)
7	Weakness/fatigue	39 (47.0)	34 (41.0)	10 (12.0)
8	Sore throat	60 (72.3)	19 (22.9)	04 (4.8)
9	Muscle pains	51 (61.4)	23 (27.7)	09 (10.8)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	18 (21.7)	57 (68.7)	08 (9.6)
11	Nausea (i.e. the feeling that you are going to vomit	42 (50.6)	30 (36.1)	11 (13.3)
12	Vomiting everything	10 (12.0)	53 (63.9)	20 (24.1)
13	A bad (severe) cough that lasts 3 weeks or longer	35 (42.2)	25 (30.1)	23 (27.7)
14	Pain in the chest	38 (45.8)	22 (26.5)	23 (27.7)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	32 (38.6)	34 (41.0)	17 (20.5)
16	Sore or itchy eyes	39 (47.0)	22 (26.5)	22 (26.5)
17	Skin complaints/rashes/eczema	45 (54.2)	33 (39.8)	05 (6.0)

Multiple responses from 83 Respondents

Source: Author’s field work (2023)

4.2.3.2 Female hostel C – G

From table 4.2 it was established that 56.7% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.35 shows the exposure hours of the occupants of the various rooms surveyed. Room A had 4 hours of bad exposure to High CO_2 content and 2 hours of bad exposure to high $PM_{2.5}$ content. They however had no exposure to high PM_{10} content. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.,* 2020). Room B, C and D had no exposure to high PM_{10} content. However, room B, C and D had 10, 6 and 10 hours of exposure to high levels of $PM_{2.5}$ respectively coupled with 11, 8 and 7-hour exposure to high levels of CO_2 respectively. From tables 4.3 and 4.6 it is safe to say the entire hostel will experience similar period of exposure to high levels of indoor air contaminants considering similar behaviours and same outdoor air concentration. The high exposure levels to CO_2 and $PM_{2.5}$ in all the rooms is seen even from the symptoms reported in table 4.36. The respiratory symptoms are recorded in the dry season. These symptoms lead to a possibility of many respiratory illness and these should be tested for.

Table 4.35: Respondents duration of Exposure to different levels of indoor air contaminants (Block C - G)

Room	Grade	Observation period	PM 10		PM 2.5		CO_2	
			Hours	%	Hours	%	Hours	%
D	Good	12 Hrs.	0	0.0	0	0.0	7	58.3
	Normal		12	100	10	83.3	1	08.3
	Bad		0	0	2	16.7	4	33.4
E	Good	12 Hrs.	0	0.0	0	0.0	1	08.3
	Normal		12	100.0	2	16.7	0	0.00
	Bad		0	0	10	83.3	11	92.7
F	Good	12 Hrs.	2	16.7	0	0	1	08.3
	Normal		10	83.3	6	50	2	16.7
	Bad		0	0.0	6	50	8	66.7
G	Good	12 Hrs.	0	0.0	0	0.0	0	0.0
	Normal		12	100.0	2	16.7	5	41.7
	Bad		0	0.0	10	83.3	7	58.3

Source: Author's field work (2023)

The diseases mentioned in table 4.37 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next ranking disease is respiratory related, asthma which ranks third. This shows there is a serious need to consider improving indoor air quality. Influenza ranks sixth and established the occurrence of these respiratory diseases as seen from the symptoms. There are other possible respiratory problems which might be inherent amongst the respondents which has not been be tested for from the symptoms mentioned such as cardiovascular diseases, Chronic Obstructive Pulmonary Disease (COPD) all resulting from cooking stoves (SO_2; Seow *et al.*, 2016)

Table 4.36: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	**Frequency & (%)**		
		Dry Season	**Raining Season**	**None**
1	Headaches and a stiff neck	52 (83.9)	04 (6.5)	06 (9.7)
2	Dizziness	32 (51.6)	16 (25.8)	14 (22.6)
3	A tingling/pins/needles feeling	19 (30.6)	09 (14.5)	34 (54.8)
4	Difficulty or fast breathing	35 (56.5)	07 (11.3)	20 (32.3)
5	Increased heart rate	29 (46.8)	07 (11.3)	27 (32.5)
6	Loss of consciousness (i.e. fainting)	26 (41.9)	07 (11.3)	29 (46.8)
7	Weakness/fatigue	39 (62.9)	09 (14.5)	14 (22.6)
8	Sore throat	37 (59.7)	11 (17.7)	14 (22.6)
9	Muscle pains	28 (45.2)	11 (17.7)	23 (37.1)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	24 (38.7)	17 (27.4)	21 (33.9)
11	Nausea (i.e. the feeling that you are going to vomit	12 (19.4)	26 (41.9)	24 (38.7)
12	Vomiting everything	19 (30.6)	16 (25.8)	27 (43.5)
13	A bad (severe) cough that lasts 3 weeks or longer	25 (40.3)	13 (21.0)	24 (38.7)
14	Pain in the chest	08 (12.9)	24 (38.7)	30 (48.4)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	17 (27.4)	09 (14.5)	34 (54.8)
16	Sore or itchy eyes	37 (59.7)	08 (12.9)	17 (27.4)
17	Skin complaints/rashes/eczema	30 (48.4)	15 (24.2)	17 (27.4)

Multiple responses from 83 Respondents

Source: Author's field work (2023)

Table 4.37: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	130	2.10	5th
Pneumonia	126	2.03	8th
Asthma	151	2.44	3rd
Meningitis	129	2.08	6th
Measles	145	2.34	4th
Chicken Pox	152	2.45	2nd
Influenza	129	2.08	6th
Malaria	198	3.19	1st

Source: Author's field work (2023)

4.2.3.3 Male hostel B

From table 4.2 it was established that 56.7% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.38 shows the exposure hours of the occupants of the various rooms surveyed. Room A and B had high exposure levels of PM_{10} for 10 and 9 hours respectively. They both had high levels of PM2.5 for long hours of 11 and 12 hours respectively. This is an extreme situation as they had some severe exposure levels going as high as 304.81 ug/m^3 for $PM_{2.5}$ and 465 ug/m^3 for PM_{10}. These result shows that the occupants of these spaces are exposed to high level contaminants for long periods and could risk serious health issues. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.,* 2020). All rooms showed a low value of CO_2 content and are within the metric standard. The high exposure levels to PM_{10} and $PM_{2.5}$ in all the rooms are seen even from the symptoms reported in table 4.38. The respiratory symptoms are recorded in the dry season. These symptoms lead to a possibility of many respiratory illness and these should be tested for.

Table 4.38: Respondents duration of Exposure to different levels of indoor air contaminants (Male hostel B)

Room	Grade	Observation period	PM 10		PM 2.5		CO_2	
			Hours	%	Hours	%	Hours	%
A	Good	12 Hrs.	0	0.0	0	0.0	12	100.0
	Normal		2	16.7	1	8.3	0	0.0
	Bad		10	83.3	11	91.7	0	0.0
B	Good	12 Hrs.	0	0.0	0	0.0	10	83.3
	Normal		3	25.0	0	0.0	2	16.7
	Bad		9	75.0	12	100.0	0	0.0
C	Good	12 Hrs.	1	8.3	0	0.0	0	0.0
	Normal		11	91.7	5	41.7	12	100.0
	Bad		0	0.0	7	58.3	0	0.0

Source: Author's field work (2023)

Some of the symptoms observed are not directly related to the air contaminants mentioned. However, other contaminants exist which were mentioned in the literature review. The diseases mentioned in table 4.39 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next ranking disease is respiratory related, asthma which ranks third. With the exposure period and high levels of PMs recorded, beyond asthma, there could be inherent signs and symptoms that are not tested for yet. The school health management should offer test for respiratory diseases if it is not been done.

Table 4.39: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	169	2.04	5th
Pneumonia	192	2.31	2nd
Asthma	180	2.17	3rd
Meningitis	164	1.98	7th
Measles	169	2.04	5th
Chicken Pox	173	2.08	4th
Influenza	163	1.96	8th
Malaria	293	3.53	1st

Source: Author's field work (2023)

Table 4.40: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	Frequency & (%)		
		Dry Season	**Raining Season**	**None**
1	Headaches and a stiff neck	68 (81.9)	08 (9.6)	07 (8.4)
2	Dizziness	59 (71.1)	06 (7.2)	18 (21.7)
3	A tingling/pins/needles feeling	26 (31.3)	19 (22.9)	38 (45.8)
4	Difficulty or fast breathing	39 (47.0)	10 (12.0)	34 (41.0)
5	Increased heart rate	22 (26.6)	10 (12.0)	51 (61.4)
6	Loss of consciousness (i.e. fainting)	63 (75.9)	05 (6.0)	15 (18.1)
7	Weakness/fatigue	41 (49.4)	12 (14.5)	30 (36.1)
8	Sore throat	51 (61.4)	14 (16.9)	18 (21.7)
9	Muscle pains	40 (48.2)	11 (13.3)	32 (38.6)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	25 (30.1)	38 (45.8)	20 (24.1)
11	Nausea (i.e. the feeling that you are going to vomit	12 (14.5)	25 (30.1)	46 (55.4)
12	Vomiting everything	13 (15.7)	18 (21.7)	52 (62.7)
13	A bad (severe) cough that lasts 3 weeks or longer	24 (28.9)	15 (18.1)	44 (53.0)
14	Pain in the chest	37 (44.6)	14 (16.9)	32 (38.6)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	16 (19.3)	26 (31.3)	41 (49.4)
16	Sore or itchy eyes	52 (62.7)	09 (10.8)	22 (26.5)
17	Skin complaints/rashes/eczema	32 (38.6)	13 (15.7)	37 (45.8)

Multiple responses from 83 Respondents

Source: Author’s field work (2023)

4.2.3.4 Shehu Aliyu female hostel

From table 4.2 it was established that 45.2% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.7 shows the exposure hours of the occupants of the various rooms surveyed. Room A had high exposure levels of $PM_{2.5}$ for 12 hours. This is an extreme condition as not even a single hour had good exposure level. However, there are good exposure levels for PM10 and CO2 for 12 and 11 hours respectively. Room B has 5 hours of bad exposure for $PM_{2.5}$ and 11 hours for CO_2. This is an extreme situation as they had some severe exposure levels going as high as 1588 ppm for CO_2, 120.21 ug/m^3 for $PM_{2.5}$ and 165.83 ug/m^3 for PM_{10}. These result shows that the occupants of these spaces are exposed to high level contaminants for long periods and could risk serious health issues. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.*, 2020). The high exposure levels to PM_{10} and $PM_{2.5}$ in all the rooms are seen even from the symptoms reported in table 4.43.

Table 4.41: Respondents duration of Exposure to different levels of indoor air contaminants (Shehu Aliyu)

Room	Grade	Observation period	PM 10		PM 2.5		CO_2	
			Hours	%	Hours	%	Hours	%
A	Good	12 Hrs.	0	0.0	0	0.0	11	91.7
	Normal		12	100.0	0	0.0	0	0.0
	Bad		0	0.0	12	100.0	1	8.3
B	Good	12 Hrs.	4	33.3	0	0.0	1	8.3
	Normal		7	58.4	7	58.3	0	0.0
	Bad		1	8.3	5	41.7	11	91.7

Source: Author’s field work (2023)

Table 4.42: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	119	1.92	7th
Pneumonia	126	2.03	5th
Asthma	127	2.05	4th
Meningitis	119	1.92	7th
Measles	121	1.95	6th
Chicken Pox	128	2.06	3rd
Influenza	130	2.10	2nd
Malaria	217	3.50	1st

Source: Author’s field work (2023)

Some of the symptoms observed are not directly related to the air contaminants mentioned. However, other contaminants exist which were mentioned in the literature review. The diseases mentioned in table 4.42 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next ranking disease is respiratory related, influenza which ranks second. With the exposure period and high levels of PMs recorded, beyond influenza, there could be inherent signs and symptoms that are not tested for yet. The school health management should offer test for respiratory diseases if it is not been done.

Table 4.43: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	**Frequency & (%)**		
		Dry Season	**Raining Season**	**None**
1	Headaches and a stiff neck	51 (82.3)	03 (4.8)	08 (12.9)
2	Dizziness	38 (61.3)	05 (8.1)	19 (30.6)
3	A tingling/pins/needles feeling	27 (43.5)	08 (12.9)	27 (43.5)
4	Difficulty or fast breathing	22 (35.5)	11 (17.7)	29 (46.8)
5	Increased heart rate	24 (38.7)	10 (16.1)	28 (45.2)
6	Loss of consciousness (i.e. fainting)	33 (32.3)	09 (14.5)	33 (53.2)
7	Weakness/fatigue	33 (53.2)	12 (19.4)	17 (27.4)
8	Sore throat	33 (53.2)	15 (24.2)	14 (22.6)
9	Muscle pains	17 (27.4)	14 (22.6)	31 (50.0)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	14 (22.6)	26 (41.9)	22 (35.5)
11	Nausea (i.e. the feeling that you are going to vomit	12 (19.4)	24 (38.7)	26 (41.9)
12	Vomiting everything	13 (21.0)	19 (30.6)	30 (48.4)
13	A bad (severe) cough that lasts 3 weeks or longer	29 (46.8)	12 (19.4)	21 (33.9)
14	Pain in the chest	30 (48.4)	13 (21.0)	19 (30.6)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	21 (33.9)	15 (24.2)	26 (41.9)
16	Sore or itchy eyes	40 (64.5)	02 (3.2)	20 (32.3)
17	Skin complaints/rashes/eczema	43 (69.4)	08 (12.9)	11 (17.7)

Multiple responses from 83 Respondents

Source: Author's field work (2023)

4.2.3.5 New male hostel

From table 4.2 it was established that 77.8% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.44 shows the exposure hours of the occupants of the various rooms surveyed. Room A had high exposure levels of $PM_{2.5}$ for 10 hours and PM_{10} for 4 hours. This is an extreme condition. However, there are good exposure levels for CO_2 for 12. Room B has 10 hours of bad exposure for $PM_{2.5}$ and 5 hours for CO_2. This is an extreme situation as they had some severe exposure levels going as high as 1500 ppm for CO_2. Room C a good internal condition generally except for the exposure level of $PM_{2.5}$ having 6 hours of high value content of $PM_{2.5}$. These result shows that the occupants of these spaces are exposed to high level contaminants for long periods and could risk serious health issues. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.*, 2020). The high exposure levels to CO_2, PM_{10} and $PM_{2.5}$ in all the rooms are seen even from the symptoms reported in table 4.45.

Table 4.44: Respondents duration of Exposure to different levels of indoor air contaminants (New male hostel)

Room	**Grade**	**Observation period**	**PM 10**		**PM 2.5**		**CO_2**	
			Hours	**%**	**Hours**	**%**	**Hours**	**%**
A	Good	12 Hrs.	0	0.0	0	0.0	12	100.0
	Normal		8	66.7	2	16.7	0	0.0
	Bad		4	33.3	10	83.3	0	0.0
B	Good	12 Hrs.	0	0.0	0	0.0	6	50.0
	Normal		12	100.0	2	16.7	1	8.3
	Bad		0	0.0	10	83.3	5	41.7
C	Good	12 Hrs.	1	8.3	0	0.0	9	75.0
	Normal		11	91.7	6	50.0	3	25.0
	Bad		0	0.0	6	50.0	0	0.0

Source: Author's field work (2023)

Table 4.45: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	Frequency & (%)		
		Dry Season	Raining Season	None
1	Headaches and a stiff neck	58 (80.6)	12 (16.7)	02 (2.8)
2	Dizziness	34 (47.2)	10 (13.9)	28 (38.9)
3	A tingling/pins/needles feeling	22 (30.6)	18 (25.0)	32 (44.4)
4	Difficulty or fast breathing	20 (27.8)	04 (5.6)	48 (66.7)
5	Increased heart rate	08 (11.1)	20 (27.8)	44 (61.1)
6	Loss of consciousness (i.e. fainting)	0 (0)	08 (11.1)	64 (88.9)
7	Weakness/fatigue	30 (41.7)	28 (38.9)	14 (19.4)
8	Sore throat	30 (41.7)	10 (13.9)	32 (44.4)
9	Muscle pains	40 (55.6)	08 (11.1)	24 (33.3)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	22 (30.6)	06 (8.3)	44 (61.1)
11	Nausea (i.e. the feeling that you are going to vomit	02 (2.8)	02 (2.8)	68 (94.4)
12	Vomiting everything	08 (11.1)	06 (8.3)	58 (80.6)
13	A bad (severe) cough that lasts 3 weeks or longer	16 (22.2)	04 (5.6)	52 (72.2)
14	Pain in the chest	14 (19.4)	04 (5.6)	54 (75.0)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	06 (8.3)	04 (24.2)	62 (86.1)
16	Sore or itchy eyes	32 (44.4)	0 (0)	40 (55.6)
17	Skin complaints/rashes/eczema	32 (44.4)	04 (5.6)	36 (50.0)

Multiple responses from 72 Respondents

Source: Author's field work (2023)

Some of the symptoms observed are not directly related to the air contaminants mentioned. However, other contaminants exist which were mentioned in the literature review. The diseases mentioned in table 4.46 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next ranking disease is respiratory related, asthma which ranks second. With the exposure period and high levels of PMs recorded, beyond asthma, there could be inherent signs and symptoms that are not tested for yet. The school health management should offer test for respiratory diseases if it is not been done.

Table 4.46: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	146	2.03	4th
Pneumonia	144	2.0	6th
Asthma	160	2.22	2nd
Meningitis	146	2.03	4th
Measles	144	2.0	6th
Chicken Pox	148	2.06	3rd
Influenza	144	2.0	6th
Malaria	208	2.89	1st

Source: Author's field work (2023)

4.2.3.6 New female hostel

From table 4.2 it was established that 83.3% of the respondents have spent 6 months in the hostel space. This duration is long enough for the air in that space to affect the occupants of the space. Table 4.47 shows the exposure hours of the occupants of the various rooms surveyed. Room A had high exposure levels of CO_2 for 11 hours and $PM_{2.5}$ for 5 hours. This is an extreme condition. However, there are good exposure levels for PM_{10} for 11. Room B has 4 hours of bad exposure for $PM_{2.5}$ and 12 hours for CO_2. This is an extreme situation as they had some severe exposure levels going as high as 1659 ppm for CO_2. Room C has a good CO_2. The exposure level of $PM_{2.5}$ is 12 hours of high value content of $PM_{2.5}$. These result shows that the occupants of these spaces are exposed to high level contaminants for long periods and could risk serious health issues. Exposure to high PMs levels generally causes asthma and increased respiratory symptoms. It can cause death to sensitive groups (Tran *et al.*, 2020). The high exposure levels to CO_2, PM_{10} and $PM_{2.5}$ in all the rooms are seen even from the symptoms reported in table 4.49.

Table 4.47: Respondents duration of Exposure to different levels of indoor air contaminants (New female hostel)

Room	Grade	Observation period	PM 10		PM 2.5		CO_2	
			Hours	%	Hours	%	Hours	%
A	Good	12 Hrs.	1	8.3	0	0.0	0	0.0
	Normal		11	91.7	7	58.3	1	8.3
	Bad		0	0.0	5	41.7	11	91.7
B	Good	12 Hrs.	1	8.3	0	0.0	0	0.0
	Normal		11	91.7	8	66.7	0	0.0
	Bad		0	0.0	4	33.3	12	100.0
C	Good	12 Hrs.	0	0.0	0	0.0	12	100.0
	Normal		10	83.3	0	0.0	0	0.0
	Bad		2	16.7	12	100.0	0	0.0

Source: Author’s field work (2023)

Table 4.48: Distribution of Respondents based on Reported Diseases in the Hostel Rooms

Reported Diseases	Weighted Score	Weighted Mean	Rank
Tuberculosis (TB)	144	2.00	4th
Pneumonia	154	2.14	3rd
Asthma	162	2.25	2nd
Meningitis	142	1.97	6th
Measles	144	2.00	4th
Chicken Pox	138	1.92	7th
Influenza	132	1.83	8th
Malaria	214	2.97	1st

Source: Author’s field work (2023)

Some of the symptoms observed are not directly related to the air contaminants mentioned. However, other contaminants exist which were mentioned in the literature review. The diseases mentioned in table 4.48 is a list of common illnesses amongst the respondents. The most common disease is malaria. The next ranking disease is respiratory related, asthma which ranks second. With the exposure period and high levels of PMs recorded, beyond asthma, there could be inherent signs and symptoms that are not tested for yet. The school health management should offer test for respiratory diseases if it is not been done.

Table 4.49: Distribution of the signs and symptoms experienced by the respondents.

	Signs and Symptoms of Diseases	Frequency & (%)		
		Dry Season	**Raining Season**	**None**
1	Headaches and a stiff neck	28 (38.9)	20 (27.8)	24 (33.3)
2	Dizziness	38 (52.8)	10 (13.9)	24 (33.3)
3	A tingling/pins/needles feeling	32 (44.4)	0 (0)	40 (55.6)
4	Difficulty or fast breathing	36 (50.0)	0 (0)	36 (50.0)
5	Increased heart rate	26 (36.1)	06 (8.3)	40 (55.6)
6	Loss of consciousness (i.e. fainting)	40 (33.3)	0 (0)	64 (88.9)
7	Weakness/fatigue	24 (33.3)	36 (50.0)	12 (16.7)
8	Sore throat	38 (52.8)	10 (13.9)	24 (33.3)
9	Muscle pains	20 (27.8)	24 (33.3)	28 (38.9)
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)	24 (33.3)	12 (16.7)	36 (50.0)
11	Nausea (i.e. the feeling that you are going to vomit	30 (41.7)	16 (22.2)	26 (36.1)
12	Vomiting everything	08 (11.1)	22 (30.6)	42 (58.3)
13	A bad (severe) cough that lasts 3 weeks or longer	12 (16.7)	30 (41.7)	30 (41.7)
14	Pain in the chest	28 (38.9)	02 (2.8)	42 (58.3)
15	Coughing up blood or sputum (mucus from deep inside the lungs)	26 (36.1)	0 (0)	46 (63.9)
16	Sore or itchy eyes	44 (61.1)	6 (8.3)	22 (30.6)
17	Skin complaints/rashes/eczema	28 (38.9)	28 (38.9)	16 (22.2)

Multiple responses from 72 Respondents

Source: Author’s field work (2023)

4.2.4 Hostel facilities and indoor air quality.

4.2.4.1 Male hostel A

The state of the hostel facility affects the indoor air. The outdoor environment, the general spaces, kitchens and sanitary spaces all affect indoor air quality. The outdoor environment is not well landscaped which could have improved air purity through the trees planted.

But beside the outdoor environment what is the state of the hostel facility? Table 4.50 focused majorly on the facilities that affect indoor air quality in the hostel directly. This hostel has no air conditioners or air extractors. The ventilation is basically through windows and fans. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically side hung double leaf. This allows 100% air into the rooms. Although some rooms do not receive enough air due to building orientation.

Table 4.50: Distribution of Respondents based on building audit

Distribution of Respondents based on means of Ventilation Available		
Available Means	**Frequency**	**Percentage**
Air Condition	0	0
Fans	79	95.2
Windows only	04	4.8
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Side hung window (i.e. Casement type)	31	37.3
Louvers Window	52	62.7
Total	83	100

Source: Author’s field work (2023)

The louvre is for the walls facing the courtyard. This is where the major challenge comes as some of these windows are damaged. From table 4.49 the hostel generally has good natural lighting but a moderate ventilation. This shows why the occupants leave the windows open for long hours. There is a high level of bad odour and stuff smell which is as a result of overcrowded spaces and poor environmental hygiene of drainages and sanitary spaces. This is a source of biological contaminants. The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold is moderately present in the rooms which can cause asthma, allergies and respiratory infections.

Table 4.51: Rating level of indoor environmental variables in the Hostel facility

Variables	WS	WM	Decision Rule	Rank
Natural ventilation	243	2.93	Moderate	5th
Natural daylight	321	3.87	High	1st
Bad odour or stuffy smell	310	3.73	High	2nd
Presence of mould (i.e. black and growing in moist places)	229	2.76	Moderate	7th
External Noise	292	3.52	High	3rd
Thermal comfort	231	2.78	Moderate	6th
Illumination (Brightness of light)	263	3.17	Moderate	4th

Number of Respondents = 83; WS = Weighted Score; WM = Weighted Mean

Source: Author’s field work (2023)

Table 4.52 is a correlation table between the reported diseases in the case hostel and the influence the indoor environmental quality variable play in the existence. The Pearson coefficient for this survey is generally low, therefore a correlation threshold is set at 1.5. There is a negative relationship between asthma and presence of mold. Tran *et al.* (2020) indicated that presence of mold can cause asthmatic occupants. Presence of mold also had a relationship with influenza but this time a positive one. The strongest correlation was seen between influenza and bad odour which was positive as well as between asthma and bad odour but this time a negative one. This proves that there exists a great ton of biological contaminants in the case hostel and a more intrinsic study be carried out to determine the existence of such allergens.

Table 4.52: Correlation between IEQ variables and the common diseases reported by respondents

		Tuberculosis	Pneumonia	Asthma	Meningitis	Measles	Chicken Pox	Influenza	Malaria
Natural ventilation	Pearson Correlation	-0.017	-0.021	0.005	-0.036	0.058	-0.042	-0.031	0.064
	Sig. (2-tailed)	0.882	0.851	0.964	0.749	0.604	0.709	0.781	0.567
Natural daylight	Pearson Correlation	-0.187	0.125	-0.063	-0.164	-0.159	-.226*	-0.087	0.016
	Sig. (2-tailed)	0.090	0.261	0.572	0.137	0.152	0.040	0.436	0.884
Bad odour or stuffy smell	Pearson Correlation	0.169	0.094	-.261*	-0.191	-0.113	-0.141	.358**	0.174
	Sig. (2-tailed)	0.126	0.397	0.017	0.084	0.308	0.205	0.001	0.115
Presence of mould (i.e. black and growing in moist places)	Pearson Correlation	.267*	.313**	-.255*	-.272*	-0.167	-0.192	0.187	0.150
	Sig. (2-tailed)	0.015	0.004	0.020	0.013	0.130	0.082	0.091	0.177
External Noise	Pearson Correlation	0.048	0.184	-0.080	-0.099	0.002	-0.085	0.045	0.125
	Sig. (2-tailed)	0.666	0.095	0.470	0.374	0.987	0.443	0.688	0.261
Thermal comfort	Pearson Correlation	-0.140	-0.118	0.137	0.115	0.028	0.072	0.082	-.219*
	Sig. (2-tailed)	0.207	0.288	0.216	0.302	0.802	0.515	0.462	0.046
Illumination (Brightness of light)	Pearson Correlation	-0.186	0.004	-0.025	-0.064	-0.097	-0.123	-0.003	-0.029
	Sig. (2-tailed)	0.093	0.968	0.826	0.568	0.381	0.267	0.978	0.796

**. Correlation is significant at the 0.01 level (2-tailed):

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author’s field work (2023)

4.2.4.2 Female hostel C – G

Table 4.53 focused majorly on the facilities that affect indoor air quality in the hostel directly. This hostel has no air conditioners or air extractors. The ventilation is basically through windows and fans. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically sliding window in the room spaces. This allows 50% air into the rooms.

Table 4.53: Distribution of Respondents based on building audit

Distribution of Respondents based on means of Ventilation Available		
Available Means	**Frequency**	**Percentage**
Air Condition	0	0
Fans	53	85.5
Windows only	9	14.5
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Side hung window (i.e. casement type)	08	12.9
Top hung window (i.e. projected type)	27	43.5
Sliding window	17	27.4
Louvers window	10	16.1
Total	62	100

Source: Author's field work (2023)

The advantage of the sliding window with glass panels is it admits adequate daylighting but blocks 50% of the air coming through the fenestration. From table 4.54 the hostel generally has moderate natural lighting and ventilation. This shows why the occupants leave the windows open for long hours. There is a high level of bad odour and stuff smell which is as a result of overcrowded spaces and poor environmental hygiene of drainages and sanitary spaces. This is a source of biological contaminants. The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold presence in the room is low. High levels can cause asthma, allergies and respiratory infections. The acoustics of the spaces is low was the level of external noise is high.

Table 4.54: Rating level of indoor environmental variables in the Hostel facility

Variables	WS	WM	Decision Rule	Rank
Natural ventilation	167	2.69	Moderate	5th
Natural daylight	193	3.11	Moderate	3rd
Bad odour or stuffy smell	213	3.43	High	2nd
Presence of mould (i.e. black and growing in moist places)	139	2.24	Low	7th
External Noise	220	3.54	High	1st
Thermal comfort	175	2.82	Moderate	6th
Illumination (Brightness of light)	185	2.98	Moderate	4th

Number of Respondents = 62; WS = Weighted Score; WM = Weighted Mean

Source: Author's field work (2023)

4.2.4.3 Male hostel B

Table 4.55 focused majorly the facilities that affect indoor air quality in the hostel directly. This hostel has no air conditioners or air extractors. The ventilation is basically through windows and fans. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically side hung double leaf, louvres and perforated walls in circulation areas. This allows 100% air into the rooms. Although some rooms do not receive enough air due to building orientation.

The louvre is for the walls facing the courtyard. This is where the major challenge comes as some of these windows are damaged. From table 4.56 the hostel generally has a moderate natural lighting and moderate ventilation. This shows why the occupants leave the windows open for long hours, which occurs majorly from occupants whose rooms are on the Leeward side of the site. There is a high level of bad odour and stuff smell which is as a result of overcrowded spaces and poor environmental hygiene of drainages and sanitary spaces. This is a source of biological contaminants.

Table 4.55: Distribution of Respondents based on building audit

Distribution of Respondents based on means of Ventilation Available		
Available Means	**Frequency**	**Percentage**
Air Condition	0	0
Fans	79	95.2
Windows only	04	4.8
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Side hung window (i.e. casement type)	19	22.9
Top hung window (i.e. projected type)	7	8.4
Sliding window	4	4.8
Louvers window	26	31.3
Sealed Window Space	3	3.6
Opened window space	23	27.7
Total	83	100

Source: Author's field work (2023)

The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold is moderately present in the rooms which can cause asthma, allergies and respiratory infections. Just like other hostels surveyed, this hostel also faces issues relating to poor acoustics (moderate level of external noise).

Table 4.56: Rating level of indoor environmental variables in the Hostel facility

Variables	**WS**	**WM**	**Decision Rule**	**Rank**
Natural ventilation	238	2.87	Moderate	6th
Natural daylight	279	3.36	Moderate	2nd
Bad odour or stuffy smell	295	3.55	High	1st
Presence of mould (i.e. black and growing in moist places)	190	2.29	Moderate	7th
External Noise	277	3.34	Moderate	3rd
Thermal comfort	241	2.90	Moderate	5th
Illumination (Brightness of light)	263	3.17	Moderate	4th

Number of Respondents = 83; WS = Weighted Score; WM = Weighted Mean

Source: Author's field work (2023)

4.2.4.4 Shehu Aliyu female hostel

Table 4.57 focused majorly the facilities that affect indoor air quality in the hostel directly. This hostel has air conditioners in some spaces. The ventilation is basically through windows and fans. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically side hung double leaf, louvres and perforated walls in circulation areas. This allows 100% air into the rooms. Although some rooms do not receive enough air due to building orientation (the leeward side of the site).

Table 4.57: Distribution of Respondents based on building audit

Distribution of Respondents based on means of Ventilation Available		
Available Means	**Frequency**	**Percentage**
Air Conditioners	08	11.3
Fans	54	87.1
Windows only	52	83.9
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Side hung window (i.e. casement type)	18	29.0
Top hung window (i.e. projected type)	09	14.5
Sliding window	08	12.9
Sealed Window Space	03	4.8
Opened window space	24	38.7
Total	62	100

Source: Author's field work (2023)

The advantage of the casement windows with glass panels is it admits adequate daylighting and can offer 100% of the air coming through the fenestration the sealed window space is achieved with the use of perforated or screen walls. From table 4.58 the hostel generally has moderate natural lighting and ventilation. This shows why the occupants leave the windows open for long hours. There is a high level of bad odour and stuff smell which is as a result of overcrowded spaces and poor environmental hygiene of drainages and sanitary spaces. This is a source of biological contaminants. The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold presence in the room is low. High levels can cause asthma, allergies and respiratory infections. The acoustics of the spaces is low was the level of external noise is high.

Table 4.58: Rating level of indoor environmental variables in the Hostel facility

Variables	WS	WM	Decision Rule	Rank
Natural ventilation	164	2.65	Moderate	6th
Natural daylight	181	2.92	Moderate	3rd
Bad odour or stuffy smell	217	3.50	High	2nd
Presence of mould (i.e. black and growing in moist places)	132	2.13	Low	7th
External Noise	227	3.66	High	1st
Thermal comfort	165	2.66	Moderate	5th
Illumination (Brightness of light)	170	2.74	Moderate	4th

Number of Respondents = 62; WS = Weighted Score; WM = Weighted Mean

Source: Author’s field work (2023)

4.2.4.5 New male hostel

Table 4.59 focused majorly the facilities that affect indoor air quality in the hostel directly. This hostel has air conditioners in all spaces upon completion of the design, the 97.2% shows a possibility of some not function in there installed spaces. The natural ventilation is basically through windows. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically the sliding windows. This allows 50% air into the rooms.

From table 4.60, the hostel generally has high natural lighting and ventilation and as such do not open the windows often. There is a moderate level of bad odour and stuff smell which is as a result of occupant behavior within the spaces. There is a low presence of mould and noise is not a problem in this hostel.

Table 4.59: Distribution of Respondents based on building audit

Distribution of Respondents based on means of Ventilation Available (multiple res.)		
Available Means	**Frequency**	**Percentage**
Air Conditioners	60	83.3
Fans	70	97.2
Windows only	36	50
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Side hung window (i.e. casement type)	04	5.6
Top hung window (i.e. projected type)	00	0
Sliding window	68	94.4
Sealed Window Space	00	00
Opened window space	00	00
Total	72	100

Source: Author’s field work (2023)

The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold presence in the room is low. High levels can cause asthma, allergies and respiratory infections. This hostel facility offers the occupants the potential of a good IAQ, better than the four hostels earlier surveyed.

Table 4.60: Rating level of indoor environmental variables in the Hostel facility

Variables	**WS**	**WM**	**Decision Rule**	**Rank**
Natural ventilation	258	3.58	High	3rd
Natural daylight	258	3.69	High	2nd
Bad odour or stuffy smell	196	2.72	Moderate	4th
Presence of mould (i.e. black and growing in moist places)	114	1.58	Low	7th
External Noise	176	2.44	Low	6th
Thermal comfort	196	2.72	Moderate	4th
Illumination (Brightness of light)	248	4.36	Very High	1st

Number of Respondents = 72; WS = Weighted Score; WM = Weighted Mean

Source: Author’s field work (2023)

4.2.4.6 New female hostel

Table 4.61 focused majorly the facilities that affect indoor air quality in the hostel directly. This hostel has air conditioners in all spaces upon completion of the design. The 97.2% shows a possibility of some not function in there installed spaces. The natural ventilation is basically through windows. It has a courtyard to aid cross ventilation as well as stack ventilation. The window type is basically the sliding windows. This allows 50% air into the rooms.

Table 4.61: Distribution of Respondents based on based on building audit

Distribution of Respondents based on means of Ventilation Available		
Available Means	**Frequency**	**Percentage**
Air Conditioners	72	100
Fans	72	100
Windows only	38	52.8
Distribution of Respondents based on their Responses on Window Type		
Window Type	**Frequency**	**Percentage**
Sealed Window Space	64	88.9
Opened window space	08	11.1
Total	72	100

Source: Author’s field work (2023)

From table 4.62 the hostel generally has high natural lighting and ventilation and as such do not open the windows often. The There is a low level of bad odour and stuff smell which occupant behavior within the spaces. There is a low presence of mould and noise is not a problem in this hostel. The thermal comfort is moderate which tells why the temperatures are high even during the dry season. Mold presence in the room is low. High levels can cause asthma, allergies and respiratory infections. This hostel facility offers the occupants the potential of a good IAQ, better than the four hostels earlier surveyed. This hostel like the new male hostel and reduce the issue of overcrowd is also in a good shape and it is bound to be more to that area.

Table 4.62: Rating level of indoor environmental variables in the Hostel facility

Variables	WS	WM	Decision Rule	Rank
Natural ventilation	254	3.53	High	2nd
Natural daylight	258	3.58	High	1st
Bad odour or stuffy smell	174	2.42	Low	4th
Presence of mould (i.e. black and growing in moist places)	94	1.31	Very low	7th
External Noise	162	2.25	Low	6th
Thermal comfort	230	3.19	Moderate	4th
Illumination (Brightness of light)	246	3.42	High	3rd

Number of Respondents = 72; WS = Weighted Score; WM = Weighted Mean

Source: Author's field work (2023)

In summary, the BASE of the hostel accommodations discovered that there is a general high CO_2 $PM_{2.5}$ and PM_{10} contents in the hostels. However, the new hostels had a lower content value of these contaminants which was influenced as a result of better design planning as well as an improved occupants' behavior. It was further observed that the female hostels generally had more CO_2 concentrations than the male hostels. These contaminants had effect on the occupants with related respiratory symptoms as well as established diseases. Some of the symptoms and contaminants concentrations suggested that some respiratory diseases may be lingering in the occupants' bodies un tested for.

The pandemic has placed a demand for a preparedness for indoor infectious disease that goes beyond the current indoor codes and standards (Awada *et al.*, 2021). It has been verified through research that poorly or non-ventilated spaces can encourage aerosol spread of air borne diseases such as COVID 19, an insufficient ventilation in closed spaces has a probable long range virus transmission and infection even through the air. Chang *et al.* (2021) opined that $PM_{2.5}$ and PM_{10} (which are prevalent in the case hostels) could be good carriers of infectious diseases amongst other air contaminants and this does not only pose a threat of the potential effect of the contaminants but also the disease causative agents they carry. Further studies will be needed to ensure that appropriate air quality standards are developed in such as a way to enhance sustainable indoor air contaminants control including the probability that they could be vectors for infectious diseases.

4.3 Proposed Student Hostel for F.U.T Minna.

4.3.1 Proposed site and its location

The proposed site is situated in the main campus of the Federal University of Technology, Minna, which is Gidan Kwano of the Bosso local government area, Niger State, Nigeria. It is situated around the residential area of the university, close to other hostels, the school clinic, as well as the staff quarters.

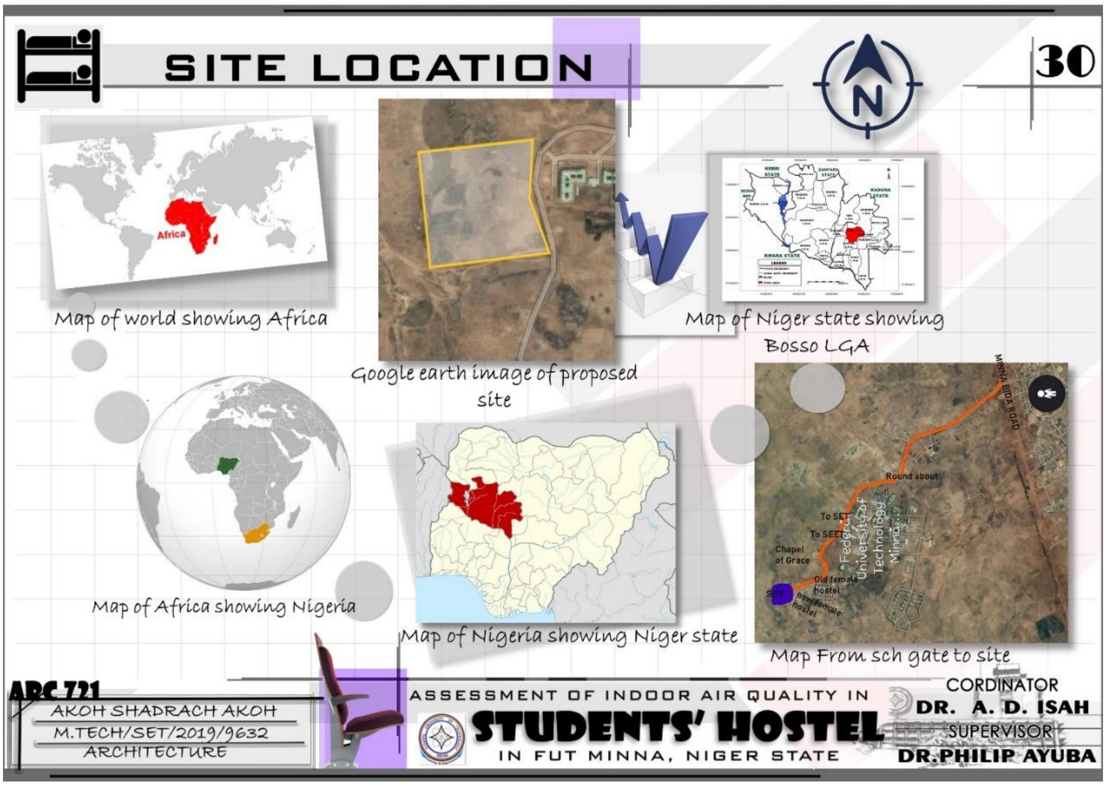


Figure 4.25: Site location.

Source: Author’s field work (2023)

4.3.2 Site selection criteria

The criteria influencing the selection of any site is primarily dependent on the nature of project the site will be harbouring. This proposal is for a student accommodation for a university and as such it must be located within the campus. Locating it within the campus also has some factors to consider. The major factor considered in selecting the site is the university's master plan. Figure 4.26 shows the master plan of FUT Minna, valid till 2025 and it upon this finding that the site was selected; the area of land within the red square is the proposed area allocated for future development. However, the general considerations to selecting the site is itemized as follows;

i. It is the area of space allocated by the master plan
ii. Presence of an existing access road
iii. Proximity to other existing hostels
iv. Presence of electricity distribution cables for power supply
v. A large open space that can contain a phased design plan targeted at reducing the student accommodation deficit as well as for adequate landscaping that will improve the outdoor air quality.

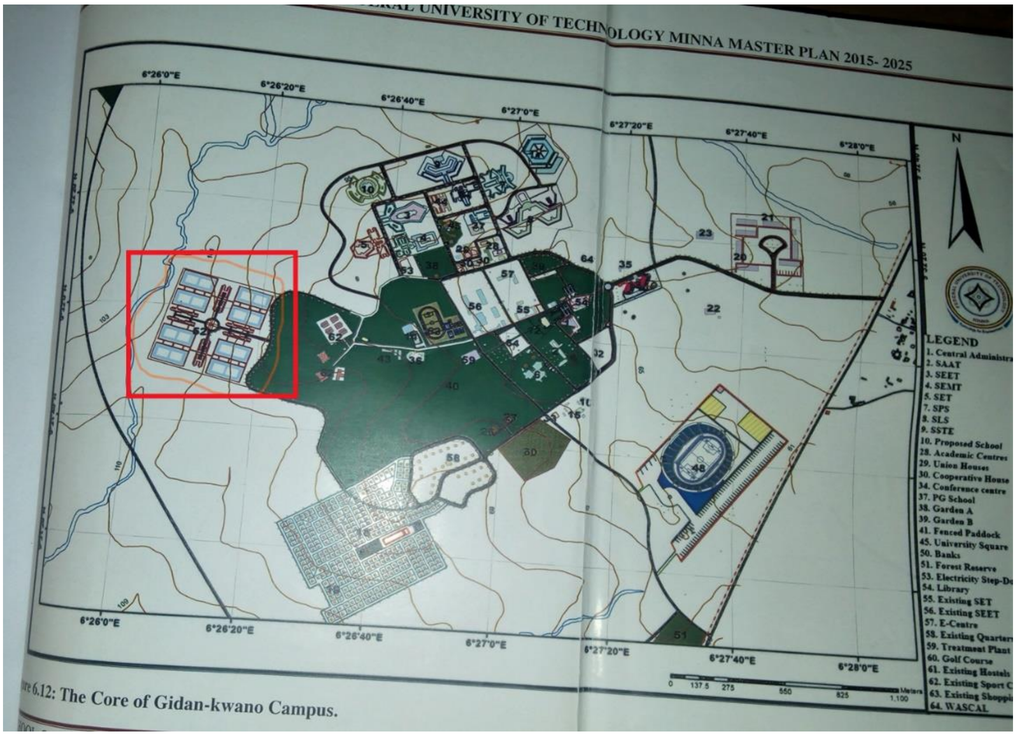


Figure 4.26: The master plan of FUT Minna.

Source: PPDU (2018).

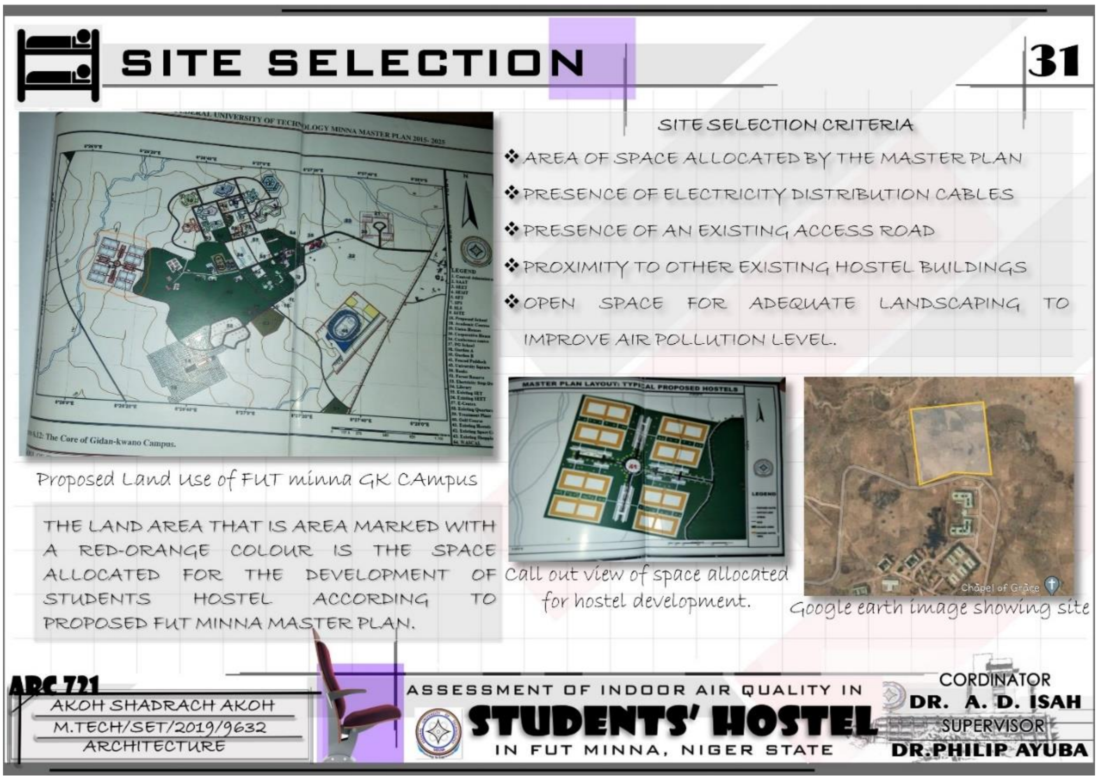


Figure 4.27: Site selection criteria.

Source: Author’s field work (2023)

4.3.3 Site analysis

A careful evaluation of the site was conducted and it has the existing access just along the south boundary and a proposed road cutting through the site. Due to the relatively flat topo surface, the steeped strip foundation was recommended at some point along with the general pad foundation. Some of the site characteristics include.

i. Site topography:

The site is relatively flat with undulations at intervals. Some rocky areas are found within the site which will be quarried and used as hardcore during the construction of the foundation.

ii. Adjourning buildings:

There are no adjourning buildings to the north, east and west of the site. This exists only to the south of the site which are the existing male and female hostels. These create a link to the community of students and exterminates the idea of isolation that the distance of the site might bring.

iii. Vegetation:

The vegetal cover is scanty with trees and shrubs as well as grasses. However, the design proposes to plant more trees that will offer a pure outdoor air that is interacting with the indoor air. This is possible as the availability of fertile soil which stems from the large River Niger cutting through the Niger State.

iv. Services on site:

There is an existing electric line established along the access to the site. However, the design suggests a mini communication mast be built or the existing ones be boosted to reach a wider coverage as the communication network is weak.

v. Climatic elements:

The prevailing winds in Nigeria generally are the North East trade wind and the South West trade wind. The former originates from the Sahara Desert in the north and it accompanied with a characteristic dry atmosphere which is hazy. It brings the harmattan season. The later originates from the Atlantic Ocean in the South and is accompanied with a cool and moist air. It brings the raining season. The temperature in Minna is averagely high during the day with a range of 28^{o}C to 30^{o}C and lower temperatures at night ranging from 19^{o}C to 21^{o}C (Weather spark, 2019).

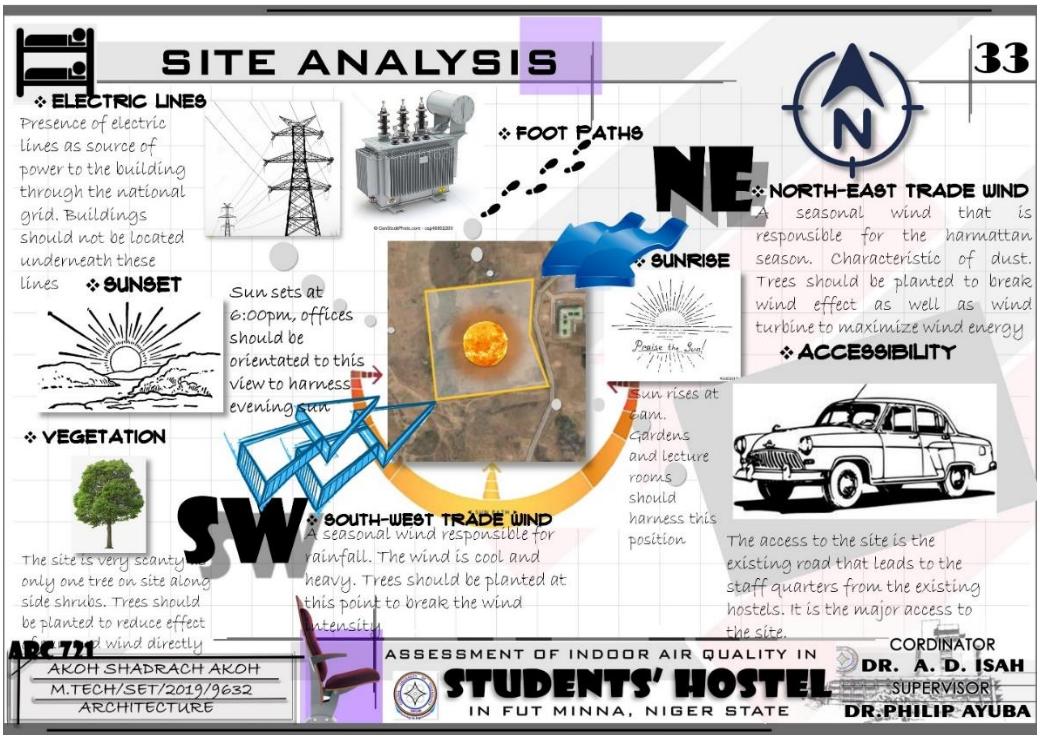


Figure 4.28: An architectural illustration of the site analysis.

Source: Author's field work (2023)

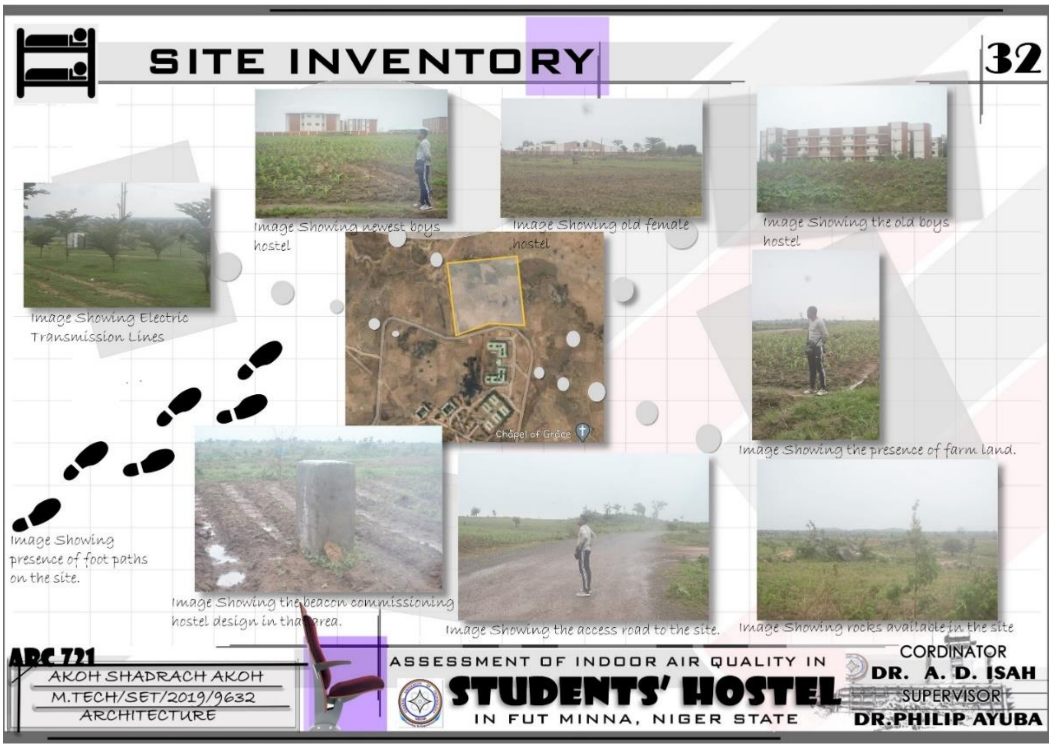


Figure 4.29: An architectural illustration of the site inventory.

Source: Author’s field work (2023)

vii. Precipitation and relative humidity:

Being a tropical settlement, the rainfall is convectional with an approximate annual rainfall of 1229 mm. The least amount of rainfall is observed in the month of January (1 mm) and highest in September (260 mm). The fluctuations in precipitation also influences the relative humidity. These fluctuations make the environment humid, oppressive and unpleasant.

4.4 Design Report

4.4.1 Design brief

The task is to design a student accommodation which enhances the students experience by delivering a high quality living, social amenity space that can give the student a good indoor environmental quality through implementation of the findings obtained in the research process. The design should not just be qualitative but also quantitative, seeking to handle the student housing shortfall in the university by at least 10%. The student housing should not just be limited to the undergraduates alone but it should also incorporate the post graduate students as well. Some guidelines to the design include;

i. All rooms and layouts shall be of a workable design and comply with the higher functional, safety, maintenance and aesthetic regulations. The building must be maintenance free with zero post occupancy challenge.
ii. Designs must comply with all relevant sections of the current building regulations and associated approved codes of practice.
iii. Fire protection and prevention measures must be provided. Fire detection and alarm systems should comply with BS 5839 to a category l1 standard and utilise multi-use detector heads. Manual fire alarm call points are to be avoided wherever possible to reduce misuse.

From the research process, the following outcomes were implemented;

i. The orientation of the buildings to harness the effect of the prevailing wind and solar gain
ii. The use of cross ventilation and stack ventilation as a means of natural cooling
iii. The adequate spacing of the buildings to enhance air flow
iv. The planning of the spaces to the minimalist form to reduce excess spacing that will encourage squatting
v. The planting of indoor plants for air purification process
vi. The use of extractor fans both in the room spaces and kitchen spaces to extract used and polluted air

vii. The adequate landscaping of the site with paved areas, green areas, trees and shrubs so as to reduce PMs and purify the outdoor air.

4.4.2 Design concept of the proposed student accommodation

4.4.2.1 Site concept

The site concept entails the idea of a cluster community. The design has three cluster communities, two to the males and one to the female. Each cluster community is distinct and acts as a colony (neighborhood) where the needed facilities are provided in the form of the residential spaces, the recreational spaces as well as the commercial spaces. These colonies are linked based on the proposed access route designed in the university master plan. Each colony has a perimeter fence with the link points been the gate entrance.

4.4.2.2 Building concept

There are three buildings types in each cluster namely; two undergraduate blocks, one post graduate block and one recreational facility. The concept for each of the building is discussed. The undergraduate building adopted the analogical concept, following the Lami's theorem of structural system. It entails three forces (wings of the building) which are coplanar, binding together radially at an exact angle of 120^0 to each other (figure 4.30). The post graduate building adopted the already existing concept of the new male and female hostel where by the building took a L shape a rectangular mass. The third building is the recreational facility open to both the post graduates and undergraduates.

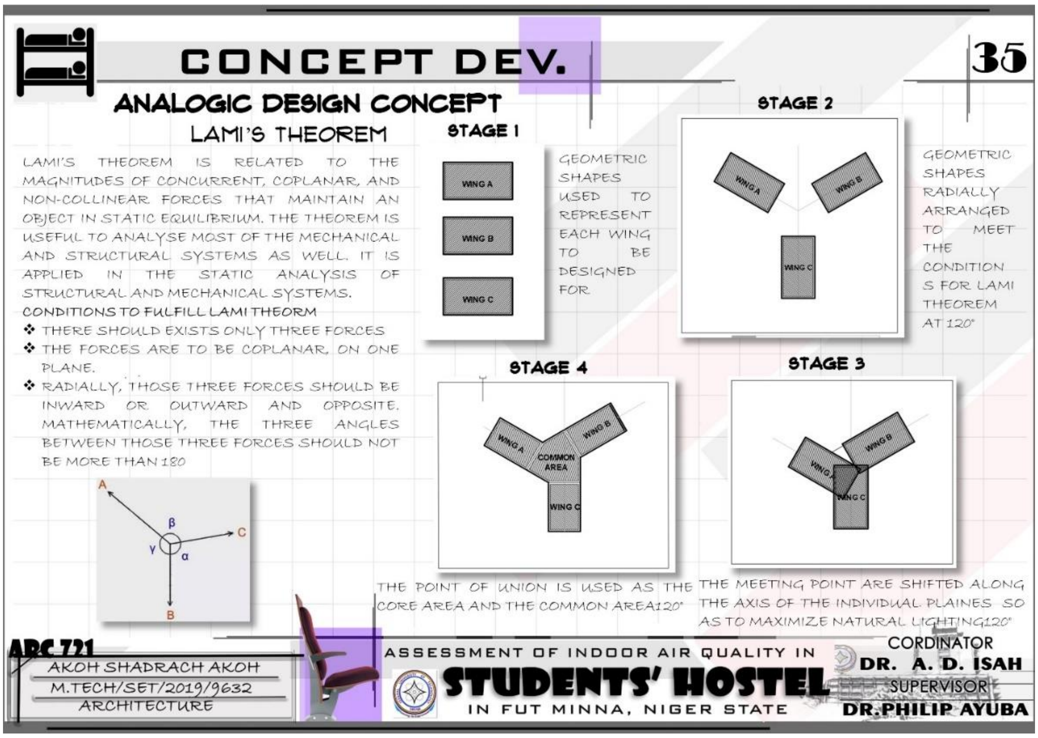


Figure 4.30: An architectural illustration of the building concept.

Source: Author's field work (2023)

4.4.3 Site planning and cluster communities

The cluster communities are targeted at creating a social niche even in solving the challenge of student housing shortfall. It comprises of two undergraduate blocks, a post graduate block and a central commercial centre. There are three niches in the site layout offering a total of 4200 bed spaces, comprising of room of 4, room of 2 and studio apartments. The site was planned in accordance to the proposed road in the master plan. Three clusters all having the needed facilities within that cluster. The landscape was designed to ensure that all outdoor pollution is minimized and in the case of any pollution, the air is purified. Figure 4.31 shows the complete layout. Figure 4.32 shows a sample cluster. The water pools were designed to cool the spaces by evaporation. The concept of this is that water that has stayed in the pool for at least 2 days will be connected to the sprinklers and used to water the grasses and shrubs will a fresh water is supplied to the pools. This is will be more useful during the heat period where there is absence of rain.

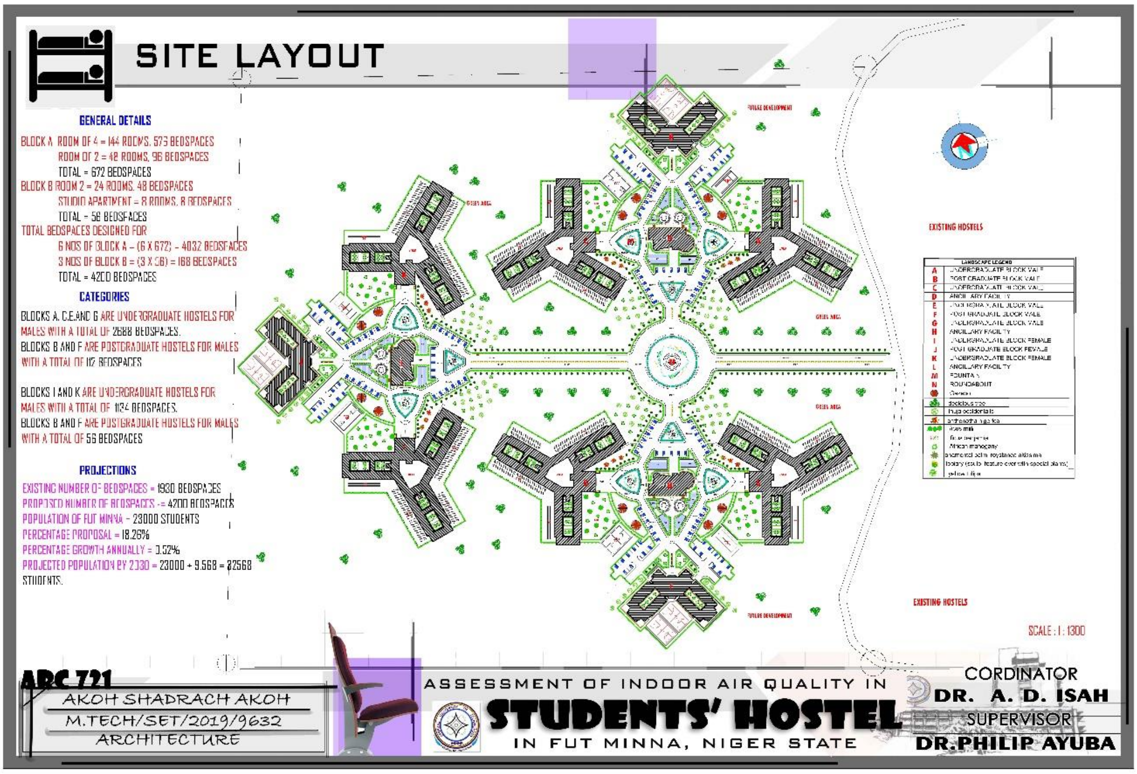


Figure 4.31: An architectural illustration of the site concept.

Source: Author’s field work (2023)

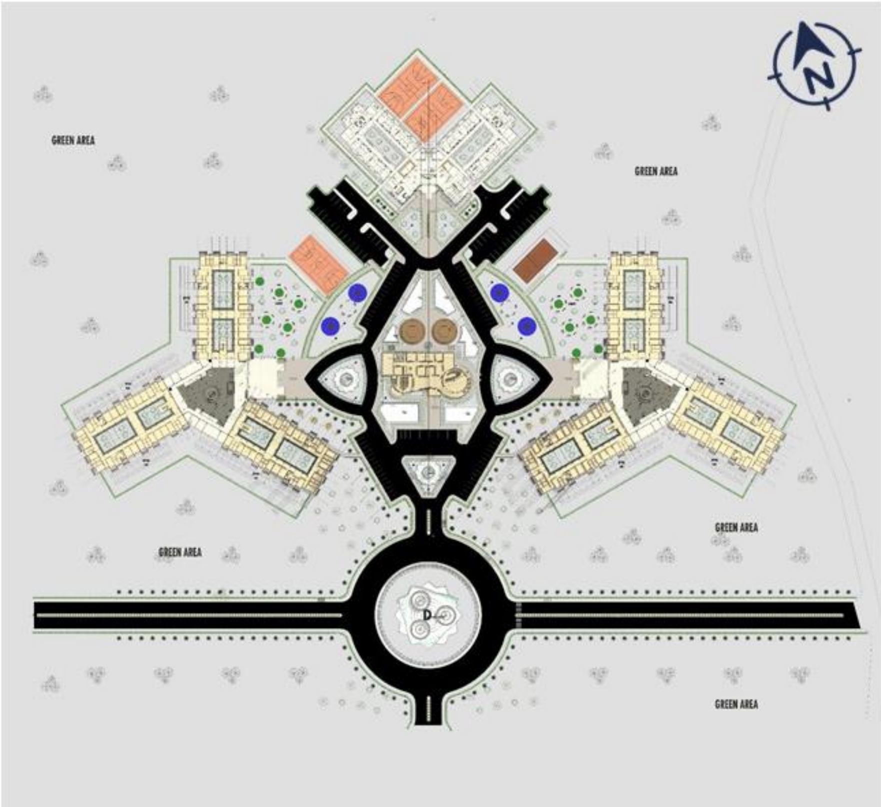


Figure 4.32: An architectural illustration of the site cluster.

Source: Author’s field work (2023)

Figure 4.33: Aerial perspective of the entire site.

Source: Author’s field work (2023)

4.4.4 Solar study of the site location

One of the advantages of the building concept exists in its ability to harness the advantages of the prevailing wind and the sun through is triple wings and shading strategy. The figure 5.10 showed the orientation of the buildings that exists in the cluster community A and how they respond to the sun movement along different times of the day. Areas that are naturally disadvantaged due to direct sun effect and direct wind effect have been protected using wind breakers and solar shading.

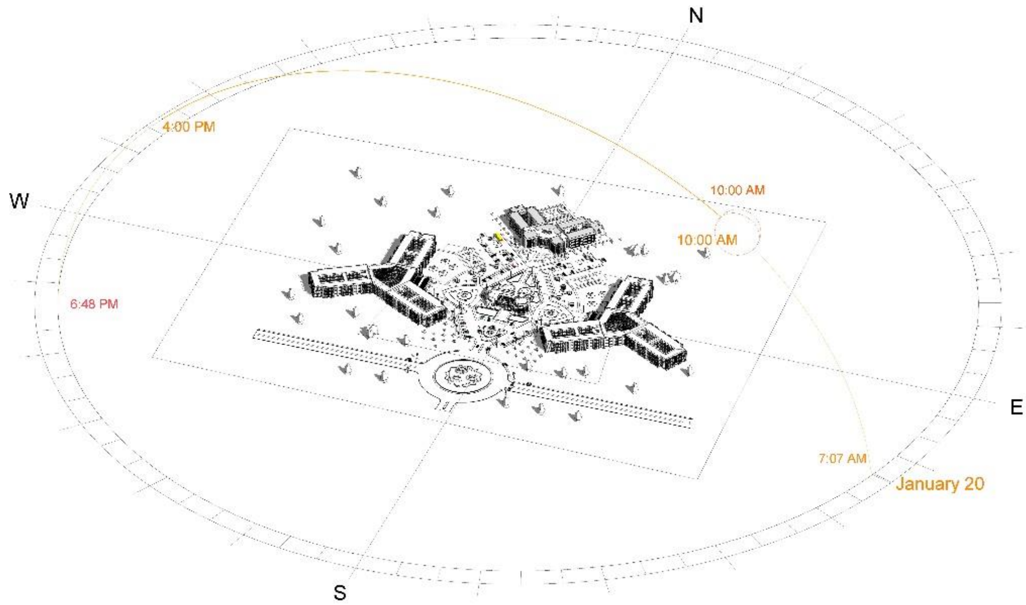


Figure 4.34: Site solar study as obtained from Revit 2021.
Source: Author's field work (2023)

4.4.5 Prof J. O Ndagi undergraduate hostel

4.4.5.1 Architectural design

Developed after the Lami's theorem, this building is a three winged hostel space, having the common area in the core area. Each wing has a central courtyard while the core area has an atrium. The living spaces has two types of room typologies (A and B). A total of

672 bed spaces was designed for in this hostel block. Table 5.1 shows the schedule of accommodation for this block. The presentation drawings to the design shows the flow and the functionality of the design. For typology A, the maximum number of students is four in a room with an attached toilet. The kitchen and laundry spaces is centralized and shared by four rooms as shown in figure 5.13

Table 4.63: Schedule of Accommodation for undergraduate Hostel

S/N	Function	Dimension (m)	Area (m^2)	Units	Total (m^2)
1	Room type A	3 x 5.1	15.3	108	1652.4
2	Room type B	3 x 4.8	14.4	36	518.4
3	General Kitchen	3.8 x 5.1	19.38	36	697.68
4	Laundry	3.8 x 5.1	19.38	36	697.68
5	Toilet and bathroom A	1.8 x 3.0	5.4	108	583.2
6	Floor manager suite	5.1 x 17.4	88.74	3	266.22
7	Ensuite kitchen	1.8 x 2.85	5.13	36	184.68
8	Toilet and bathroom B	1.8 x 2.4	4.32	36	155.52
9	Reception	4.8 x 6.0	28.8	1	28.8
10	Entrance	15.2 x 21.3	323.76	1	323.76
11	Common area (Atrium)	Not regular	637.7	1	637.7
12	Pharmacy/sick bay	5.1 x 13.0	66.3	1	66.3
13	Corner shops	4.1 x 5.1	20.91	9	188.19
14	Cyber cafe	5.1 x 13.0	66.3	2	132.6
15	Games room	Not regular	126.5	2	253.0
16	Panel rooms	Not regular	14.2	6	85.2
17	Courtyard	12.0 x 44.4	532.8	3	1598.4

Source: Author’s field work (2023)

Figure 4.35: An architectural illustration of the ground floor plan.

Source: Author's field work (2023)

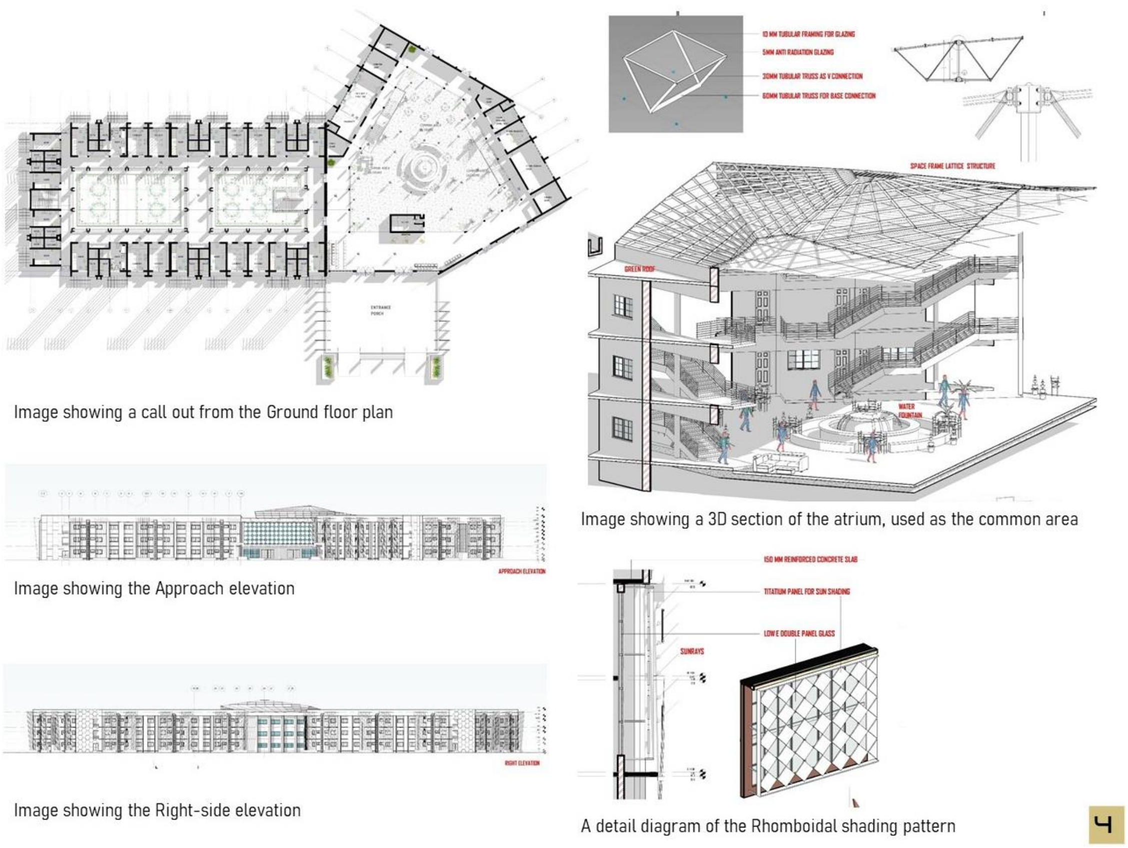


Figure 4.36: Call outs of different aspects of the design.

Source: Author's field work (2023)

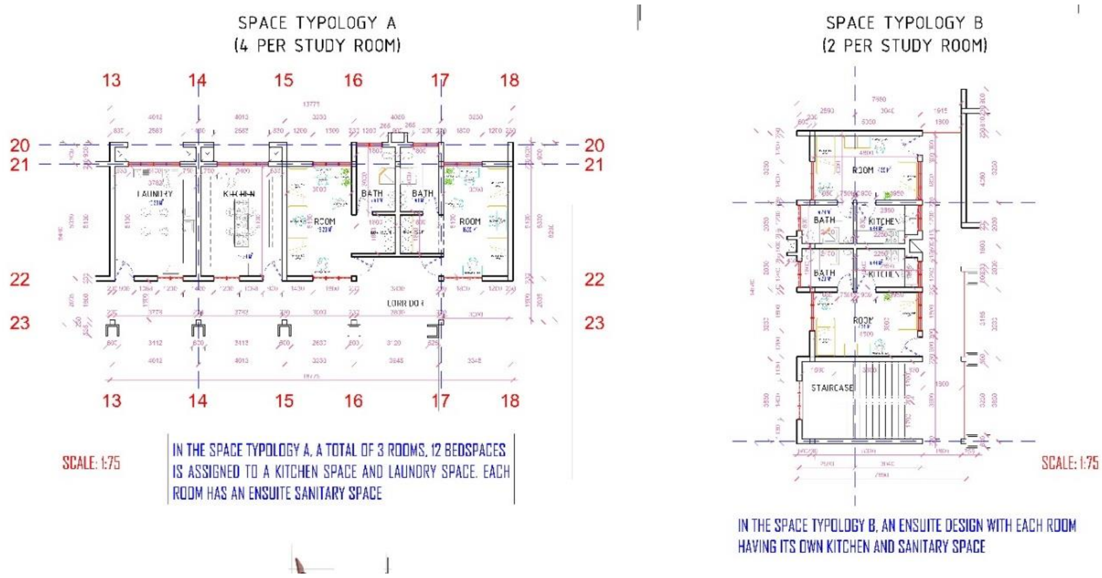


Figure 5.37: Floor plans showing the two space typologies in the design.

Source: Author's field work (2023)

Figure 4.38: 3-Dimensional call outs of the building.

Source: Author's field work (2023)

Figure 4.39: An architectural rendering of the exterior environment
Source: Author’s field work (2023)

4.4.5.2 Structural system

The structural system used is the post and lintel system. The foundation type used is the deep strip foundation and the pad foundation. The deep strip foundation is used for the external load bearing walls as well as most of the partition walls. The pad foundation was used for the columns in which the beams connect forming a monolith structural system. The atrium covering was achieved with the use of space frame lattice structure. Each frame is connected to another to for multiple triangulation network and can span great distances. The double panel glass was used to enable daylight penetration.

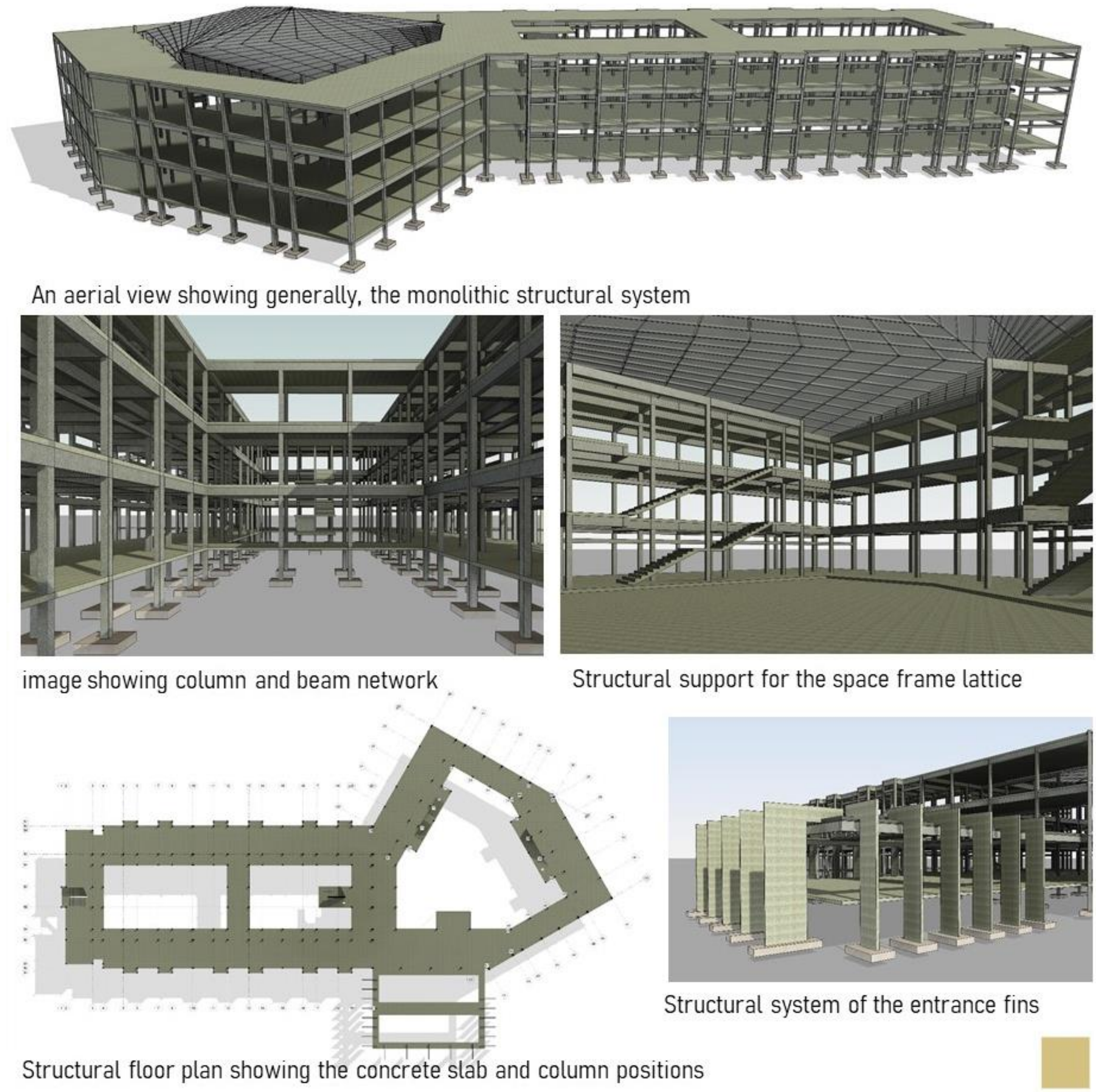


Figure 4.40: An architectural illustration of the structural systems.
Source: Author’s field work (2023)

4.4.6 Prof. Musbau Akanji postgraduate hostel

4.4.6.1 Architectural design

Taking an L shape and a rectangular mass, this block was designed to cater for the needs of the postgraduate students. It has courtyards at every wing to harness the flowing air at every point owing to the high temperature of the tropical climate. It was designed with typologies that houses two PG students and also a studio apartment which can accommodate a small family. Recreational facilities are within the building making it an abode in itself.

Table 4.64: Schedule of Accommodation for Postgraduate Hostel

S/N	Function	Dimension (m)	Area (m^2)	Units	Total (m^2)
1	Standard room	3.6 x 6.0	25.0	48	1200
2	kitchen	2.4 x 2.6	6.24	48	299.52
3	Bathroom	1.65 x 3.1	19.38	48	930.24
4	Studio apartment	Not regular	23.0	8	184.0
5	Bedroom	Not regular	22.0	8	176.0
6	kitchen	2.8 x 3.6	9.0	8	72.0
7	Snacks bar	4.7 x 4.3	20.0	7	140.0
8	gymnasium	Not regular	104.0	1	104.0
9	Reception	4.9 x 8.2	40.18	1	40.18
10	Entrance	Not regular	37	1	37.0
11	Common room	9.0 x 8.8	79.2	4	316.8
12	Hostel manager suite	6.0 x 6.25	37.5	1	37.5
13	Anchor store	8.8 x 9.0	79.2	1	79.2
14	Restaurant	9.0 x 8.8	79.2	1	79.2
15	Courtyard	Not regular	213	2	426.0

Source: Author’s field work (2023)

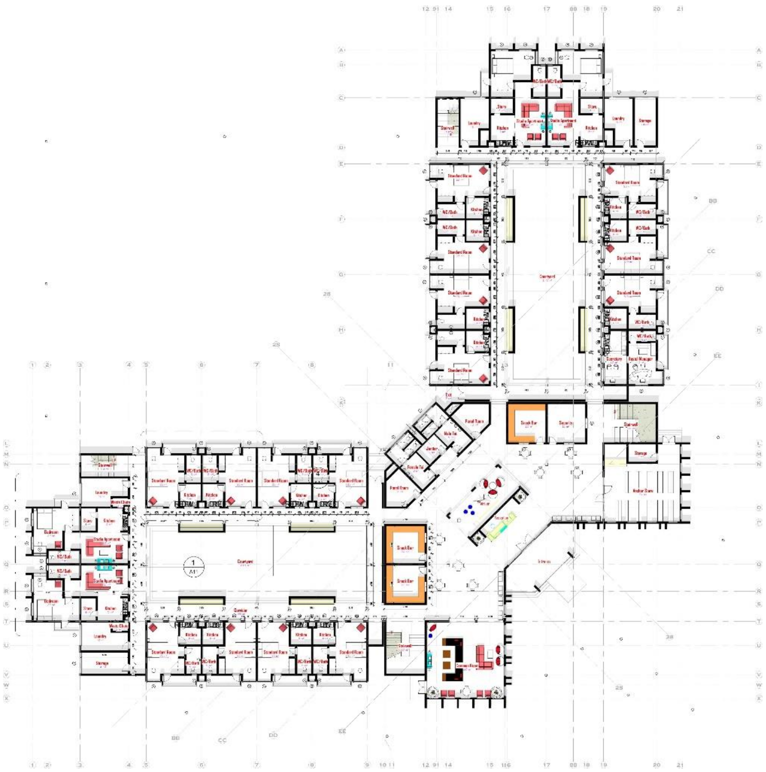


Figure 4.41: An architectural illustration of the ground floor plan.

Source: Author’s field work (2023)

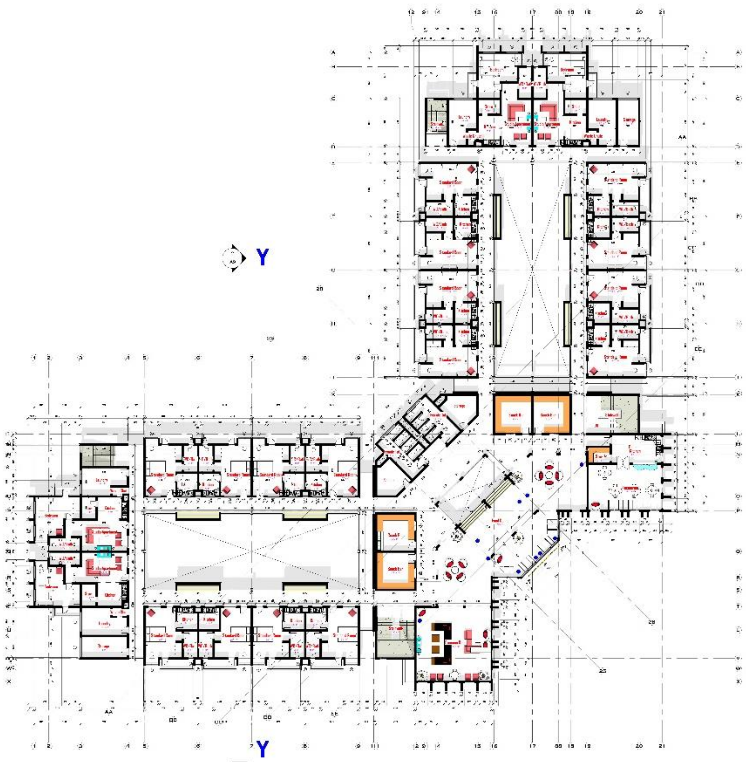


Figure 4.42: An architectural illustration of the first floor plan.

Source: Author's field work (2023)

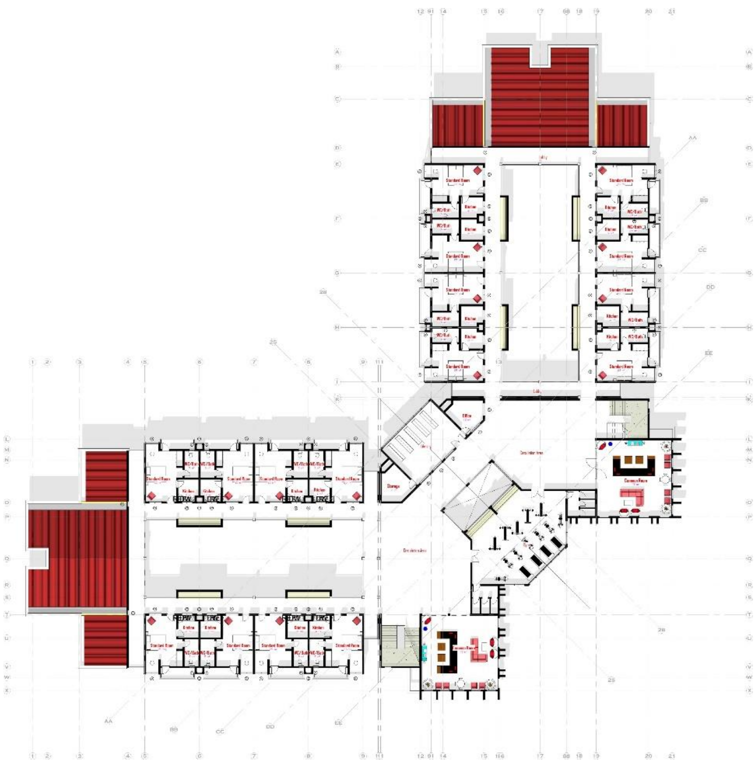


Figure 4.43: An architectural illustration of second floor plan.

Source: Author's field work (2023)

Image showing the plan of the two per room space typology 3D plan of the 2 per room type

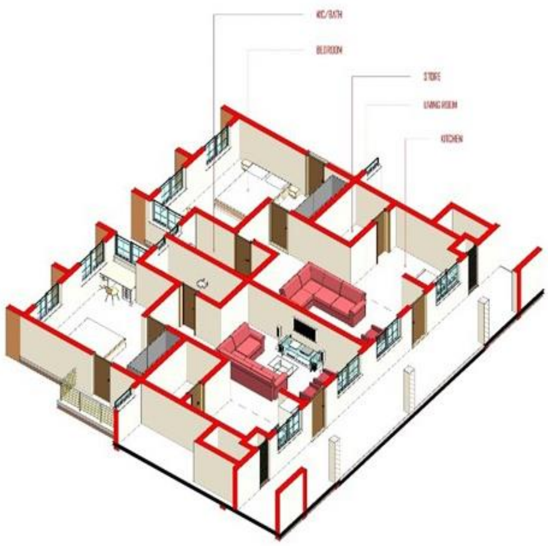


Image showing the plan of the studio apartment

3D plan of studio apartment

Figure 4.44: The different space typologies.

Source: Author’s field work (2023)

Figure 4.45: An architectural renderings of the external environment.
Source: Author's field work (2023)

4.4.7 Recreational facility

4.4.7.1 Architectural design

The general idea behind this design is for the hostel occupants to have a social community. This community will have spaces that can meet other needs such as printing services, groceries supply, beauty and haircut, eatery, social gathering, boutique, fitness gym as well as indoor games. All in a small scale. This give the students options to the supply of their non-educational needs and will not have to commute long distances to get them as it is the current situation.

Table 4.65: Schedule of Accommodation for Recreational Facility

S/N	Function	Dimension (m)	Area (m^2)	Units	Total (m^2)
1	Entrance	Not regular	12.6	1	12.6
2	Reception	Not regular	133.9	1	133.9
3	Gymnasium	Circular	129.6	1	129.6
4	Beauty salon	4.6 x 4.5	21.1	2	42.2
5	Barber shop	4.6 x 4.5	21.1	2	42.2
6	Printing shop	4.6 x 4.5	21.1	1	21.1
7	Laundry/dry cleaning	5.4 x 4.5	24.7	1	21.1
8	Boutique	Not regular	55.5	1	55.5
9	Cyber cafe	6.0 x 12.0	72.0	1	72.0
10	Office 1	Not regular	31.6	1	31.6
11	Office 2	Not regular	24.4	1	24.4
12	Server room	4.6 x 4.5	21.1	2	42.2
13	Groceries	4.5 x 9.5	43.3	1	43.3
14	Green roof	Not regular	133.9	1	133.9
15	Restaurant	Not regular	71.7	1	71.7
16	Courtyard	Not regular	62.4	1	62.4
17	Kitchen	Not regular	57.9	1	57.9
18	Seminar room	Not regular	80.7	1	80.7

Source: Author’s field work (2023)

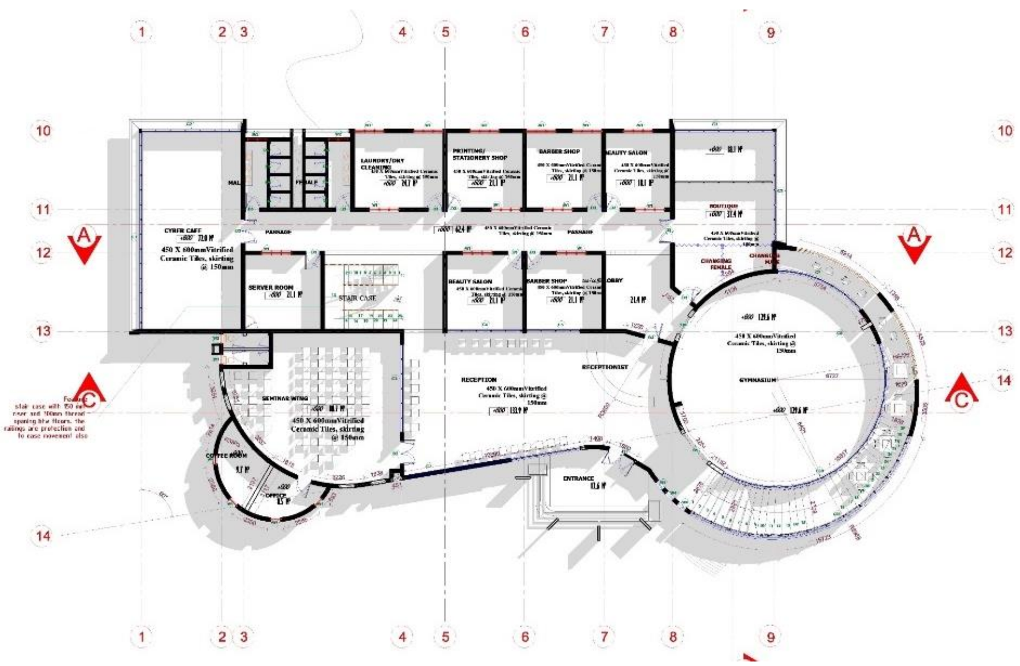


Figure 4.46: An architectural illustration of the ground floor plan.

Source: Author’s field work (2023)

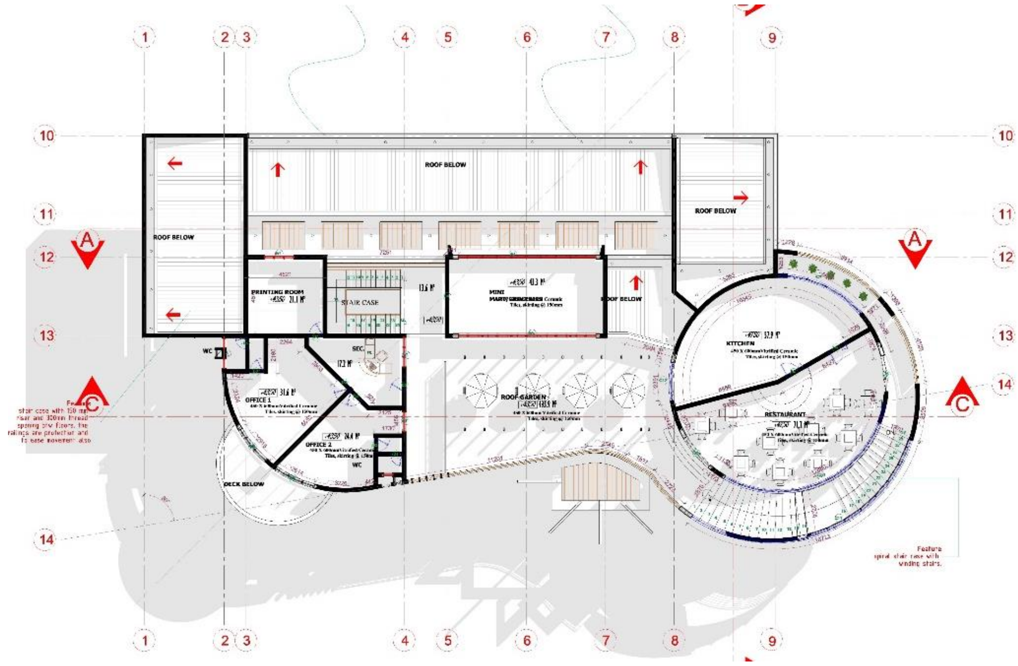


Figure 4.47: An architectural illustration showing the first floor plan.

Source: Author’s field work (2023)

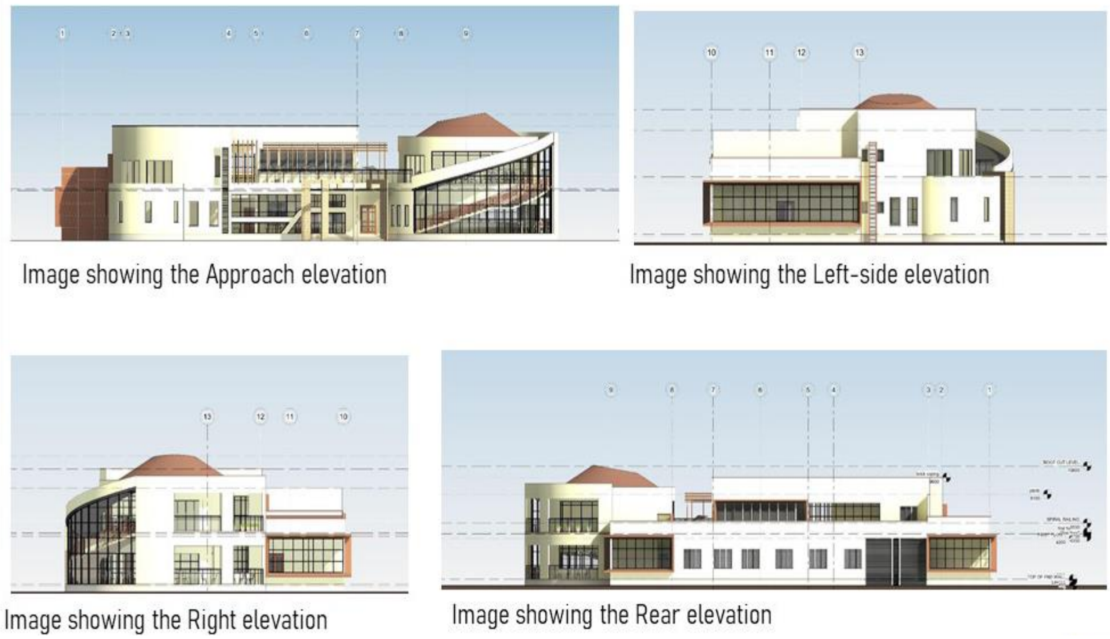


Figure 4.48: An architectural illustration of the elevations.

Source: Author’s field work (2023)

Figure 4.49: An architectural rendering of the external environment.
Source: Author's field work (2023)

4.4.8 The interior environment

4.4.8.1 The kitchen

The kitchen space designed for the space typology A (room of four) is a general kitchen having 16 (sixteen) users. Each user has his or her cabinet for both wall and base cabinets. A total of six cooker tops to be used amongst them having three kitchen hoods to extract gas and heat emissions from the surface of the work top. Also attached is an extra wall mounted air extractor which extract used or hot air that has diffused into the general kitchen space. The location of this kitchen is such that it shares a party wall with the laundry room and both are equidistant from the two room pairs beside them. The kitchen is cross ventilated on the external walls, one facing the exterior environment and the other facing the courtyard.

Figure 4.50: An architectural rendering of the kitchen interior.

Source: Author’s field work (2023)

Figure 4.51: The use of extractor fans in the kitchen interior.

Source: Author’s field work (2023)

4.4.8.2 The room of four persons

This space was designed to accommodate a maximum of four occupants. It adopted the double bunk system and as such booth bunks were designed not to be on the direct path of the two windows so as to maximize the advantage of the cross ventilation. There is a sanitary area which opens directly into the wardrobe area were each occupant has a locker. The use of indoor plants for purification in the form of plants such as Aloe vera, was placed closed to window. Also air extraction was achieved with the use of wall mounted air extractor fan.

Figure 4.52: The use of extractor fans and indoor plants in the bedrooms.
Source: Author’s field work (2023)

Figure 4.53: Architectural rendering of the room interior.
Source: Author’s field work (2023)

4.5 Summary of Findings

In Male Hostel, a significant issue of overcrowding is evident, with 83.1% of respondents occupying rooms designed for five persons but housing between 5 and 12 occupants, and most respondents (96.8%) have stayed in the hostel for a considerable duration, emphasizing the potential impact of indoor air quality on occupants over time.

The survey was conducted over 12 hours from 6:00 PM to 6:00 AM, focusing on a period when most occupants were present and engaged in daily activities, including cooking, which often extended late into the night due to the male hostel's lack of cooking time restrictions. Room A, where cooking took place in the corridor, maintained normal CO_2 levels, while Rooms B and C, where cooking occurred inside the rooms, exhibited significantly higher and unhealthy CO_2 concentrations due to these cooking activities.

The data indicates that indoor air particulate concentrations are likely to increase due to occupants' behaviors, with a significant percentage using kerosene for cooking and a substantial number cooking inside their rooms, potentially leading to elevated CO_2 levels. To precisely measure these concentration levels, an instrument survey was conducted in three rooms (A, B, and C) during the dry season, revealing that Room B had the poorest environmental conditions, with high temperatures and abnormal humidity levels. Room A exhibited excessively dry and hot conditions, while Room C had consistently high temperatures, emphasizing the need for effective ventilation and cooling systems.

A significant majority, 71%, of respondents had spent a minimum of 6 months in the hostel, allowing sufficient time for the indoor air quality to impact them. The exposure hours to indoor air contaminants were recorded for various surveyed rooms, with Room B and Room C showing prolonged exposure to high levels of $PM_{2.5}$, PM_{10}, and CO_2. Given similar behaviors and consistent outdoor air concentrations across the hostel, it's likely that other rooms experienced similar periods of exposure to indoor air contaminants, as indicated by symptoms and signs.

Some observed symptoms may not be directly linked to the mentioned air contaminants, suggesting the presence of other unaddressed contaminants. The prevalence of respiratory-related illnesses such as asthma and influenza, along with the potential for other respiratory problems like cardiovascular diseases and Chronic Obstructive Pulmonary Disease (COPD), highlights the health risks associated with indoor air quality, particularly from cooking stoves emitting CO_2.

The study indicates that a significant portion (56.7%) of respondents had spent six months or more in the hostel, exposing them to potentially harmful indoor air conditions. Rooms A, B, C, and D had varying degrees of exposure to high CO_2 and $PM_{2.5}$ levels, with respiratory symptoms being reported in the dry season. These findings suggest a potential risk of respiratory illnesses among occupants that should be further investigated and addressed.

The study highlights that various factors within the hostel facility impact indoor air quality, including the absence of air conditioning or air extractors, reliance on windows and fans for ventilation, and the orientation of the building affecting air circulation in some rooms. The outdoor environment, such as landscaping, could have played a role in improving air quality, but this aspect was found to be lacking. Overall, the state of the hostel's facilities directly influences the indoor air conditions experienced by occupants.

The correlation analysis reveals some interesting relationships between reported diseases and indoor environmental quality variables in the case hostel. Notably, a negative relationship is found between asthma and the presence of mold, suggesting that mold may not be a significant factor in asthma cases among occupants. However, a positive relationship is observed between influenza and mold, indicating a potential association between mold presence and influenza cases. Additionally, the strongest correlations are seen between influenza and bad odor, as well as between asthma and bad odor, suggesting the presence of biological contaminants in the hostel that warrant further investigation.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Indoor air quality is an important aspect of human existence. The air we breathe has a great effect on our human systems and as such attention be given to it especially when it relates to enclosed spaces where good hours are spent daily. The impact of the air quality was seen even as a number of respiratory symptoms and diseases were reported, although some might be inherent and untested for. Occupants' behaviour had a major influence on indoor air particulate concentrations through the basic chores as well as the opening of fenestrations. Indoor air quality remains a vital factor in ensuring human sustainability even in this post pandemic era. At the commencement of this project, four objectives were set to be achieved and here is the summary of how it was achieved

The first objective was geared towards determining the factors that affects indoor air quality and through literature it was established that indoor air quality is influenced by two categories of factors namely the internal factors which are; space configuration, occupants behaviour, ventilation, number of occupants, building materials used in the space. Also the external factors which include the building orientation and air flow, the nature of the outdoor air (outdoor pollution) and landscaping.

The second objective was geared towards an assessment of the hostel facilities with regards to IAQ and this was achieved using the BASE where it was discovered that four out of the six blocks are in a state that broods a poor IAQ. It was further established that aside the poor state of these facilities, the overcrowded space and occupants behaviours are pivotal in affecting the IAQ through poor environmental hygiene as well as activities that sources and or increases indoor air pollutants in the spaces.

The third objective focused on the health implication the IAQ of the hostel has on the students and this was achieved through the BASE which showed that the occupants major illness is malaria, asthma and influenza. However, the symptoms documented and the high exposure levels to CO_2 and $PM_{2.5}$ and PM_{10} pointed to the fact that some latent illness not tested for could be lingering in the bodies of the occupants and it was recommended that such tests be conducted.

Finally, a design proposal was made which was added as a design report which implemented some good strategies that improves IAQ.

5.2 Recommendations

The strength of every research is the positive solutions that the researcher(s) can proffer even after establishing various issues regarding the study area and its respondents. The recommendations are geared towards two parties relating to the occupants of the space as well as the hostel management.

There should be no indoor cooking activities or even cooking along the corridors. All cooking activities should be done in the kitchens even if it is a little bit far. Illnesses do not appear instantly on first exposure but it is gradual and deliberate. Laundry activities can be done in the laundry rooms and none should be done in the rooms, open air in the courtyard or around the hostel premises. The hygiene of the hostel spaces and surroundings should be maintained as it prevents the brooding of biological contaminants.

Considering the state of ventilation in the spaces, curtains should be placed and maintained on each window and door so as to reduce outdoor particle migration even when there is a need to open windows. Try as much as possible to reduce overcrowding of spaces through squatting as it creates more contaminants even from added human activities and life. Occupants are encouraged to harbour indoor plants. This helps in purifying the air through oxygen fixation. These however should be maintained.

The major way to combat overcrowding is by building more hostel spaces. The school management is advised to build more hostel blocks and maintain a strict non squatting policy through management and design. The hostel management should be more meticulous when it relates to hostel hygiene and sanitation. Staff should be employed and equipped with the necessary safety equipment for good thorough sanitation especially in the sanitary areas. The occupants can be involved through tangible incentives for the cleanest rooms. Also this management system should penalize indoor cooking activities as well as indoor laundry activities. Cooking should be done in the kitchens. If the hostel management can handle food supply and students patronize at a low or non-interest rate, it will eliminate totally cooking activities by occupants.

Air extractors and or air conditioners should be installed in each roof to extract and regulate used air in the spaces. This controls CO2 emissions. Indoor air sensors can be placed to gather information about the facilities. Landscaping of the courtyard and hostel environs should be implemented. This will add new trees that purifies the air. Also cloth drying areas can then be implemented.

For the new designs recommended, the hostel should consider grouped kitchen or if possible individual kitchens for each rooms or a group of rooms. However, each room should have private sanitary areas and indoor hygiene and sanitation be maintained. The school should go as far as create awareness and offer tests for students who have shown or complained about respiratory related symptoms. Also the school health facility can offer more tests for respiratory related illness that they are not currently offering and have affiliations with health institutions within the local environment that can offer treatment to any related illness they cannot handle.

5.3 Contribution to Knowledge

The research had objectives and from the set objectives, a hypothesis was postulated. It was established that occupants behaviour is the primary source of indoor air particulate concentrations. The survey showed high concentrations of PM and CO_2 in all the monitor rooms that conduct cooking activities indoor. Averagely, 82.83% of students use either gas or kerosene to cook with 35.12% cooking indoors. During the cooking hours which is majorly during night hours, there was a hike in the particulate concentrations especially CO_2, where values as high as 1326 ppm of CO_2 were recorded. However, this trend did not exist in the monitor rooms that made use of the designated kitchens to cook. Low values of CO_2 were recorded in such rooms, values as low as 648 ppm. Indoor cooking and laundry were not the only established behavioural patterns. Rooms that were overcrowded showed tangible differences in CO_2 and PM concentrations particularly $PM_{2.5}$ and PM_{10}, with values as high as 116.78 ug/m^3 and 172.99 ug/m^3 respectively against less crowded spaces having values as low as 23.4 ug/m^3 and 27.8 ug/m^3 respectively.

One significant finding that was established is that gender influences the indoor particulate concentrations as the female hostels had higher values of CO_2 and PMs compared to the male hostels. The monitor rooms had values of 1326 ppm, 175 ug/m^3 and 225 ug/m^3 of CO_2, $PM_{2.5}$, and PM_{10} respectively as against 1136 ppm, 116.78 ug/m^3 and 172.99 ug/m^3 of CO_2, $PM_{2.5}$, and PM_{10} respectively for the males. The duration of exposure to high amounts of CO_2 was more in the female hostels, with some monitor rooms having as long as 11 hours of bad exposure compared to 3 hours of bad exposure in the male hostel.

5.4 Further Research

It was established that gender influences the indoor CO_2 concentrations as the female hostels had high values of CO_2 ppm and even PMs. Further research can be done to ascertain the reasons why this trend exists. It was also established in all the hostels the presence of latent diseases which have not been tested for but have shown symptoms from the survey undertaken. A medical survey can be taken to test for the prevalent respiratory diseases in the hostel spaces as projected from the reported symptoms.

REFERENCES

Abdul-Wahab, S.A.; En, S.C.F.; Elkamel, A.; Ahmadi, L.; Yetilmezsoy, K. (2015). A review of standards and guidelines set by international bodies for the parameters of indoor air quality. *Atmospheric Pollution Research*, 6, 751–767

Abiodun, O. E. (2014). Thermal comfort and occupant behaviour in a naturally ventilated hostel in warm humid climate of Ile-Ife Nigeria; field study report during hot season. *Global Journal of Human-Social Science*.

Abraham, S.; Li, X. (2016). Design of a low-cost wireless indoor air quality sensor network system. *International Journal of Wireless Information Networks*, 23, 57–65.

Adama, U. J, Ocheja, D, Ayoola, A. B, Ayuba, P. & Ogunbode, E. B. (2019). Influence of availability and serviceability of student accommodation facilities on student performance in Federal University of Technology Minna, *Environmental Technology & Science Journal*, 10 (1), 28 – 36.

Adebiyi, J. O., Tanko, B. L., & Oyetunji, A. K. (2017). Assessment of first-year students' decisions on housing preference in the University of Benin, Nigeria. *Built Environment Journal*, 14(1), 17-26.

Adedayo, A., & Sulyman, A.O. (2013). Pattern of infrastructure-induced socio-economic development in rural settlements of Niger State, Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 6, 802 – 816.

Adewunmi, F. (2012). *Student accommodation in Nigeria – an opportunity for investors, how we made it in Africa*, vol. Business Articles.

Adilieme, C. M. (2019). Assessment of student housing satisfaction among students of University of Lagos, *Global Journal of Human Social Science - (H),*19 (9), 21-27

Aiman, A., Dariusz, A., Page , A., & Moghtaderi, B. (2015). Assessment of the thermal performance of complete buildings using adaptive thermal comfort. *Journal of Social and Behavioural Sciences*, 655-661.

Akaranga, S. I. & Makau, B. K. (2016). Ethical considerations and their applications to research: a case of the University of Nairobi. *Journal of Educational Policy and Entrepreneurial Research*, 3(12), 1-9.

Alefu C., Samuel T., and Dalga Y. (2017). Impacts of building designs on indoor air quality in developing countries: review. *International Journal of Scientific and Engineering Research*, 8 (4), 475 – 480.

Alfa, M. T. & Öztürk, A. (2019). Perceived indoor environmental quality of hospital wards and patients' outcomes: a study of a general hospital, Minna, Nigeria. *Applied Ecology and Environmental Research* 17(4), 8235-8259.

Allison, J.J, Calhoun, J.W, Wall, T.C, Spettell, C.M, Fargason, C.A, Weissman, N.W. (2000). Optimal reporting of health care process measures: inferential statistics as help or hindrance. *Managed Care Quarterly*, 8(4).

Amoatey, P., Omidvarborna, H., Baawain, M.S., & Al-Mamun, A. (2018). Indoor air pollution and exposure assessment of the gulf cooperation council countries: a critical review. *Environment International*, 121, 491–506.

Amoatey, P., Omidvarborna, H., Baawain, M.S., Al-Mamun, A., Bari, A., & Kindzierski, W.B. (2020). Association between human health and indoor air pollution in the Gulf Cooperation Council (GCC) countries: A Review. *Review on Environmental Health*, 35, 157–171.

Andrew, D.T. (2014). *Automatic natural ventilation*. Princeton, New Jersey: Princeton University Press, 1-5.

ANSI/ASHRAE Standard 62.1- (2013). *Ventilation for acceptable indoor air quality*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.: Atlanta, GA, USA.

Arceňo, R. A. (2018). Motivations and expectations of graduate students of the college of advanced education (caed). *PEOPLE: International Journal of Social Sciences*, 4(1), 239-256.

ASHRAE (2004). *Thermal environmental conditions for human occupancy*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

Asiedu, R. A. (2012). *The performance of high rise building in Ghana perspective of the occupants*. Accra: Accra University.

Atkinson, R. W., Butland, B. K., Dimitroulopoulou, C., Heal, M. R., Stedman, J. R., Carslaw, N., Jarvis, D., Heaviside, C., Vardoulakis, S., Walton, H., & Anderson, H. R. (2016). Long-term exposure to ambient ozone and mortality: a quantitative systematic review and meta-analysis of evidence from cohort studies. *British Medical Journal*, *6*(2), 160-165

Avgelis, A., Papadopoulos, A.M. (2004). Indoor air quality guidelines and standards–a state of the art review. *International Journal of Ventilation*, 3, 267–278.

Awada, M., Becerik-Gerber, B., Hoque, S., O'Neill, Z., Pedrielli, G., Wen, J., & Wu, T. (2021) Ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic, *Building and Environment* 188, 107480.

Blanc, P. (2018). Vertical gardens: the new challenges. *Green Cities in the World*, 330-355.

Botti M & Endacott R. (2008). Clinical research quantitative data collection and analysis. *International Emergency Nurs*ing, 16(2),

Branco, P.T.; Alvim-Ferraz, M.C.M.; Martins, F.G.; Sousa, S.I. (2019). Quantifying indoor air quality determinants in urban and rural nursery and primary schools. *Environmental Research*, 176.

Brittain, O.S.; Wood, H.; Kumar, P. (2020). Prioritizing indoor air quality in building design can mitigate future airborne viral outbreaks. *Cities Health*, 1–4.

Busch-Geertsema, V., & Sahlin, I. (2007). The role of hostels and temporary accommodation. *European Journal of Homelessness*, 9, 67–93.

Chai, Y. U., Ning, Z., Kyungmo, K., HooSeung, N., Hanel, C., & Taeyeon K. (2022). Occupant behavior and indoor particulate concentrations in daycare centers. *Science of The Total Environment*, 824.

Chan, W.R., Nazaroff, W.W., Price, P.N., Sohn, M.D., & Gadgil, A.J. (2005). Analyzing a database of air leakage in the United States. *Atmospheric Environment*, (39), 3445–55.

Chang, H., Capuozzo, B., Okumus, B., & Cho, M. (2021) Why cleaning the invisible in restaurants is important during COVID-19: a case study of indoor air quality of an open-kitchen restaurant, *International Journal of Hospital Management* 94, 54.

Chen, C., Zhao, Y., and Zhao, B. (2018). Emission Rates of Multiple Air Pollutants Generated from Chinese Residential Cooking. *Environmental Science Technology*, 52, 1081–1087.

Chen, Q., & Glicksman, L. (2001). *Application of Computational Fluid Dynamics for Indoor Air Quality Studies*, Chapter 59, in J. D. Spengler, J. M. Samet, J. F. McCarthy (Eds) *Indoor Air Quality Handbook*, New York, McGraw-Hill.

Ching D.K. (2008). *Building Construction Illustrated*, John Wiley and Sons, Inc., New Jersey. Fourth Edition, 9-50.

Colligan, M. J. (1981). *The Psychological Effects of Indoor Air Pollution*. Bulletin of the New York Academy of Medicine, 57, 1014 – 1026

COMEAP, 2018. The effects of long-term exposure to ambient air pollution on cardiovascular morbidity: mechanistic evidence. *"Committee on the Medical Effects of Air Pollutants*.

Creswell, J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, California: SAGE.

Cronbach, L. J. (1951). Coefficient alpha and the interval structure of tests. *Psychometrika*, 16, 297–334.

D'Souza J.C., Jia C.R., Mukherjee B. and Batterman S. (2009). Ethnicity, housing and personal factors as determinants of VOC exposures. *Atmosphere Environment* 43(18), 2884–2892.

Dabo, B. H., Joel, M. M., Ali G. R. and Isaac I. A. (2013). Criteria for the selection of students' accommodation model in nigeria tertiary institutions using analytic hierarchy process. *Academic Research International*, 4 (5).

Dales, R.; Liu, L.; Wheeler, A.J.; Gilbert, N.L. (2008). Quality of indoor residential air and health. *Cancer Medical Association Journal*, 179, 147–152.

Darçın, P., Balanlı, A., (2020). *"Examining the Effects of Space on Indoor Air Pollution Exposure"*, ICONARCH IV, International Congress of Architecture and Planning Space and Process in Architecture and Planning, Konya, 403-412.

Demokritou, P. (2001). *Modelling IAQ and Building Dynamics*, Chapter 57, In J. D. Spengler, J. M. Samet, J. F. McCarthy (Eds) *Indoor Air Quality Handbook*, New York, McGraw-Hill.

Dharitri B. Ramanlal, Rita N. Kumar and Nirmal Kumar, J.I (2019). Plants and their magnificent indoor air purifying attributes. *Everyman's Science*, 53, (5) 311 – 315.

Douglas, G. B and Thomas, A. W (2014). Cronbach's alpha reliability: interval estimation, hypothesis testing, and sample size planning, *Journal of Organisational Behaviour,* Copyright © 2014 John Wiley & Sons, Ltd.

Dubos, R. (1969). The human environment. *Science Journal Society,* 75-80

Dudovskiy, J. (2022). *The Ultimate Guide to Writing a Dissertation in Business Studies: a step by step assistance* (6th Edition ed.). Research-methodology.net. Retrieved from http://research-methodology.net/about-us/ebook/ accessed on July 7, 2021.

Edgar, B. & Meert, H. (2006). *Fifth Review of Statistics on Homelessness in Europe*. European Observatory on Homelessness, Brussels, 7-10.

Ehsanul, K., Kim, K. H., Jong, R.S., Bo, Y.K., & Jong, H.S. (2012). Indoor air quality assessment in child care and medical facilities in Korea. *Environment Monitoring Assessment*. 184, 6395–6409.

Ekejiuba, P. & Emetarom, U. (2014). Administration of secondary schools in time of insecurity in Nigeria: problems and prospects. *Benin: University of Benin*.

Emilio, D.M, (2018). Living conditions in Europe. *Eurostat*, p. 148.

Emmanuel, A. I. (2006). *Environmental Air Quality Exposure Assessment in a Rural Nigerian Village*. Western Kentucky University Bowling Green, KY 42101 AIHce, Podium 111.

Ezzati M., & Kammen D.M. (2001). Quantifying effects of exposure to indoor air pollution from biomass consumption on acute respiratory infections in developing countries. *Environmental Health Perspectives*, 109, (5).

Ezzati, M., Lopez A.D., Rodgers, A., & Murray, C.J.L. (2004). *Comparative Quantification of Health Risks. Global and Regional Burden of Disease Attributable to Selected Major Risk Factors, Volumes 1 & 2.* Geneva, Switzerland: World Health Organization.

Ferro, A. R., & Hildemann, L. M. (2007*). Inhalation Exposure, Uptake and Dose*, Chapter 4, In W. R. Ott, A. C. Steinemann, & L. A. Wallace (Eds), *Exposure Analysis*. Boca Raton, CRC Press Taylor & Francis Group.

Fiona, M (2019). *Reliability vs validity: what's the difference?* https://www.scribbr.com/methodology/reliability-vs-validity, accessed on July 7, 2021.

Fisk, W.J., Lei-Gomez, Q., & Mendell, M.J. (2007). Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. *Indoor Air*, 17, 284–296.

Fleming, J., & Zegwaard, K.E. (2018). Methodologies, methods and ethical considerations for conducting research in work-integrated learning. *International Journal of Work-Integrated Learning*, 19(3), 205-213.

Gichere, F., Adem, A & Adenya, R. (2019). Determining the mean differences in students' performance based on type of accommodation, *International Journal of Education and Research* 7 (1), 11 – 20.

Girman, J.R., Hadwen, G. E., Burton, L. E., Womble, S. E and J F McCarthy (1997). *Individual Volatile Organic Compound Prevalence and Concentrations in 56 Buildings of The Building Assessment Survey and Evaluation (Base) Study, U.S.* Environmental Protection Agency (U.S. EPA).

Givoni, B. (1994). *Passive Low Energy Cooling of Buildings*. John Wiley & Sons. 1(1),23.

Gocgeldi, E., Berdan, M.E., Ucar, M., Turker, T., Istanbulluoglu, H., Gulec M., & Hasde. M. (2011) analysis of children's rooms in terms of microbiological air quality. *Journal of Experimental Integrated Medicine*, 1, 51-58.

Haddadi, A.; Hosseini, A.; Johanssen, A. & Olsson, N. (2017). Pursuing value creation in construction by research -a study applied research methodologies. *Procedia Computer Science*, 121, 1080–1087.

Halcomb, E. J. (2018). Mixed methods research: The issues beyond combining methods. *Journal of Advanced Nursing*, *75*(3), 499–501.

Hameed A.A.A., Yasser I.H., & Khoder I.M (2004). Indoor air quality during renovation actions: A case study. *Journal Environ Monitoring* 6(9):740–744.

Hänninen, O., Kruize, H., Lebret, E., & Jantunen, M. (2004) Expolis simulation model: PM2.5 application and comparison with measurements in Helsinki. *Journal of Exposure Analysis and Environmental Epidemiology*, 13, 74–85.

Hasgül E. (2015). *Space as Configuration: Patterns of Space and Culture*. A Conference Paper Presentation in ARCHTHEO 2015_ 9th Theory and History of Architecture Conference 05 - 07 November 2015, Istanbul Kultur University, Istanbul, Turkey.

Hassanain, M.A. (2008). Performance evaluation of sustainable student housing facilities". *Journal of Facilities Management*, 6, 212–225.

Hiricko, A. (2009). Outdoor air pollution. *Safe and Healthy School Environments*.

Ho, D. C. W., Leung, H. F., Wong, S. K., Cheung, A. K. C., Lau, S. S. Y., Wong, Chau, K. W. (2004). Assessing the health and hygiene performance of apartment buildings. *Facilities*, 22(3/4), 58-69.

Holt, E., Audy, O., Booij, P., Melymuk, L., Prokes, R., & Klánová, J. (2017) Organochlorine pesticides in the indoor air of a theatre and museum in the Czech

Republic: inhalation exposure and cancer risk. *Science of Total Environment*, 609, 598–606.

Hoskins, J.A. (2007). Health effects due to indoor air pollution. *Indoor Built Environment*, 12, 427-433.

Huang, Y.; Yang, Z.; Gao, Z. (2019). Contributions of indoor and outdoor sources to ozone in residential buildings in Nanjing. *International Journal of Environmental Research and Public Health*, 16, 2587.

IAQMP (Indoor Air Quality Management Plan) (2012). Des Moines Public Schools District. Adopted from Minnesota Department of Health Model Indoor Air Quality Management Plan June 2010

İzgi, U. (1999). *Mimarlıkta Süreç. Kavramlar – İlişkiler (Process in Architecture. Concepts Relations)*. İstanbul: YEM.

Jaakkola, J.J.K.; Verkasalo, P.K.; Jaakkola, N. (2000) Plastic wall materials in the home and respiratory health in young children. *America Journal of Public Health*, 90, 797–799.

Jones, A.P. (1999). Indoor air quality and health. *Atmospheric Environment*, 33, 4535–4564.

Kamaruzzaman S.N. & Sabrani N.A. (2011). The effect of indoor air quality (IAQ) towards occupants' psychological performance in office buildings. *Journal Design and Built*, 4, 49 – 61.

Kelly, L. M. & Cordeiro, M. (2020). Three principles of pragmatism for research on organizational processes. *Methodological Innovations*, 13(2).

Kephalopoulos, S., Koistinen, K., & Kotzias, D. (2006). *Strategies to Determine and Control the Contributions of Indoor Air Pollution to Total Inhalation Exposure (STRATEX) European Collaborative Action, Urban Air Indoor Environment and Human Exposure* (Environment and Quality of Life Report No: 25 – EUR 22503 EN) Luxembourg, European Commission Directorate Joint Research Center.

Khozaei, F., Ayub, N., Hassan, A.S. & Khozaei Z. (2010). The factors predicting students' satisfaction with University hostels: Case Study, Universiti Sains Malaysia. *Asian Culture and History*, 2, (2), 49 – 50.

Kim, C., Choi, D., Lee, Y.G., & Kim, K. (2021). Diagnosis of indoor air contaminants in a daycare center using a long-term monitoring. *Building and Environment*, 204, 1 – 16.

Kleiven, T. (2003). *Natural Ventilation in Buildings: Archtectural Concepts, Consequences and Possibilities*. Norwegian University of Science and Technology, 9-20.

Koivisto, A.J.; Kling, K.I.; Hänninen, O.; Jayjock, M.; Löndahl, J.; Wierzbicka, A.; Fonseca, A.S.; Uhrbrand, K.; Boor, B.E.; Jiménez, A.S.; (2019). Source specific exposure and risk assessment for indoor aerosols. *Sci. Total Environment*, 668, 13–24.

Kolawale, O., and Boluwatife, A. (2016). Assessment of the factors influencing students' choice of residence in Nigerian tertiary institutions. *Journal of Education and Practice*, 4(1), 1-10.

Komarnicki, G.J.K. (2005). Lead and Cadmium in indoor air and the urban environment. *Environmental. Pollution*, 136, 47–61.

Kothari, C. R. (2004). *Research Methodology: Methods and Techniques*. New Delhi, India: New Age International Publishers, Second Edition. 29-35.

Kumar, P.; Imam, B. (2013). Footprints of air pollution and changing environment on the sustainability of built infrastructure. *Science of Total Environment*, 444, 85–101.

Kumar, P.; Morawska, L. (2019). Could fighting airborne transmission be the next line of defense against COVID-19 spread? City *Environment Interaction*, 4, 33.

Kumar, P.; Omidvarborna, H.; Pilla, F.; Lewin, N. (2020). A primary school driven initiative to influence commuting style for dropping off and picking-up of pupils. *Science of Total Environment*, 727, 60.

Lauren, F., Jonathon, T., Michael, D., Clive, S., Phil, S. and Sani D. (2020) Exposure to indoor air pollution across socio-economic groups in high-income countries: a scoping review of the literature and a modelling methodology, *Environment International*, 143, 48.

Lawani, A. (2021). Critical realism: What you should know and how to apply it. *Qualitative Research Journal*, 21(3), 320-333.

Lincoln, Y. S., Lynham, S. A., & Guba, E. G. (2011). *Paradigmatic Controversies, Contradictions, and Emerging Confluences*. In N. K. Denzin, The SAGE Handbook of Qualitative Research (4th ed., 97–128). Thousand Oaks, CA: Sage.

Loomis, D.; Grosse Y.; El Ghisassi F. (2013). The carcinogenicity of outdoor air pollution. *Lancet Oncology*. 14 (13), 1262–1263.

Lukkumanul H. S (2019). Environmental health and sanitation. *International Journal of Trend in Scientific Research and Development (ijtsrd)*, 3(3), 912-915.

Maina J.J, Aji J.Y (2017). Influence of accommodation on the academic performance of architecture students. *Built environment journal*, 47-59

Mannan, M.; Al-Ghamdi, S.G. (2021). Indoor air quality in buildings: a comprehensive review on the factors influencing air pollution in residential and commercial structure. *International Journal of Environmental Research and Public Health*, 18, 3276. https:// doi.org/10.3390/ijerph18063276.

Marć M., Śmiełowska M., Namieśnik J. & Zabiegała B. (2017). Indoor air quality of everyday use spaces dedicated to specific purposes—a review. *Environmental Science and Pollution Research*, 4.

Marjo. P., (2021) *Better Indoor Air Quality Decreases the Risk of Coronavirus*, Marjo Paija; www.genano.com. Accessed on July 5 2021.

Marmot, A.F., Eley, J., Stafford, M., Stansfield, S.A., Warwick, E., & Marmot, M.G. (2006) Building health: an epidemiological study of "sick building syndrome" in the Whitehall ii study. *Occupational Environmental Medicine*, 63, 283–289.

Mehta, S. (2002). *Characterizing Exposures to Indoor Air Pollution from Household Solid Fuel Use*; University of California: Berkeley, CA, USA.

Méndez-Hernández, D.D., Tarakeshwar, P., Gust, D., Moore, T.A., Moore, A.L., & Mujica, V. (2013). Simple and accurate correlation of experimental redox potentials and DFT-calculated HOMO/LUMO energies of polycyclic aromatic hydrocarbons. *Journal of Molecular Modeling*, 19, 2845–2848

Milner, J., Vardoulakis, S., Chalabi, Z., & Wilkinson, P. (2011). Modelling inhalation exposure to combustion-related air pollutants in residential buildings: application to health impact assessment. *Environment International* (37), 268–279.

Ministry of Lands and Housing Minna (2012). *Map of Niger State showing Minna*. A brochure published by the Niger State Geographical Information System Center. Niger State.

Monby, P. S. and Vestergaard, T., Birch & Krogboe A. S. (1998). Natural ventilation (controlling natural ventilation), *Article in the Danish HVAC journal.* 13(20) 24.

Morakinyo O.M., Rowland, A.G., Hammed T.B., & Adejumo M. (2015) Indoor air quality and perceived health effects experienced by occupants of an office complex in a typical tertiary institution in Nigeria. *Science Journal of Public Health*, 3, (4), 552-558.

Morakinyo, T. E., Adegun, O. B., & Balogun, A. A. (2016). The effect of vegetation on indoor and outdoor thermal comfort conditions: evidence from a microscale study of two similar urban buildings in Akure, Nigeria. *Indoor and Built Environment*, 25(4), 603– 617.

Moulton, P V, Yang, Wei, (2012). Air pollution, oxidative stress, and alzheimer's disease. *J. Environ. Publ. Health* 2012, 1–9.

Muhammad, M Z, Dodo M, and Adamu Y M (2014) "*Hostel Accommodation Procurement using Build-Operate Transfer (BOT) in Ahmadu Bello University, Zaria, Nigeria*" Proceedings' of the International Council for Research and Innovation in Building and Construction (CIB) Conference (CIB) W107

Mukaka, M.M., (2012) Statistics Corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Medical Journal*, 24(3), 69-71.

Najib, N. U., Yusuf, N. A., & Sani, N. M. (2012). The effects of students' socio-physical background onto satisfaction with student housing facilities. *Procedia – Social and Behavioral Sciences*, 62, 64–74.

Naoum, D. S. (2013) *Dissertation Research & Writing for Construction Students.* 3rd ed. London & New York: Routledge, 7.

National Health and Medical Research Council (NHMRC) (1996). *Goals for Maximum Permissible Levels of Pollutants in Indoor Air*. In Interim National Indoor Air Quality Goals; The National Health and Medical Research Council: Melbourne, Australia.

Nicol, F., Humphreys, M., & Roaf, S. (2012). *Adaptive Thermal Comfort: Principles and Practice*. Routledge, Abingdon, 10

Nimako, S. G., and Bondinuba, K. F. (2013). Relative importance of students' accommodation quality in higher education. *Current Research Journal of Social Sciences*., 5, 1-5.

Nnadozie, C.F., Njoku, D.I., Onu, U.L., & Anyanwu. O.M. (2017). Indoor air quality levels of some criteria pollutants in university hostels in Nigeria. *International Journal for Scientific Research and Development*, 5, (9), 21-23.

NUC, (2000). *Approved Policy for Private Sector Participation in the Provision and Management of Students Hostel in Nigeria Tertiary Institution*, Memo to all Vice Chancellors, 1-8.

Oguh C E Uzoefuna C C, Oniwon W O, Ugwu V C, Ahaiwe P T, Okeke B C, Ezikanyi G K (2019), risk assessment on bioaccumulation of potentially toxic elements on soil and edible vegetables *Corchorus olitorius* and *Amaranthus cruentus* grown with water treatment sludge in Chanchaga Minna, Niger state, Nigeria. *Journal of Research in Environmental Science and Toxicology*, 8(2), 92-103

Ong, S.E., Petrova, M., Spieler, A., (2013). Demand for University student housing: An empirical analysis, *Journal of Housing Research*, 22 (2), 141–164.

Owolabi, B. O. (2015). The effects of students housing on academic performance at the University of Ibadan in Nigerian. *International Journal of Scientific & Engineering Research*, 6 (3).

Oyetunji, A. K., & Abidoye, R. B. (2016). Assessment of the factors influencing students' choice of residence in Nigerian tertiary institutions. *Sains Humanika*, 8(2), 39-47.

Padula, A.M., Tager, I., Carmichael, S.L. and Hammond, S. K. (2013). The association of ambient air pollution and traffic exposures and congenital anomalies in the San Joaquin Valley of California. *American Journal of Epidemiology*.27 (4), 329–339.

Park, J.H., Spiegelman, D.L., Burge, H.A., Gold, D.R., Chew, G.L., & Milton, D.K. (2001) Longitudinal study of dust and airborne endotoxin in the home. *Environmental Health Perspective*, 108, 1023–1028.

Pearson, M.K. & Richards, C., (1994). Architecture and Order: Approaches to Social Space, from the article "*Ordering The World: Perceptions of Architecture, Space and Time*'', Routledge, London and New York, 1-33.

Physical Planning and Development Unit (PPDU) (2018). Federal University of Technology, Minna, Master Plan 2015 - 2025.

Physical Planning and Development Unit (PPDU) (2023). Architectural working drawings for the proposed block d – g, need assessment hostel project. Federal University of Technology, Minna, Niger State.

Pietrzyk, K. (2022). Wicked Problems in Architectural Research: The role of research by design. *ARENA Journal of Architectural Research*, 7(1), 3. pollution-1525416845-1, 2018.

Pope III, C.A., Burnett, T.R. and Thun, M.J. (2011). Lung cancer and cardiovascular disease mortality associated with ambient air pollution and cigarette smoke: shape of the exposure–response relationships. *Environmental Health Perspectives.* 119 (11), 1616–1621.

Prajakta, P. S. (2013) Indoor air quality monitoring for human health. *International Journal of Modern Engineering Research*, 3, 891–897.

Pritha, B (2020) (a). *An Introduction to Descriptive Statistics*, https://www.scribbr.com/statistics/descriptive-statistics, accessed on July 7, 2021.

Pritha, B (2020) (b). *An Introduction to Inferential Statisitics*, https://www.scribbr.com/statistics/descriptive-statistics, accessed on July 7, 2021.

Rashed, M.N. (2008). Total and extractable heavy metals in indoor, outdoor and street dust from Aswan City, Egypt. *Clean*, 36, 850–857.

Raw, G.J. (1992). *Sick Building Syndrome: A Review of the Evidence On Causes and Solutions*. HSE Contract Research Report No. 42/1992, Health and Safety Executive, UK, 110.

Repace, J. L. (2007). *Exposure to Secondhand Smoke*, Chapter 9, In W. R. Ott, A. C. Steinemann, L. A. Wallace (Eds) *Exposure Analysis*, Boca Raton, CRC Press Taylor & Francis Group, 112.

Salonen, H.; Salthammer, T.; Morawska, L. (2018). Human exposure to ozone in school and office indoor environments. *Environment International*, 119, 503–514.

Salthammer, T. & Bahadir, M. (2009). Occurence, dynamics and reactions of organic pollutants in the indoor environment, *Clean – Soil, Air, Water*, 37(6), 417-435.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2015). *Research Methods for Business Students* (7th ed.). England: Pearson Education Limited, 7-9

Saunders, M.; Lewis, P. & Thornhill, A. (2016). *Research Methods for Business Students*. England: Pearson Education Limited, 8-15.

Sawyerr, P. T., and Yusof, N (2013). Student satisfaction with hostel facilities in Nigerian polytechnics. *Journal of Facilities Management*, 29(3/4), 149-168.

Schlink U., Roder S., Kohajda T., Wissenbach D.K., Franck U., and Lehmann I. (2016). A framework to interpret passively sampled indoor-air voc concentrations in health studies. *Building Environment* 105, 198–209.

Schober P, Boer C, Schwarte L. (2018). Correlation coefficients: appropriate use and interpretation. *Anesthesia &Analgesia*. 126.1.

Schrager, R. H. (1986). The impact of living group social climate on student academic performance. *Research in Higher Education*, 25(3), 265–276.

Seow, W.J., Downward, G.S., Wei, H., Rothman, N., Reiss, B., Xu, J., Bassig, B.A., Li, J., He, J., & Hosgood, H.D. (2016) Indoor concentrations of nitrogen dioxide and sulfur dioxide from burning solid fuel for cooking and heating in yunnan province, China. *Indoor Air*, 26, 776–783

Shady, A., Pierre, A., Mohamed, A. and Guirec, R. (2020). towards a European rating system for sustainable student housing: key performance indicators (KPIS) and a multi-criteria assessment approach, *Environmental and Sustainability Indicators*, 7, 1-7.

Shimer, P.L.J.D.; Thomas, J. Phillips, (2005). *Indoor Air Pollution in California; Report to the California Legislature.* Available online: https://ww2.arb.ca.gov/sites/default/files/classic//research/apr/reports/l3041.pdf (accessed on 27 July 2020).

Shorten, A., & Smith, J. (2017). Mixed *Methods Research: Expanding the Evidence Base*. *Evidence Based Nursing*, *20*(3), pp.74–75.

Singh, H. (2018). *Top 5 indoor Plants that help in combating Air Pollution*. Retrieved from https://www.jagranjosh.com/generalknowledge/top-indoor-plants-that-help-incombating-air, accessed on 27 July 2020.

Spengler, J. D., Chen, Q., & Dilwali, K. M. (2001). *Indoor Air Quality Factors in Designing a Healthy Building*, Chapter 5, In J. D. Spengler, J. M. Samet, J. F. McCarthy (Eds) *Indoor Air Quality Handbook*, New York, McGraw-Hill.

Spengler, J.D.; McCarthy, J.F.; Samet, J.M. (2001) *Indoor Air Quality Handbook*; McGRAW-HILL: New York, NY, USA; ISBN 9780074455494.

Swanchhindia (2018). *5 Plants to Make Your Home Clean and Green and Combat Indoor Air Pollution | Do It Yourself*. Retrieved from https://swachhindia. ndtv.com/plants-to-combatindoor-air-pollution-23011/,2018.

Tang, H., Ding, Y., & Singer, B. C. (2020). Post-occupancy evaluation of indoor environmental quality in ten nonresidential buildings in Chongqing, China. *Journal of Building Engineering*, 32, 101.

Tang, X., Misztal, P.K., Nazaroff, W.W., & Goldstein, A.H. (2015). Siloxanes are the most abundant volatile organic compound emitted from engineering students in a classroom. *Environmental Science & Technology Letters*, 2, 303–307.

Tjelflaat, P. O. and Rødahl, E. (1997). *Design of Fan-Assisted Natural ventilation. General Guidelines and Suggested Design for Energy-Efficient Climatization-System for School Building in Grong, Norway*. SINTEF Report STF22 A97557.

Tran, V.V., Park, D. & Lee, Y. (2020). Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality. *International Journal of Environmental Research and Public Health*, 17, 2927.

Turk, B.H., Prill, R.G., Grimsrud, D.T., Moed, B.A., & Sextro, R.G. (1990). Characterizing the occurrence and variability of radon in pacific northwest homes. *J. Air Waste Management Association*, 40, 498 - 506.

U.S. Department of Health and Human Services. (2006) *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General*; Department of Health and Human Services; Centers for Disease Control and Prevention; Coordinating Center for Health Promotion; National Center for Chronic Disease Prevention and Health Promotion; Office on Smoking and Health: Atlanta, GA, USA.

U.S. Environmental Protection Agency. (USEPA) (1994). *A Standardized EPA Protocol for Characterizing Indoor Air in Large Office Buildings*, Washington, DC, Office of Research and Development and the Office of Air and Radiation, U.S. Environmental.

United Nations Environment Programme UNEP (2019), *Clean Air as a Human Right*. https://www.unep.org/news-and-stories/story/clean-air-human-right, accessed on 27 July 2020

USEPA. (2016) *Formaldehyde's Impact on Indoor Air Quality*. Available online: https://www.epa.gov/indoor-air-quality-iaq/formaldehydes-impact-indoor-air-quality (accessed on 25 May 2020).

USEPA. (2020) *Fundamentals of Indoor Air Quality in Buildings*. Available online: https://www.epa.gov/indoorair-quality-iaq/fundamentals-indoor-air-quality-buildings (accessed on 28 January 2020)

Valiyappurakkal, V. K. (2021). Gap theory based performance analysis: A case study of an Indian hostel building with passive architectural character. *Journal of Building Engineering*, 41, 102395.

WHO (2000). *Air Quality Guidelines for Europe*, 2nd ed.; The World Health Organization: Geneva, Switzerland. 10-15.

WHO. (2010) *WHO Guidelines for Indoor Air Quality: Selected Pollutants*. The WHO European Centre for Environment and Health, Bonn Office; 1 – 484

Wong, L. T., Mui, K. W., & Hui, P. S. (2008). A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices. *Building and Environment*, 43(1), 1–6.

World Health Organization. (2018). *Household Air Pollution and Health*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-andhealth, accessed on 27 July 2020.

Xpelair (2021). *Xpelair Kitchen Manual*, retrieved from www.Xpelair.co.uk, accessed on July 27, 2021.

Xu, X., Peng, L., Yu, B., Chen, Z., Shi, F., and He, H. (2022). Study on the Influence of Fresh Air System of Range Hood on Kitchen Air Quality. *Atmosphere*, 13, 920.

Yazeed, I.A., & Halil, Z.A. (2018). Evaluation of thermal comfort in university dormitories; a case study of suleiman hall, Ahmadu Bello University Zaria, Nigeria. *International Journal of Scientific and Engineering Research* 9(12), 795-802

Zhang, J., & Smith, K.R. (2007). Household air pollution from coal and biomass fuels in china: measurements, health impacts, and interventions. *Environmental Health Perspective*, 115, 848–855.

Zheng, X.Y.; Ding H.; Chen Q. (2015). Association between air pollutants and asthma emergency room visits and hospital admissions in time series studies: A systematic review and meta-analysis. *PLoS ONE*, 10 (9).

Zuhaib, S., Manton, R., Griffin, C., Hajdukiewicz, M., Keane, M. M., & Goggins, J. (2018). An indoor environmental quality (IEQ) assessment of a partially-retrofitted University building. *Building and Environment*, 139, Pp. 69–85.

APPENDICES

Appendix A: Letter of request for the building drawings of the existing hostels

Akoh Shadrach Akoh,
Architecture,
P.M.B 65,
F. U. T. Minna,
Niger State,
Nigeria.
11th January, 2023.

The Director,
Physical Planning and Development Unit
Federal University of Technology,
PMB 65, Minna,

Through
The H. O. D.,
Architecture Department

Through
The P.G Coordinator,
Architecture Department,

Dear Sir,

REQUEST FOR BUILDING DRAWINGS

I, **Akoh Shadrach Akoh**, with matriculation number **MTech/SET/2019/9632** from architecture department wish to make a request for the building drawings particularly the floor plans of the existing hostel accommodation of the Federal University of Technology, Minna. This request is been made as a result of an ongoing research on the assessment of indoor air quality in the students' hostel. This research is a requirement for the successful completion of my masters programme ongoing in this prestigious institution. I will appreciate it if my request is granted.
Attached is a copy of my student identification card as a proof of identity.

Yours Faithfully,

Akoh Shadrach Akoh.

08185309809, 09018636609

Appendix B. Sample of the Questionnaire distributed to the occupants of the space

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA
DEPARTMENT OF ARCHITECTURE

Assessment of Indoor Air Quality in Students Accommodation in Federal University of Technology, Minna, Niger State

We are currently researching the above subject in order to determine and share deeper concerns on the above topical and critical issue. The purpose of the Survey is to assess the impact of the indoor air quality on the health status of the occupants of this building. Your response to the questionnaire for this study is very important without which, the study will not be able to add specific value to improving the situation.

This research is for academic purposes alone and all data obtain would be kept confidential and anonymous. You are not mandated to answer the questions if you do not want to, however, I appeal to you to provide the right and appropriate responses to the questions asked.

Thank you.

OCCUPANT SURVEY AND BUILDING AUDIT

Questionnaire Number……………………………………. Date………………………..

Data logger label No……………………..…….Data logger location/room No:………...

Survey duration (Start time) ……………………..….(Equipment stop)……………..…

Equipment pick up time…………………………………………………………….

Hostel block name………………………………………………………………….

PART I: OCCUPANT'S SURVEY

Section A: Occupant Data

1. Your gender
    1. Male
    2. Female
2. Educational year (please indicate your present level in the University)
    1. 100 level
    2. 200 level
    3. 300 level
    4. 400 level
    5. 500 level
    6. Postgraduate

3. How many of you share this room?
   1 = 1-4 pers
   2 = 5-8 pers
   3 = 9-12 pers
   4 = 13-16 pers
   5 = 16 pers & above
4. How long have you lived in this room?
   1. Less than 1 month
   2. 1 - 3 months
   3. 4 - 6 months
   4. 7 - 9 months
   5. 10 – 12 months
   6. Over 1 year

Section B: Occupant's Health and Indoor Environment

5. Please indicate (√) in the relevant box from the following list below you or any anyone living with you in this room in the last 1 year have experienced either in the dry or raining season?

Reported diseases in the room		1 Yes (Dry season)	2 Yes (Wet season)	3 None	4 Don't know
1	Tuberculosis (TB)				
2	Pneumonia				
3	Asthma				
4	Meningitis				
5	Measles				
6	Chickenpox				
7	Influenza				
8	Malaria				

6. Please indicate (√) the season you or anyone in the room experience any of the following in the list below whenever you are indoor

		Dry season	Raining season
1	Headaches and a stiff neck		
2	Dizziness		
3	A tingling/pins/needles feeling		
4	Difficulty or fast breathing		
5	Increased heart rate		
6	Loss of consciousness (i.e. fainting)		
7	Weakness/fatigue		
8	Sore throat		

9	Muscle pains		
10	Severe watery or loose diarrhea (i.e. more than three runny stools per day)		
11	Nausea (i.e. the feeling that you are going to vomit		
12	Vomiting everything		
13	A bad (severe) cough that lasts 3 weeks or longer		
14	Pain in the chest		
15	Coughing up blood or sputum (mucus from deep inside the lungs)		
16	Sore or itchy eyes		
17	Skin complaints/rashes/eczema		

7. Please rate (1 = very low; 5 = very high) the level of the following in the room

	1 Very low	2 Low	3 Moderate	4 High	5 Very high
Natural ventilation					
Natural daylight					
Bad odour or stuffy smell					
Presence of mould (i.e. black and growing in moist places)					
External Noise					
Thermal comfort					
Illumination (Brightness of light)					

Section C: Building Operation

8. Which of the following do you use in the hostel for cooking?
    1. Electric cooker
    2. Gas/propane,
    3. Kerosene
    4. Firewood
    5. Charcoal
9. Where do you carry out your cooking place?
    1. Inside room
    2. Along the corridor of the room
    3. Separate room in the hostel (i.e. kitchen)
    4. Separate building outside the hostel
10. Do you or anyone smoke inside room?
    1. Yes
    2. No

11. Please indicate how often you open your windows in the room when indoor.

	Never	Rarely	Sometimes	Often	Always
Dry season					
Raining season					

12. Please indicate any of the following conditions when you do not open windows when indoor.

1	When it’s windy outdoor	
2	When it’s dusty outdoor	
3	When it’s raining	
Others, Please specify		

13. Please indicate any of the following coverings you use for your window.

1	Shutters	
2	Louvers	
3	Window blinds (i.e. Curtains)	
Others, please specify		

SECTION D: BUILDING AUDIT/SURVEY

Building Ventilation Characteristics

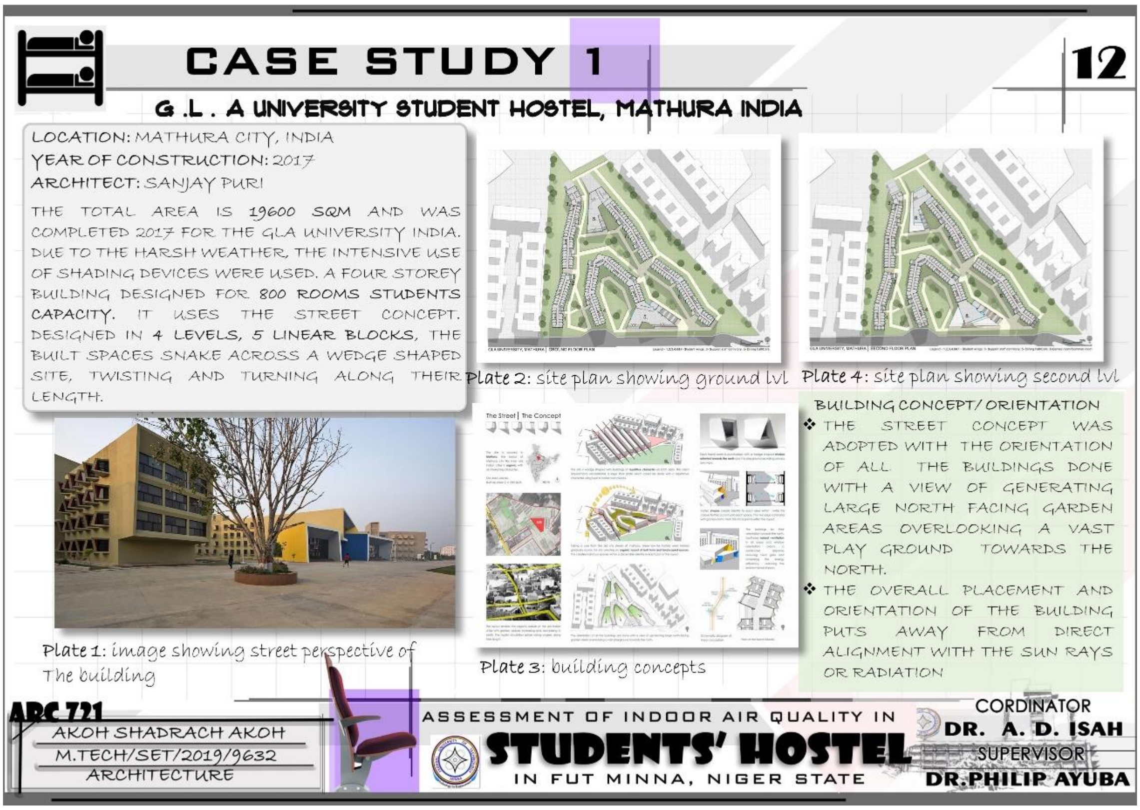
14. What means of ventilation is available in the room?
    1. Air Conditioning (AC)
    2. Fan (s)
    3. Windows only

15. Please rate (1 = never; 5 = always) the frequency of how you use the following ventilation systems in the room

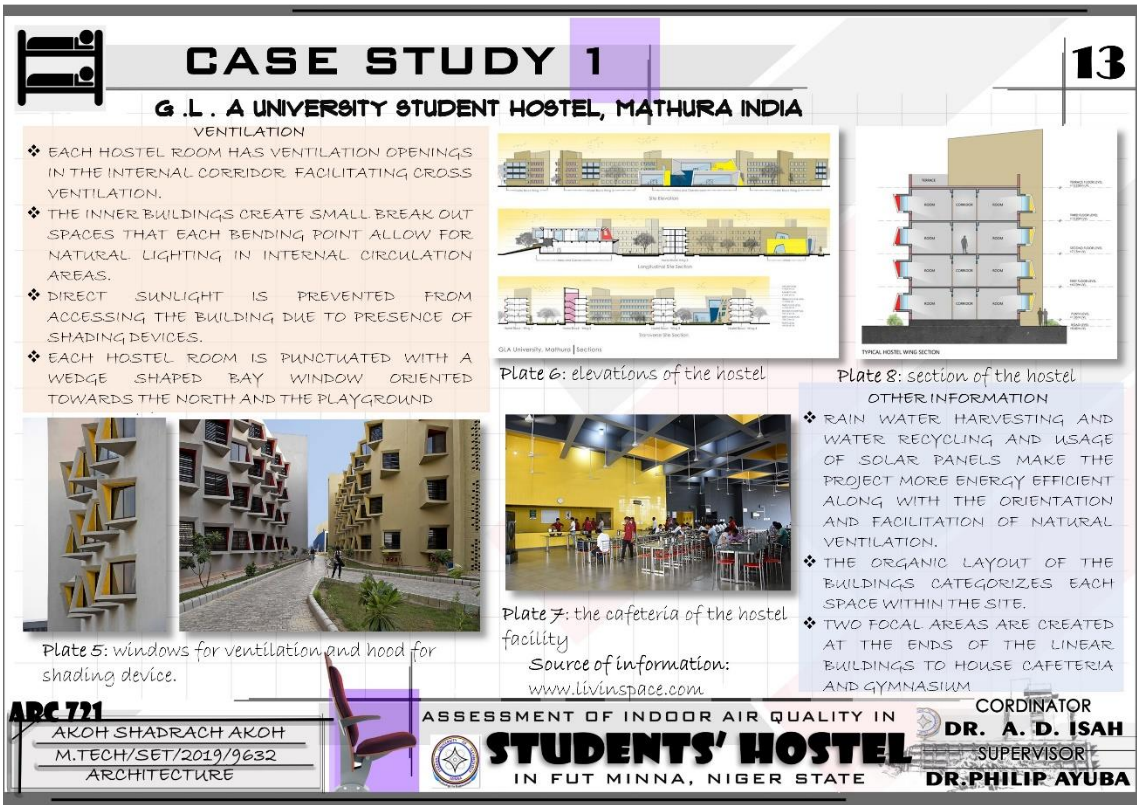
Alternative source of light when there is no electricity		1 Never	2 Rarely	3 Sometimes	4 Often	5 Always
1	Air Conditioning					
2	Fan (s)					
3	Windows only					
4	Fan and windows only					
5	AC and Fans only					

16. Window type in the room
    1. Side hung window (i.e. casement type)
    2. Top hung window (i.e. projected type)
    3. Sliding window
    4. Louvers window
    5. Sealed window space
    6. Opened window space
17. Any existing openable window (s) on the opposite or adjacent walls of the room?
    1. Yes
    2. No

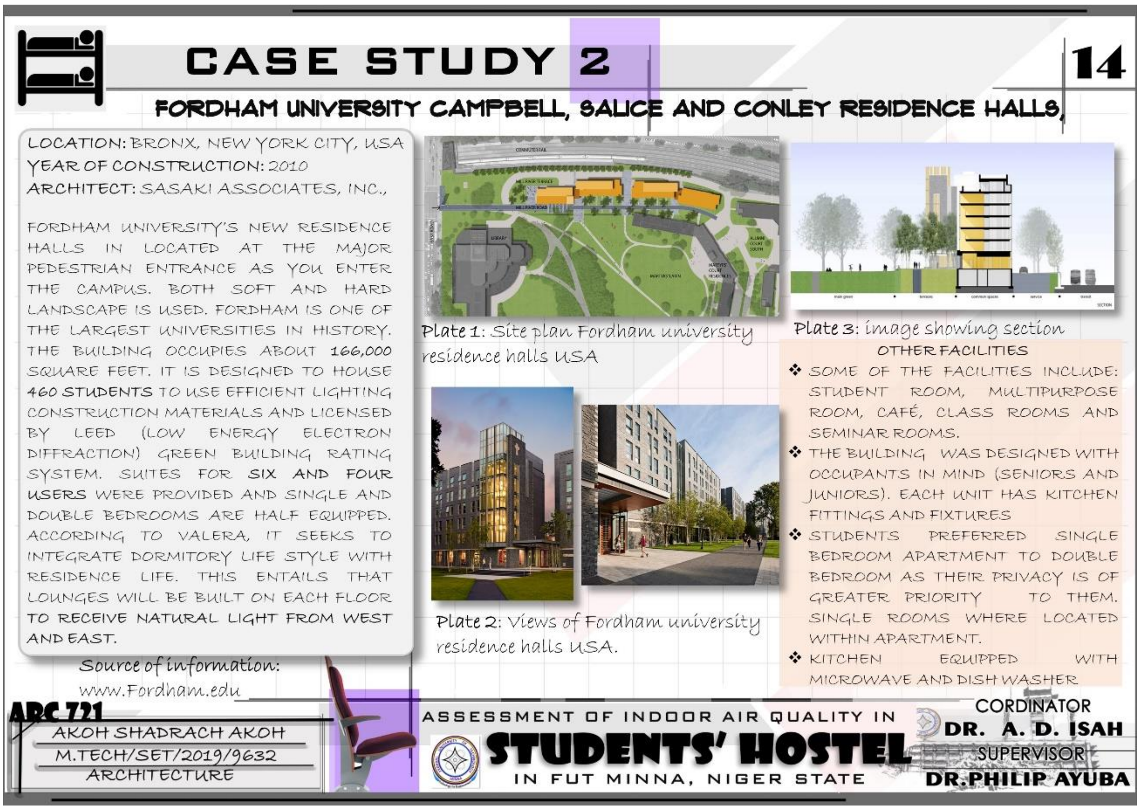
Appendix C: Case Study 1 (sheet 1)



Appendix D: Case Study 1 (sheet 2)

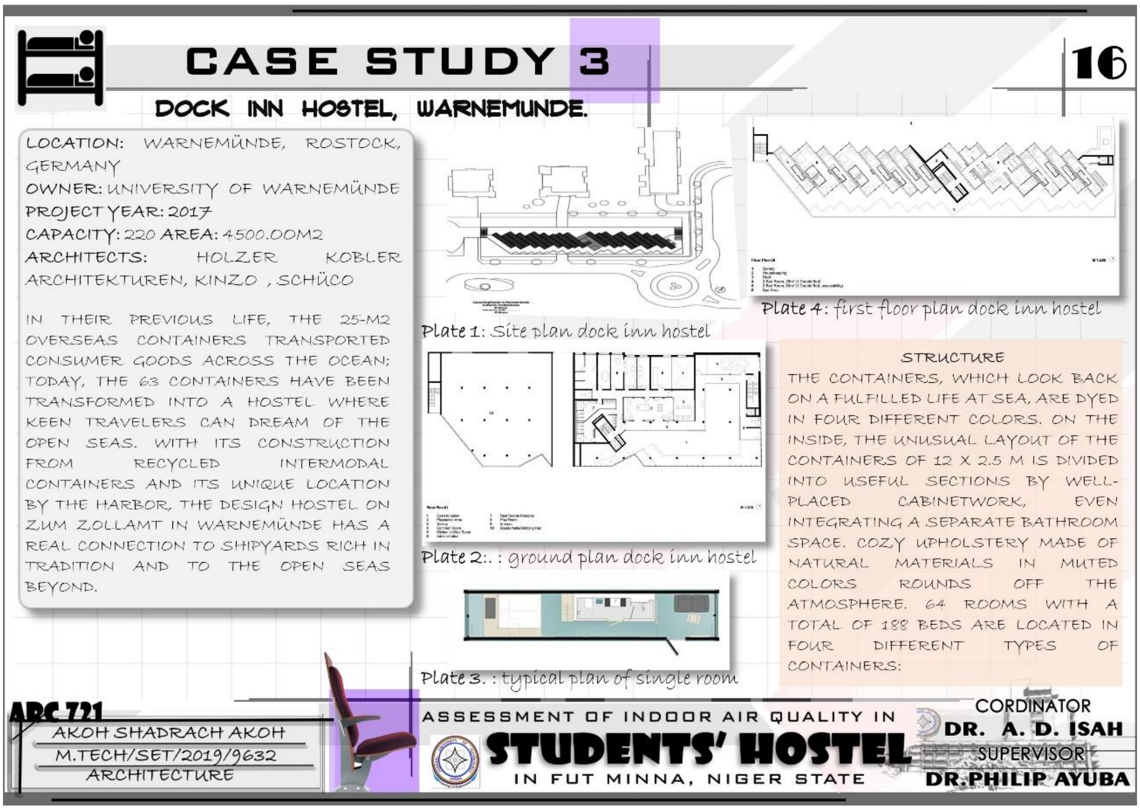


Appendix E: Case Study 2 (sheet 1)

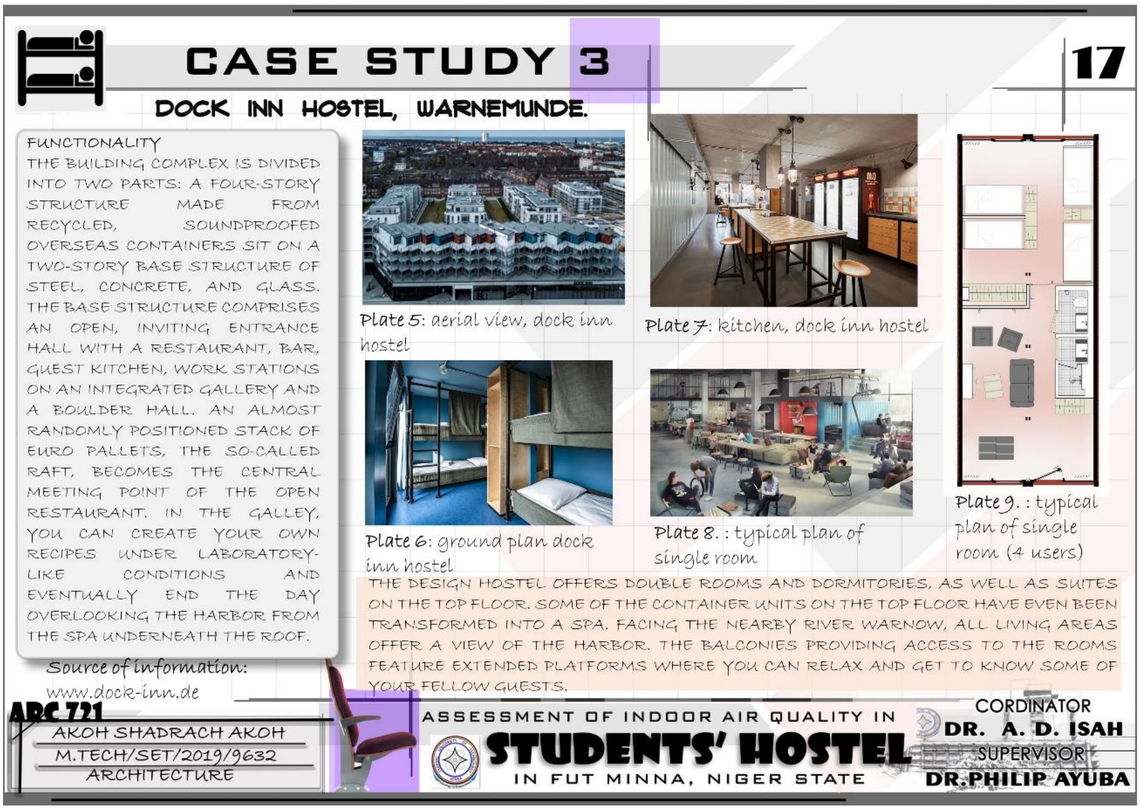


Appendix F: Case Study 2 (sheet 2)

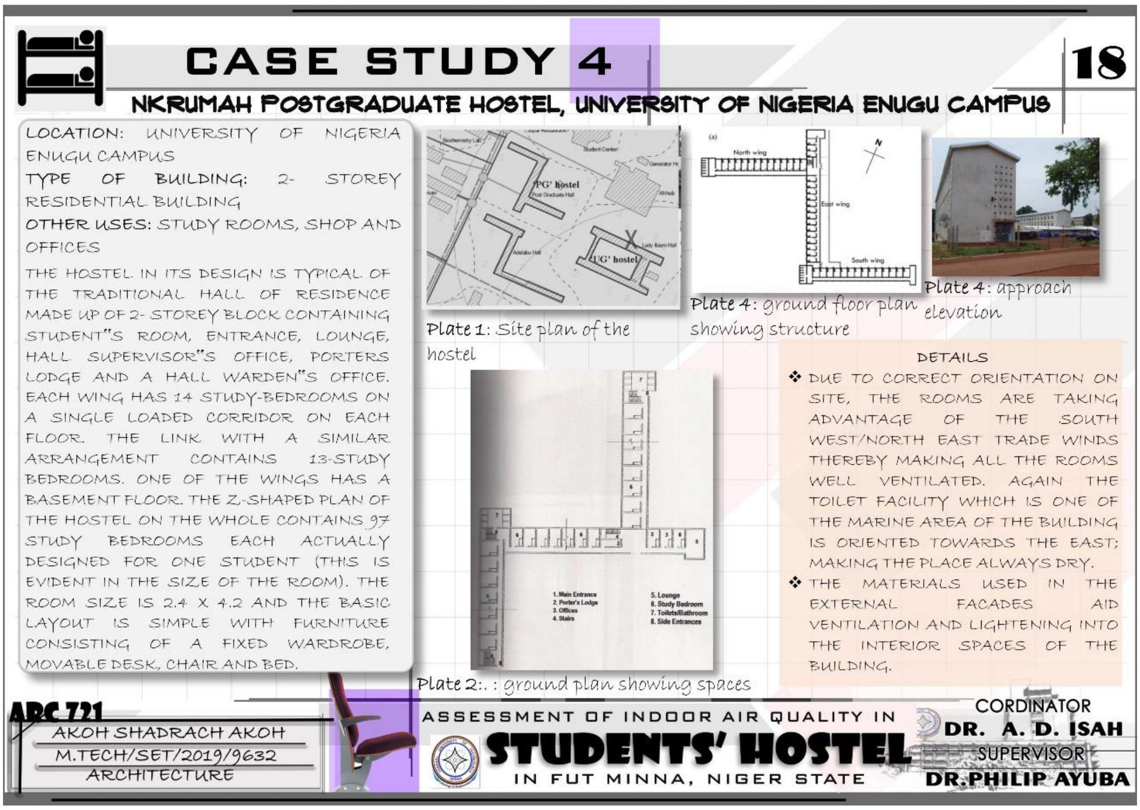
Appendix G: Case Study 3 (sheet 1)



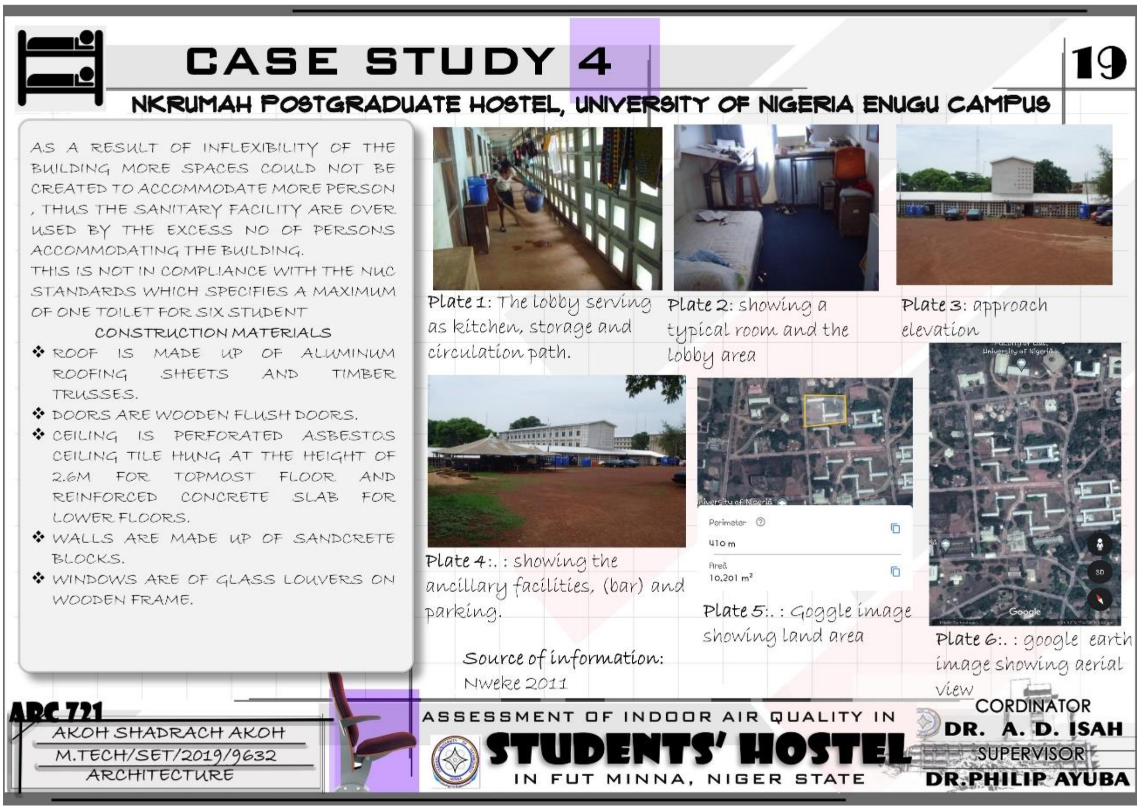
Appendix H: Case Study 3 (sheet 2)



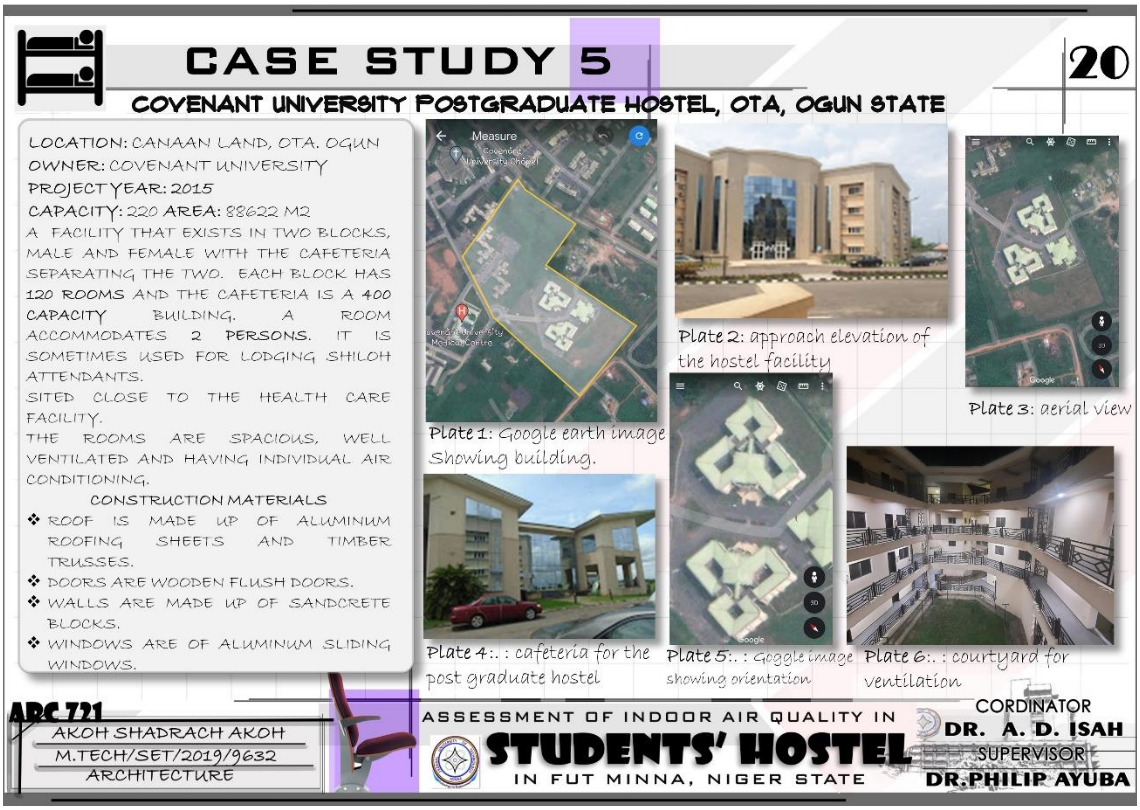
Appendix I: Case Study 4 (sheet 1)



Appendix J: Case Study 4 (sheet 2)

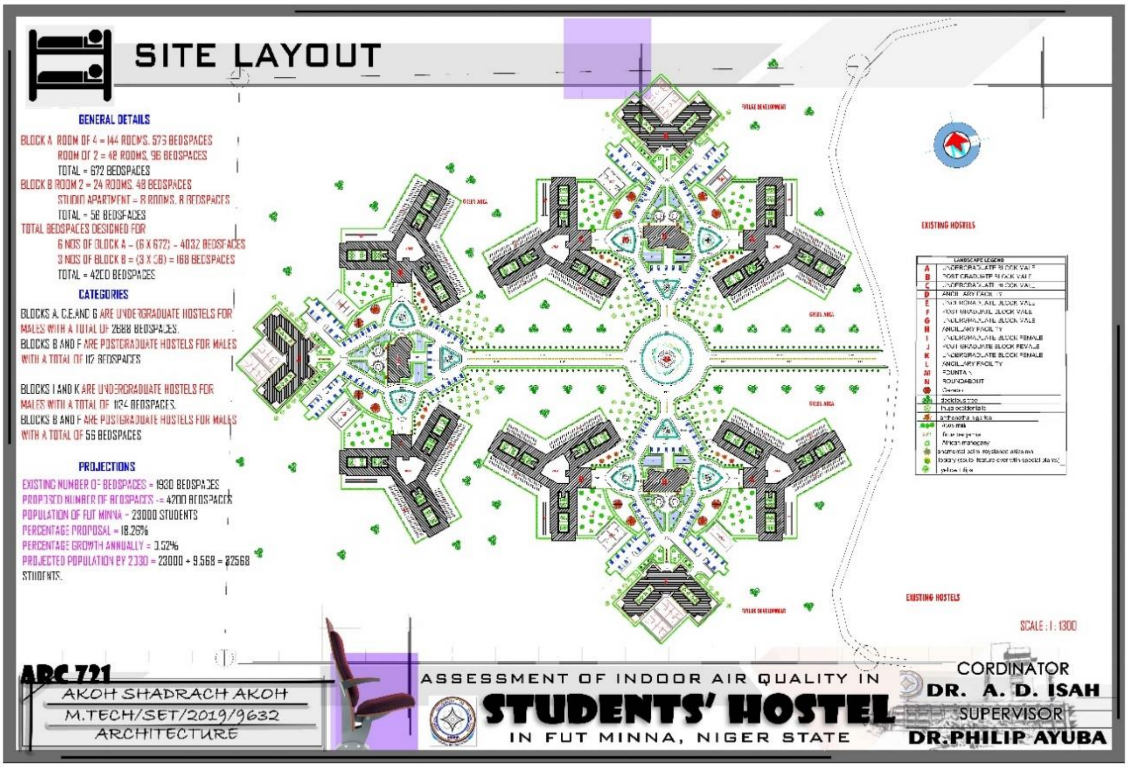


Appendix K: Case Study 5 (sheet 1)



Appendix L: Case Study 5 (sheet 2)

Appendix M: Site Layout



Appendix N: Site Elevation

Appendix O: Perspectives (Sheet 1)

Appendix P: Perspectives (Sheet 2)