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THE IMPACT OF ONDOOR
ENVIRONMENTAL QUALITY ON
OCCUPANTS WORK PRODUCTIVITY

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NEAR EAST UNIVERSITY
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THE IMPACT OF INDOOR ENVIRONMENTAL QUALITY ON OCCUPANTS WORK PRODUCTIVITY; INDOOR AIR QUALITY AND THERMAL COMFORT IN OFFICE BUILDINGS IN ABUJA, NIGERIA

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Approval

We certify that we have read the thesis submitted by Ahmad Tijjani Mohammed titled **"The Impact of Indoor Environmental Quality on Occupants Work Productivity; Indoor Air Quality and Thermal Comfort in Office Buildings in Abuja, Nigeria."** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Applied Sciences.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Ahmad Tijjani Mohammed

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Ahmad Tijjani Mohammed

Abstract

The Impact of Indoor Environmental Quality on Occupants Work Productivity; Indoor Air Quality and Thermal Comfort in Office Buildings in Abuja, Nigeria

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The level of achievement that an organization achieves in relation to its objectives is directly proportional to the level of performance that the employees of that organization are capable of delivering. This study is undertaken to examine the impact of indoor environmental quality on occupants' productivity (indoor air quality and thermal comfort) in office buildings in Abuja. The national assembly was chosen as the place of study. A survey research design was employed to elicit responses from respondents. A total of 203 participants who are occupants of the National Assembly building in Abuja, participated in this study. Participants were recruited using the convenience sample approach. The responses to the questionnaire were analyzed using descriptive statistics while the Pearson moment correlation was employed in testing the null hypotheses. The findings revealed that factors related to indoor air quality, such as the physical dimensions of the office space, the proportion of people working there, the location of the office window, as well as indoor air quality agents, such as food, paintings, perfumes, office cleaning products, tobacco smoke, and other factors, had an impact on the productivity of those who occupied the National Assembly. Also, there is a positive correlation between cold temperature and occupant work productivity, as supported by evidence in this study. The study recommends that architects and engineers must take into account several factors, including sick building syndrome, thermal conditions, and interior and exterior designs, to ensure that newer buildings adhere to the requisite standards for optimal indoor air quality.

***Key Words*:** thermal comfort, work productivity, indoor air quality, office buildings, Abuja Nigeria

Özet

İç Mekan Kalitesinin Kullanıcıların İş Verimliliği Üzerindeki Etkisi; Abuja, Nijerya'daki Ofis Binalarında İç Mekan Hava Kalitesi ve Termal Konfor

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Bir kurumun hedefleriyle ilgili olarak ulaştığı başarı düzeyi, o kurum çalışanlarının gerçekleştirmeye orantılı oldukları performans düzeyiyle doğru orantılıdır. Bu çalışma, Abuja'daki ofis binalarında iç mekan kalitesinin bina kullanıcılarının üretkenliği (iç hava kalitesi ve termal konfor) üzerindeki etkisini incelemek için yapılmıştır. Ulusal meclis çalışma yeri olarak seçildi. Katılımcıların yanıtlarını ortaya çıkarmak için bir anket araştırması tasarımı kullanıldı. Bu çalışmaya Abuja'daki Ulusal Meclis binasını kullanan toplam 203 katılımcı katılmıştır. Katılımcılar uygun örneklem yaklaşımı kullanılarak seçilmiştir. Ankete verilen yanıtlar tanımlayıcı istatistikler kullanılarak analiz edilirken, boş hipotezlerin test edilmesinde Pearson moment korelasyonu kullanıldı. Bulgular, ofis alanının büyüklüğü, ofiste çalışan kişi sayısı, ofis penceresinin konumu ve ayrıca iç mekan havası gibi iç mekan hava kalitesiyle ilgili faktörlerin yanında, gıda, resim, parfüm, ofis temizlik maddeleri, tütün dumanı ve diğer faktörlerden de, Ulusal Meclis'i kullananların iş verimliliğinin etkilendiğini göstermiştir. Ayrıca, bu çalışmadaki kanıtlarla da desteklendiği gibi, soğuk hava sıcaklığı ile bina sakinlerinin iş verimliliği arasında pozitif bir ilişki vardır. Çalışma, mimarların ve mühendislerin, yeni binaların optimum iç hava kalitesi için gerekli standartlara uymasını sağlamak için hasta bina sendromu, termal koşullar ve iç ve dış tasarımlar dahil olmak üzere çeşitli faktörleri dikkate almaları gerektiğini önermektedir.

***Anahtar Kelimeler*:** termal konfor, iş verimliliği, iç hava kalitesi, ofis binaları, Abuja Nigeria

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List of Abbreviations

TO	Toxic Organic
PV	Personalized Ventilation
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
BMI	Body Mass Index
PMV	Predicted Mean Vote
WHO	World Health Organization
SBS	Sick Building Syndrome
SPSS	Statistical Package for The Social Sciences
POE	Post-Occupancy Evaluation
VOC	Volatile Organic Compounds
HVAC	Heating, Ventilation, and Air Conditioning
PPDO	Percentage of Dissatisfied Occupants
POE	Performance Oriented Engineering
FCDA	Federal Capital Development Authority
CCTV	Closed-Circuit Television
NIOSH	National Institute for Occupational Safety and Health
ACBVOC	Airborne Chemical and Biological Volatile Organic Compounds
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers

CHAPTER I
Introduction

The comfort of today's single-family and multifamily homes and other structures is not dependent on the whims of the weather or the climatic conditions outside. Over the course of several millennia, the contemporary society have progressed from using natural features like rock shelters, caves, and crude homes as their primary means of weatherproofing. Shelter today, comes in different designs, both large and small, that accommodates the many different kinds of industrial processes and activities, as well as the many different kinds of institutions, such as schools, universities, hospitals, and government buildings, as well as the many different kinds of transportation vehicles, housing units, commercial centres, and entertainment venues, such as arenas, theatres, and amphitheatres (Haroglu, 2012; Assche et al., 2012). This built environment varies in function, size, and even form. In addition to serving practical purposes, man-made settings are also a reflection of the goals and creativity of their creators. They also reveal deeper truths about things like the disposition of human nature, the limitations of the physical world, prevailing cultural norms, and the availability of basic construction materials (Widodo, 2019).

Larger buildings are mechanically ventilated to reduce odours and discomfort caused by human bio-effluents. In addition, building professionals take precautions to avoid the incursion of precipitation (rain, snow, and wind) into our dwellings, to produce and maintain appropriate thermal conditions regardless of the weather outside, and to make the oppressive heat of summer tolerable (Ayanlade et al., 2019). The ability to regulate thermal comfort and other features of interior environments necessitates the adoption of numerous climate-control technologies and a dedication to their proper operation (Ayanlade, 2017). The man-made surroundings created by people are fragile. Numerous factors contribute to Earth's position as the dominant power in the universe, putting it in perpetual danger (Dhaka et al., 2015). Over time, man-made buildings are subject to the same elements that erode mountains: wind, ice, and water. Ancient temples and structures may have remained largely untouched over the centuries, yet they are no longer used as places of worship or community gathering. For a very long time in human history, wooden buildings were frequently fabricated using moulds. Even our most modern structures are vulnerable to degradation due to human carelessness and the natural elements. The filth they spread around our houses could be harmful to our health (Giridharan & Emmanuel, 2018).

Even though we construct houses and other structures, protection from the frequently hostile external environment is not perfect (Nasrolahpour, 2020). In addition to natural forces, the randomness-based second rule of thermodynamics and its progeny, the law of unintended consequences, can have an effect (Yang & Clements, 2012). In our efforts to provide shelter and the many comforts that make living more comfortable, we frequently introduce contaminants that have the potential to diminish the quality of our lives or pose moderate to severe health risks to residents (Nejati et al., 2018). Indoor settings are frequently contaminated with several potentially poisonous or hazardous compounds, including those of a biological nature. Due to the heavy burden of wood smoke (similar to that created by present-day cooking fires in developing nations), early humans' indoor environments were subject to irritating and more severe health effects when they discovered fire and introduced it to rock shelters, caves, and dwellings (Larsen, 2016). Throughout human history, biological pollutants such as bacteria, fungi, and the excrement of commensal animals have been the primary source of disease and suffering (Louise, 2017). When compared to contagious and fatal diseases like tuberculosis and bubonic plague, asthma and chronic allergic rhinitis may appear insignificant (Nasrolahpour, 2020).

Advanced economies, today, have shown a growing concern in recent years over the effects of poor indoor environmental quality on occupants as well as the potential implications of exposure to occupants (Sakellaris et al., 2016a). The development of such procedures was spurred by concerns regarding the long-term effects that harmful compounds, such as pesticides, PCBs, dioxin, and other industrial chemicals, may have on human health (Bluyssen et al., 2016). According to Al Horr et al (2016a), it is possible for an improvement in the indoor environmental quality of a place of business, such as an office, to have a sizeable effect on the return on investment. Workers are more likely to complete their work when the atmosphere in which they are working makes them feel happier and more relaxed (Coulby et al., 2020). Whether a workplace is large or small, the level of productivity within it is one of the most important variables in predicting how successful it will be. Because office workers are so critical to the success of any company, it is important to make significant investments in the goal of providing them with a pleasant environment to work. Considering that salaries are typically the single largest expense for most businesses, this is especially important to recoup such from workers' productivity (Yudelson 2008). According to previous studies on the correlation between the work environment and output, the various physical and chemical components of the workplace was considered to have a significant impact on the health and performance of the residents, and as a result, on the workplace's overall output (Savelieva, 2019). However, there is still a dearth of concrete evidence to support this claim globally as different results seems to exists in different literature on studies carried out in different countries (Newsham 2008). When it comes to estimating and organizing the level of productivity in a workplace in relation to environmental factors, there are still a lot of unknowns (Thach et al., 2020; Coulby et al., 2020). Examples of psychological factors that affects productivity include, health, company characteristics, stress, job satisfaction, and motivation. Examples of environmental factors include workplace design and indoor environmental quality (IEQ), which is affected by items such as air quality, thermal comfort, and light (Ortiz & Bluyssen, 2022).

Statement of the Problem

If people in today's modern civilization are constantly cold or hot, the work they do will be inefficient and possibly even counterproductive. Inadequately warm environments can cause fatigue and headaches, which can have an unpleasant impact on mental performance, whereas chilly hands can lead to unacceptable levels of manual dexterity (Nakayama et al., 2021). Thermal comfort and indoor air quality are crucial indoor environmental components that must be adequately accounted for in an office building for maximum productivity. A building adjusts the external climate so that the indoor environment is suitable for the human activities it is meant to enclose and protect. Only the simple tasks that sustain primitive groups can be performed routinely outside, and even then, only under optimal weather and climate conditions (Suzuki et al., 2019a). Modern civilizations employ buildings to regulate the working environment, eliminating the need for weather, time of day, and season to effect work performance.

According to the National Institute for Occupational Safety and Health (NIOSH, 2013), A common component in indoor environmental quality is the air quality, which is related to the health and well-being of workers. This observation was consistent with research from the Brookings Institution that demonstrated a correlation between the health effects of air pollution and the productivity of workers. Additionally, Jung et al (2021) showed that air contaminants may have more severe impacts on workers due to the fact that they may increase the risk of respiratory problems and death. The degree to which poor indoor environmental quality (IEQ) contributes to productivity losses depends on the type of office building and the nature of the job being performed by employees. Extreme temperatures are associated with an increase in hospitalizations for kidney, respiratory, and cardiovascular illnesses (Lin et al., 2013; Wang et al., 2014). By 2030, the World Health Organization (WHO, 2014) forecasts that climate change will be responsible for over 250,000 annual deaths, either directly through exposure to extreme weather (such as heat waves) or indirectly through the spread of diseases, inaccessibility to water, and food poverty. Asthma and allergies, headaches, respiratory problems, irritated eyes, noses, and throats, birth defects, neurological disorders, cardiovascular disease, and some types of cancer all have a connection to poor IEQ (Esfandiari et al., 2017).

In contrast, improving IEQ can significantly reduce absenteeism and boost productivity. Poor indoor environmental quality in corporate buildings can affect worker productivity (Fengxuan, 2022). This thesis on this rationale, investigates the impact of indoor environmental quality on occupants work productivity. Given how much time we spend indoors, it should be in our best interest to create work environments that enhance productivity and performance, this is what this study sets out to investigate.

Purpose of the Study

1. To determine the influence of Indoor Air Quality (IAQ) influence occupants' work productivity
2. To assess the impact of thermal comfort in office buildings influence occupants work productivity.
3. To develop and recommend approaches essential for achieving indoor environmental quality.

Research Questions

1. How does Indoor Air Quality (IAQ) influence occupants' work productivity?
2. How does thermal comfort in office buildings influence occupants work productivity?
3. What approaches can be adopted to achieve indoor environmental quality?

Research Hypotheses

H1: There is no significant relationship between indoor air quality and occupants' work productivity.

H2: There is no relationship between thermal comfort in office buildings and work productivity.

Significance of the Study

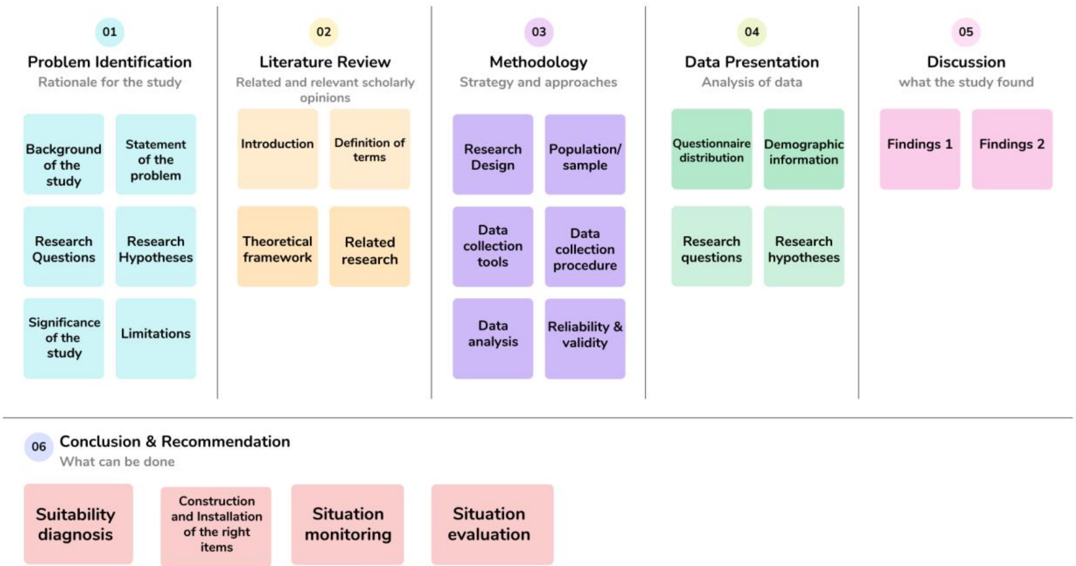
The import of this study lies in its ability to critically present evidence that demonstrates the influence of indoor air quality on workers' productivity in the light of contemporary significance. Also, very little Africa-centred study on this topic have been carried out, thus, this study is a contribution to the scarce literature in this field as it investigates office buildings in Abuja, Nigeria. This study will be useful to employers as it will equip them with the right understanding on the need to ensure quality indoor environment which will lead to reduced workers' health issue and increased productivity.

Research Outline

This research outline presents a comprehensive plan for investigating the impact of indoor environmental quality on occupants' work productivity in office buildings in Abuja, Nigeria, with a particular focus on indoor air quality and thermal comfort. The research outline is structured into several key sections, including an introduction that provides an overview of the research topic and its significance, a literature review that synthesizes existing studies on indoor environmental quality, a methodology section that describes the research design and data collection procedures, findings that present the results of the study, a discussion section that analyzes and interprets the findings, and a conclusion that summarizes the key findings of the study and makes suggestions for future research and practise. By following this structured outline, the study aims to provide a rigorous and systematic investigation of the impact of indoor environmental quality on occupants' work productivity, which can inform building design and policy decisions and contribute to improving the health and well-being of workers in office buildings in Abuja and beyond.

Figure 1

Research Outline (Author,2023)



Limitations

This study is limited in three aspects. First, to effectively measure indoor environmental quality on occupants' work productivity, two components of IEQ which includes, indoor air quality and thermal comfort was carefully considered. Other components not captured in this study are acoustic and visual ambience, this is a contextual limitation. Second, the chosen area for this study is Nigeria, this implies that the findings of this study may not be qualified to be generalized to other countries, thus creating a regional limitation. Lastly, the methodology adopted for this study has been considered appropriate by the researcher and may not be considered appropriate for future similar studies. These limitations do not in any way interfere with the validity of the results presented in this thesis, but allows opportunity for future researches in order to increase and contribute to knowledge.

Definition of Terms

Air Quality

These are all the characteristics of indoor air that have an impact on a person's health and wellbeing. Indicators of indoor air quality must therefore assess how well indoor air satisfies respiratory and thermal needs, guards against harmful pollutants, and promotes wellbeing. The presence of pollutants at levels that impair occupant health can also be referred to as indoor air quality.

Occupants

People's presence in the building, as well as their actions (or lack thereof), can affect the indoor environment (Hoes et al., 2009).

Productivity

A common definition of productivity is the ratio of input volume to output volume. In other words, it assesses how effectively an economy uses labour and capital as production inputs to produce a particular level of output. Productivity is regarded as a major driver of economic growth and competitiveness and, as such, serves as the foundational statistical data for many international comparisons and assessments of country performance.

Thermal Comfort

Thermal comfort is also defined as a person's awareness of their own body's thermal environment and as their sweat-free, neutral response to a particular thermal environment.

Environment

The environment encompasses the collective influence of biotic and abiotic factors on human existence. Abiotic components, such as water, land, sunlight, rocks, and air, are distinct from biotic components, which encompass living entities such as animals, plants, forests, fisheries, and birds.

Office Space

An office may be defined as a location where the coordination and management of activities related to the production and distribution of products and services take place.

CHAPTER II
Literature Review

Office buildings in Nigeria are supposed to create a clean, cozy, and pleasant environment with high indoor air quality (IAQ) to protect employees' physical and mental health while doing their jobs within the facility. This need is essential since the health of workers are affected by their environment, which in turn affects their work performance and, eventually, the productivity of companies. According to Al Horr et al. (2016a), the indoor environment within a limited area is a multifaceted and ever-changing amalgamation of chemical, physical, and biological constituents that can potentially impact the well-being and physiological responses of the inhabitants, regardless of whether or not this is recognized. Moreover, there exists evidence indicating that volatile organic compounds, which are frequently present in the indoor air of office buildings, can lead to symptoms resembling those of sick building syndrome. Cheung et al. (2021) posit that the provision of a hygienic and pleasant indoor environment for building occupants is the sole means of attaining optimal indoor air quality (IAQ). In this chapter, a literature review is undertaken spanning two sections. First, a theoretical framework explicating the rationale for this research was examined, followed by a study of further facts pertinent to this investigation. The purpose of this review is to critically place this argument within the context of previously conducted research.

Indoor Environmental Quality

The term "indoor environmental quality" pertains to the standard of indoor conditions, encompassing factors such as air purity, thermal satisfaction, illumination, sound quality, and ergonomic design. Optimal Indoor Environmental Quality (IEQ) is of paramount importance for the physical and mental health, comfort, and overall welfare of building occupants. Furthermore, it has a direct impact on their productivity and performance. The goal of this literature review is to offer a complete overview of available studies on Indoor Environmental Quality. Quality (IEQ) and its impact on individuals occupying diverse building structures.

An important part of IEQ is indoor air quality (IAQ), which can be defined as the state of the air in an indoor environment in terms of contaminants, humidity, and temperature. Poor IAQ can cause a variety of health issues, including headaches, tiredness, and respiratory infections. According to Seppänen et al. (2006), enhancing IAQ in office buildings led to a considerable boost in productivity, with a 9% increase in work speed and an 8% reduction in worker mistakes.

Thermal comfort, which relates to the subjective experience of feeling comfortable in terms of temperature, humidity, and air movement, is another key component of IEQ. Thermal discomfort, according to Zhang et al. (2010), can lead to decreased cognitive function and higher stress levels, which can have a detrimental influence on productivity. The study also discovered that tenants who have control over their thermal environment were more satisfied and productive.

Lighting is another key aspect of IEQ that can have an impact on both physical and psychological well-being. According to Veitch et al. (2008), inadequate lighting conditions in offices can cause visual discomfort, headaches, and eyestrain, which can reduce productivity. Workers who had access to daylight and views of nature also reported better levels of job satisfaction and well-being, according to the research.

Acoustics, which relates to the quality of sound in a building in terms of noise levels and speech intelligibility, is also an essential component of IEQ. Shield and Dockrell (2004) discovered that excessive noise in classrooms can contribute to poor academic performance, increased stress, and behavioral issues. The study also discovered that acoustic design interventions, such as improved sound insulation and lower background noise levels, can result in considerable gains in academic performance.

The study of how the physical environment impacts human behavior and performance is known as ergonomics. Hedge et al. (2004) discovered that ergonomic treatments, such as offering adjustable seats and workstations, can lead to considerable increases in productivity and decreased musculoskeletal diseases. The study also discovered that ergonomic adjustments can increase work satisfaction and well-being.

IEQ is a multidimensional term that has a substantial influence on building inhabitants' health, comfort, and well-being. While a low IEQ can result in a number of health problems and poor performance, a high IEQ can help increase productivity, work satisfaction, and well-being. Improving IEQ in buildings necessitates a multifaceted strategy that considers aspects such as IAQ, thermal comfort, lighting, acoustics, and ergonomics.

Figure 2

Indoor Environmental Quality Factors (Radostina,2016)

Visual Comfort

It has been shown that visual comfort is a key element of indoor environmental quality because it significantly affects occupants' health, happiness, and productivity. CIE (2018) defines visual comfort as "the state of visual awareness that allows a person to perform visual tasks comfortably and effectively while minimizing the perception of discomfort and visual weariness." Visual comfort in office buildings is largely determined by lighting design, which includes both natural and artificial lighting. Several studies have been conducted to explore the effect of lighting on visual comfort in office buildings, especially illuminance, color temperature, and glare.

Illuminance is the quantity of light that falls on a surface and is an important aspect in visual comfort. According to research conducted by Reinhart and Fitz (2006), the best illuminance level for a visual display terminal (VDT) workstation is between 300 and 500 lux. This illuminance level was shown to be appropriate for a variety of visual tasks such as reading, writing, and typing. According to Veitch et al. (2008), the ideal level of illumination is contingent upon the type of task being performed and the age of the individuals occupying the space.

Another important component in visual comfort is color temperature, which relates to the colour of the light emitted by a light source. Lower numbers indicate warm or yellowish light, whereas higher values indicate cool or blueish light. The best color temperature for workplace lighting, according to the Lighting Research Center (2019), is between 3500K and 5000K. This color temperature range offers a combination of warm and cold light that is pleasant for most individuals and appropriate for a variety of visual tasks.

Glare is a prevalent issue in office buildings and happens when there is a substantial difference between the brightness of the job and the brightness of the surrounding space. Glare can induce eye discomfort, headaches, and weariness, all of which can have a negative impact on occupant productivity. According to Boyce and Hunter (2003), an office lighting system that delivers a balance of direct and indirect light can assist to decrease glare and increase visual comfort.

Visual comfort is an important part of interior environmental quality, and lighting design must be considered while developing office buildings. Illuminance, color temperature, and glare are important visual comfort elements that should be carefully examined to guarantee that occupants can accomplish visual activities pleasantly and efficiently.

Acoustics

Acoustics is an important aspect of indoor environmental quality since it has been shown to have a considerable influence on occupant health, well-being, and productivity. Acoustics in office buildings are largely affected by sound quality, noise levels, and speech intelligibility. Several studies have looked at the effect of acoustics on occupant productivity, especially open-plan office acoustics, private office acoustics, and the use of acoustic design and materials.

The entire impression of sound, including clarity, brightness, and warmth, is referred to as sound quality. According to research conducted by Bradley and Gupta (2008), sound quality is a crucial component in occupant happiness and productivity in open-plan workplaces. They discovered that when the sound quality was excellent, occupants were more happy and productive, which was achieved by the use of sound-absorbing materials, sound masking, and strong voice intelligibility.

Noise levels, which refer to the amount of unwanted sound in an area, are another important component in acoustics. Excessive noise can induce discomfort, tension, and weariness, which can affect the productivity of occupants negatively. According to Banbury and Berry (1998), moderate noise levels (about 65 dBA) can boost occupant performance in jobs requiring creativity, such as brainstorming sessions. High noise levels (over 75 dBA) on the other hand, can considerably decrease occupant performance in all sorts of jobs.

Speech coherence is an important consideration in private office acoustics when occupant privacy is paramount. Speech intelligibility relates to the capacity to understand speech and is determined by elements such as speaker-listener distance, sound absorption in the room, and background noise level. Sato et al. (2010) discovered that the use of sound-absorbing materials and attentive room layout design may greatly increase speech intelligibility in private workplaces.

Acoustic design and materials are important components of office buildings that may have a substantial impact on acoustics and occupant productivity. Noise levels can be reduced and speech intelligibility improved by using sound-absorbing materials such as ceiling tiles, carpets, and wall panels. The inclusion of a low-level background sound, known as sound masking, can serve to hide unpleasant noises and enhance sound quality. The arrangement of the space, such as the placement of furniture and partitions, can also have a substantial impact on acoustics and occupant privacy.

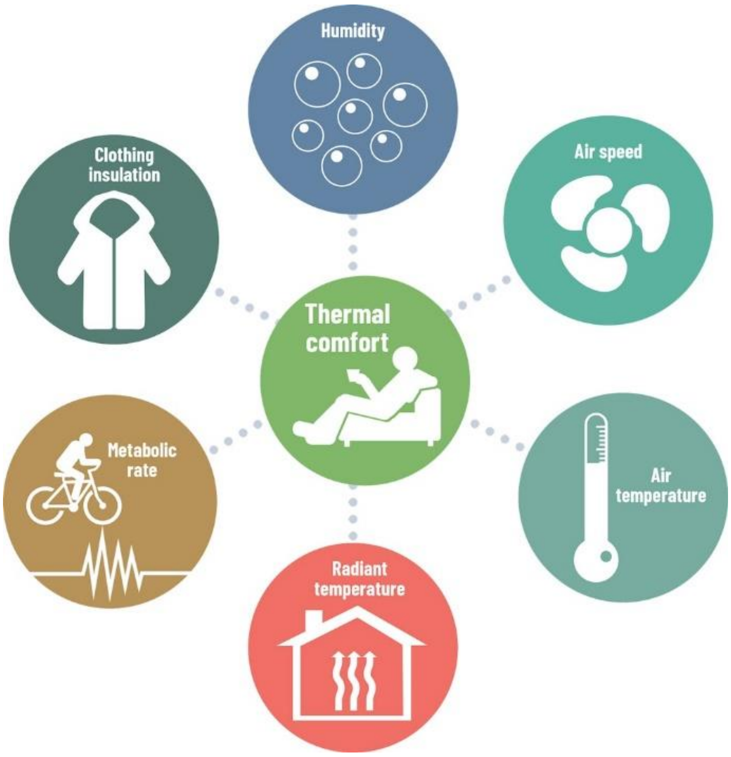
Thermal Comfort

According to ASHRAE (2004), the concept of thermal comfort pertains to a psychological condition that indicates contentment with the thermal surroundings. The aforementioned phenomenon is a subjective state that exhibits variability across individuals. The assessment of comfort is a cognitive procedure that integrates various inputs, including physiological, psychological, and physical factors (Nakayama et al., 2021). Comfort is influenced by a range of dynamic and independent factors, including but not limited to clothing, activity level, posture, window placement, and mood, as noted by ASHRAE in 2005. Due to the varied character of the phenomena, providing thermal comfort in a building is a challenge. Thermal comfort is determined by a combination of various physical factors that contribute to the establishment of a thermal state, as well as human responses to that situation. Individual and regional thermal comfort is affected by a number of factors, including but not limited to age, sex, metabolic rate, and seasonality, as noted by Suzuki et al. (2019b).

The number of unsatisfied workers can be used to gauge the level of thermal comfort in a workplace (Jung et al., 2021). Analysis of complaints is a defensive tactic. By expanding our IEQ research, we can create building structures that are more efficient as well as accommodating for human beings. The phrases thermal sensation, thermal acceptability, and thermal preference are frequently used in literature to describe how individuals react to heat. (Langevin et al., 2013).

Figure 3

Thermal Comfort Illustration (Cat.org, 2022)



According to Nasrolahpour (2021), thermal sensitivity is an objective measure, whereas thermal comfort is a subjective experience. According to ASHRAE's (2010) definition, thermal sensation pertains to an individual's thermal perception in terms of both intensity and direction. ASHRAE employs a seven-point metric ranging from negative three (indicating cold) to positive three (indicating warm). Six different aspects impact thermal comfort. Lin and Deng (2008) enumerate a set of variables that include air temperature, air velocity, relative humidity, mean radiant temperature, clothing insulation, and metabolic rate.

Elements that Affect Thermal Comfort: There are several elements that affect the thermal comfort of an indoor environment, these elements are discussed below;

a. Indoor air temperature

The temperature of the air within a building, which can be impacted by factors such as external temperature, HVAC systems, and solar heat gain.

The best indoor air temperature range for thermal comfort varies based on activity and season, but normally falls between 20°C and 26°C. Extremely high or low interior air temperatures can be uncomfortable and have an impact on occupants' job performance and well-being Humphreys, M. A. (2005).

b. Air movement

The circulation of air within a room, which can be natural or artificial, can impact the thermal comfort of the inhabitants. Proper air circulation can help to effectively disperse heat around a space and promote occupant comfort. Excessive air movement, on the other hand, can generate discomfort, such as drafts, and compromise thermal comfort Fanger (1970).

c. Humidity

According to the American Lung Association (2021). Humidity describes the amount of dampness in the air and can impact thermal comfort by affecting the body's ability to release heat via sweat evaporation. High humidity levels can make inhabitants feel hotter and more unpleasant, whilst low levels of humidity can induce dry skin, respiratory irritation, and discomfort.

d. Radiant temperature

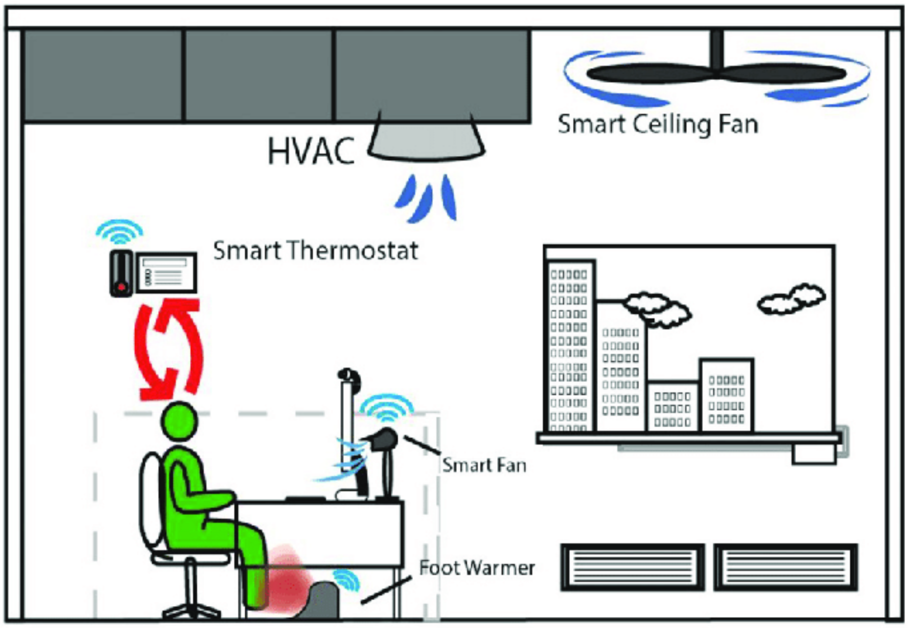
According to Nicol, J. F., and Humphreys, M. A. (2002), radiant temperature is the temperature of surfaces inside a space that can affect thermal comfort by influencing the amount of heat radiated to or absorbed from the human body. Cold or hot surfaces can be uncomfortable, and the appropriate radiant temperature is determined by the activity and season.

The popularity of an environment is determined by the thermal acceptability of its occupants. According to Langevin et al. (2013), thermal preference is determined by the environment. The rise in temperature within a given space is positively correlated with an increase in occupant productivity. The optimal temperature for individuals varies. According to Tuomaala et al. (2013) and

Indraganti et al. (2015), individuals of varying ages, genders, and BMIs exhibit varying preferences for thermal states. According to studies conducted by Karjalainen in 2012 and 2007, as well as by Kim et al. in 2013, it has been observed that women experience lower levels of happiness than men in colder climates and are more susceptible to temperature fluctuations.

Figure 4

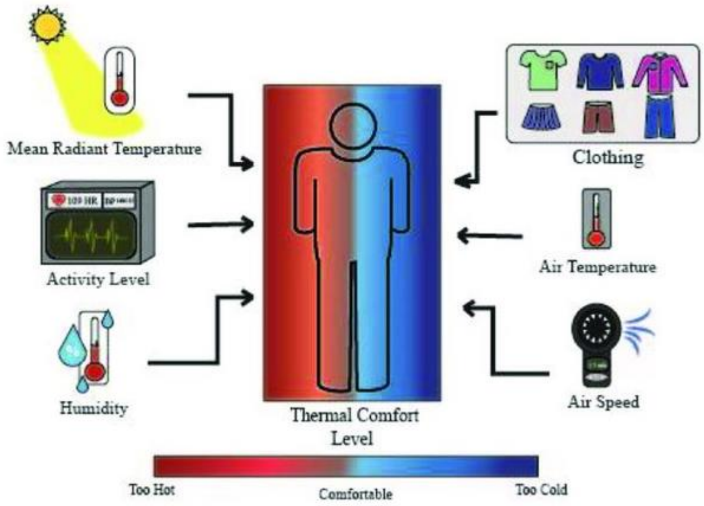
Personal Thermal Comfort in An Office Environment (Ali,2020)



Energy is needed to heat and cool a building (Kwok and Rajkovsky, 2010). It interests many built environment sustainability researchers. Thermal comfort has been studied for years. The Predicted Mean Vote index, developed by Fanger (1984), predicts thermal comfort by combining two human factors—clothing insulation and activity level—with two physical characteristics—air temperature, mean radiant temperature, air velocity, and relative humidity. The PMV index calculates PPD (Fanger, 1984). It predicts how many people will be uncomfortable in a hot environment. It forecasts whether a big number of individuals are going to perceive the temperature to be "too hot" or "too cool," as indicated by votes on a rating system of +3, +2, -3, and -2. (Yang & Clements-Croome, 2012).

Figure 5

Fanger's (PMV) Model Showing Six Factors that Contribute to the Thermal Comfort of Occupants (David Lehrer,2020)

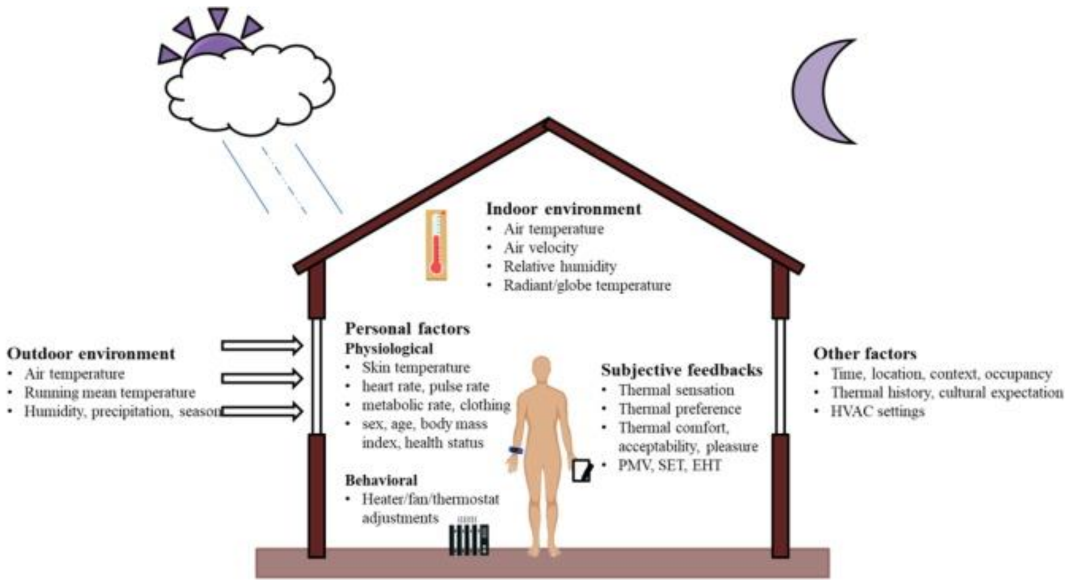


The method employed in this study is based on data obtained from a climate chamber and is rooted in the principles of heat balance theory and thermoregulation physiology, as previously discussed by Charles (2003) and Djongyang et al. (2010). Nejati, Habib, and Shahcheraghi (2018) reported that De Dear proposed the utilisation of the "adaptive approach" in achieving thermal comfort. The study of thermal environments and their impact on human behaviour is a subject of interest in field research. According to the assertion, thermal acceptance has an impact on the level of comfort experienced. The thermal tolerance of an organism is influenced by its adaptation. Numerous standards and evaluation methods have been developed as a result of research on thermal comfort (ASHRAE, 2005; ISO, 2005). Experts in the sector use these standards all around the world. The guidelines were formulated with the intention of catering to the North American and Northern European models and research, as stated by Larsen and Popovic (2016). According to Louise (2017), rather than taking into account factors such as age, gender, or regional behavioral norms, individuals are better suited for static and homogeneous thermal environments.

It is important to note that these specifications may not be universally applicable across all climatic conditions and indoor activities. Numerous international research studies have discredited the "rational approach" criteria and thermal comfort forecasting techniques, which overlook demographic factors such as gender, ethnicity and age, and advocate for a limited, precisely defined thermal comfort spectrum (Ogbonna and Harris, 2008). There exists a strong correlation between population comfort and average temperature. According to Ayanlade (2017), in edifices that employ natural ventilation, the average comfort temperature is subject to fluctuations in the average temperature. Comfort temperature is influenced by the climate of the locality and the occupants of the building. According to Morgan and de Dear's (2003) research, the implementation of formal dress codes has an impact on the level of comfort experienced by employees. Formal dress codes are observed across various global cultures. This enables one to make a comparative analysis of the attire adopted by different countries in mild climatic conditions.

Figure 6

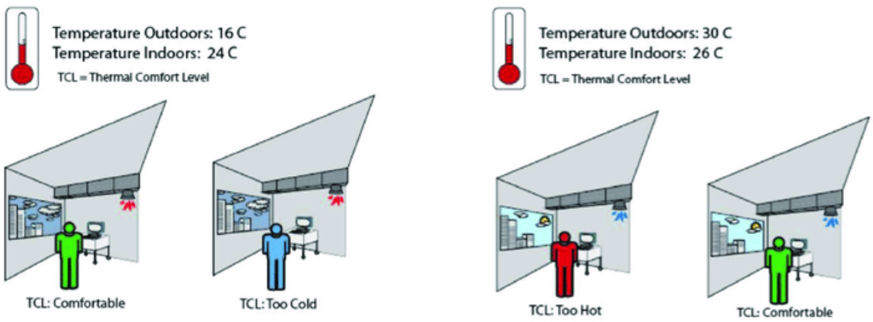
Image Showing Occupant Centric Thermal Comfort Sensing (Jiaqing Xie et al, 2020)



Thermal comfort boosts efficiency. Thermal discomfort lowers productivity (Dhaka et al., 2015). These studies found that office temperatures between 18°C and 30°C can impair typing, learning, and reading. Office productivity peaks at 21–25 degrees Celsius. Every 1°C increase in temperature between 25°C and 30°C decreases occupant performance by 2% (Giridharan & Emmanuel, 2018). Ambient temperature and task conditioning affect occupant thermal comfort. Task conditioning systems allow one or more occupants to control thermal conditions in a small space (Ayanlade et al., 2019). Individual thermal conditioning system control boosts productivity (Widodo, 2019). Local climate control and individual temperature regulation work best in multi-seating offices. It also applies to physical-task-intensive workplaces. Thermal control improves employee satisfaction but hinders occupant control. Expectations determine thermal acceptance. Comfort and environment expectations vary (Ezzeldin & Rees, 2013). Office thermal management systems waste energy due to occupant disagreement over thermal comfort and system comprehension (Shahzad et al., 2017).

Figure 7

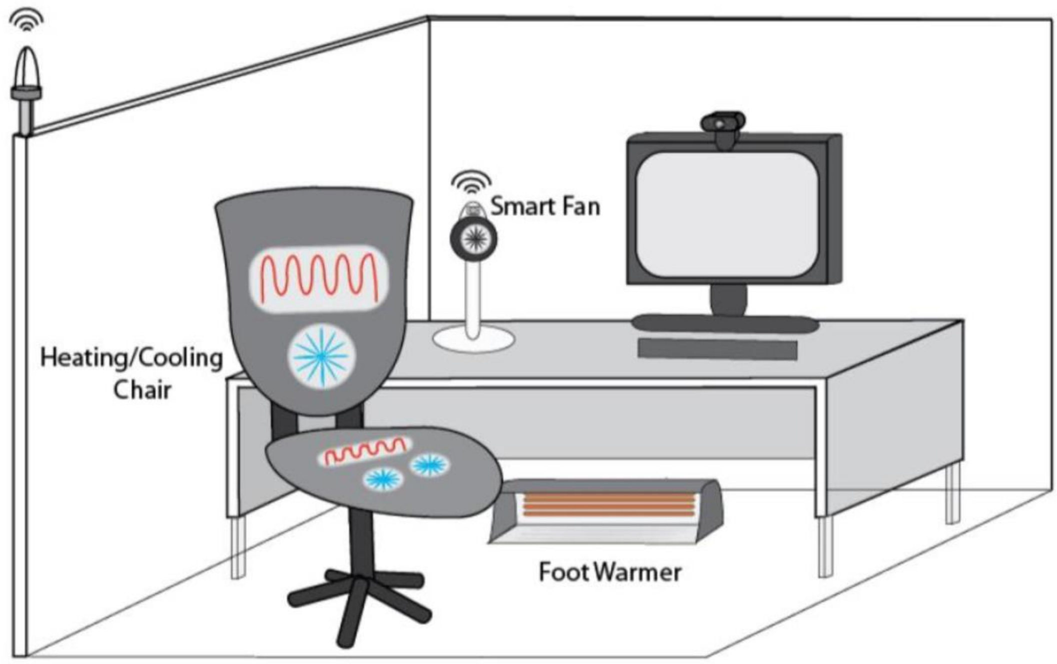
Building Occupants Experience of Different Thermal Comfort Experience (Parson,2020)



According to Tetlow et al. (2012) and Nisiforou & Charalambides (2012), the promotion of energy awareness can enhance occupant comfort and productivity, as well as foster energy-conscious operations. In order to modify the conduct of occupants and regulate device usage, novel approaches for managing building energy and enhancing comfort levels must be employed. The present scenario necessitates an interface that is grounded in practicality and is fortified by robust computational assistance. According to the study conducted by Assche et al. (2012), there exists a variation in office tasks, temperature, and productivity based on their respective functions. The specific type of duties may not be compatible with optimal thermal comfort and performance. For instance, the ideal thermal environment and optimal performance may coincide when performing creative mental work. Conversely, for some types of mental work, a slightly colder environment may be necessary for optimal/increased productivity (Haroglu, 2012). These results emphasize the need of considering office responsibilities when choosing an office's thermal design. To maintain overall occupant comfort and productivity, local control systems should be implemented in various office job zones.

Figure 8

Local Control Systems for Thermal Comfort in An Office Space (Kampmann,2020)



Indoor Air Quality Performance in Building

Indoor air pollution is a major environmental, health, and economic issue in most countries. Al Horr et al. (2016a) found that indoor air pollution is more prevalent than outdoor pollution. Thus, indoor air has been the main source of air contaminants, not outdoor air. Most individuals spend 80-90% of their day within a building, whether at their house, at the office, or somewhere. The quality of indoor air should be examined more frequently compared to outside air quality. Hamedani et al. (2019) defined indoor air as air within a building inhabited for no less than sixty minutes by individuals with varied health issues. Hoskins (2003) A building is defined as any home, or covered shelter, regardless of use. The occupational standard excluded all structures except homes, schools, restaurants, public spaces, residential institutions, and workplaces. Hu and David (2021) defined "indoor air quality" as all factors affecting wellness and good health. As a result, factors of indoor air quality have to evaluate the extent to which it fits respiratory and thermal demands, protects against pollutants, and promotes health. Indoor air quality is the presence of contaminants at levels that threaten occupant health (Jung et al., 2021). According to Kubba (2016), indoor air pollution is a measurement of acceptable air pollutants, comfort, and the standard gas concentration needed for respiration. Poor indoor air quality can worsen indoor air pollution. Liu et al. (2017) list five main causes of indoor air pollution: an inadequate ventilation system, smoking, untidy clothing, shoes and hair, building products like powder and fibre, and processing methods like heating, grinding, sawing or crushing. However, the World Health Organisation (WHO) in 1982 found that at least 30% of building occupants, especially those in air-conditioned offices, experience a variety of irrational symptoms, collectively called “sick building syndrome" (SBS).

Figure 9

Common Indoor Air Pollutants in Our Houses (BASF Industries, 2020)

According to Rajagopalan et al. (2022), a building that is conducive to good health can have a positive impact on the well-being of its occupants. The World Health Organisation established a definition for the concept of health in the year

1946. This definition posits that health is characterised by the absence of disease and the presence of sound mental and social well-being. According to Roumi et al. (2021), it is advisable to optimise the well-being characteristics of a building to enhance the comfort and satisfaction of its occupants. The factors under consideration are air quality, thermal comfort, aural comfort, and spatial dimensions. According to Roumi et al. (2022), it is imperative for an office's behaviour and environment to align with the needs and satisfaction of employees, as these factors have a significant impact on work output. According to Sakellaris (2016b), the standard of the office environment is contingent upon a range of factors such as the occupants' capacity and proficiency to establish a physical connection with their workspace, the interactions among office workers, and individual conduct. Dubos (1969) posited that humans are incapable of adapting to air pollution that contains harmful compounds. The anticipated outcomes of the former are presumed to be immediate and targeted, modifying the individual's physiological and psychological conditions in reaction to external stressors.

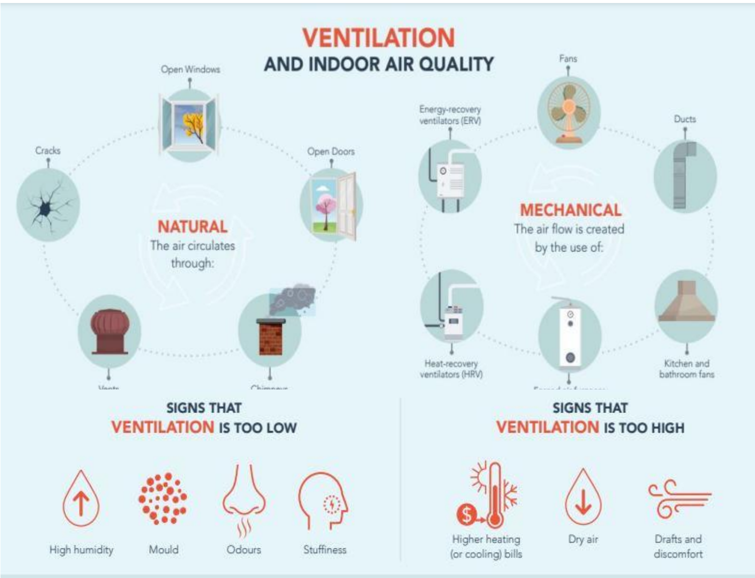
Selye (1956) posited that exposure to environmental stressors triggers the adaptation syndrome, which manifests in psychological responses such as the desire to vacate the premises. According to Suzuki et al. (2019b), indoor air pollution can result in two distinct types of psychological effects. The first type concerns the direct and specific impacts of certain contaminants on the behavioral system, such as how well memory functions. The second type of effect is more complex and involves psychological reactions that impact mood state, motivation, and interpersonal relationships. The second approach induces activation of the sympathetic nervous system of the building's inhabitants, resulting in heightened levels of tension and anxiety. This particular symptom has the potential to induce feelings of anxiety, fear, or dread among residents, thereby elevating their heart and respiratory rates.

Indoor Air Quality and Ventilation

The Indoor Air Quality (IAQ) of buildings is assessed through measurement. The level of indoor air quality has a significant impact on workplace productivity. According to Langer and Beko (2013) and Ng et al. (2012), the enhancement of air quality has been found to have a positive impact on office activities such as typing, proofreading, and arithmetic calculations. A significant proportion of individuals who participated in indoor air quality assessments expressed dissatisfaction with the indoor air quality of buildings that conform to industrial air quality regulations. The authors of the study by Wang et al. (2021) engage in a discussion regarding the health concerns of individuals occupying a building. Yadav et al. (2017) have identified several medical conditions, namely SBS, allergies, and asthma. Sick Building Syndrome (SBS) related to building conditions. Typical symptoms of Sick Building Syndrome (SBS) include ocular discomfort characterised by dryness, itchiness, pain, and burning sensation, as well as nasal irritation and sinusitis-like manifestations. According to Zhang et al. (2019), symptoms such as headaches, fatigue, respiratory discomfort, and mental exhaustion are also observed. Given the worldwide prevalence of these symptoms and illnesses, scholars are conducting investigations into the constituents of indoor air quality.

Figure 10

Ventilation and Indoor Air Quality Graphical Representation (Health Canada, 2019)

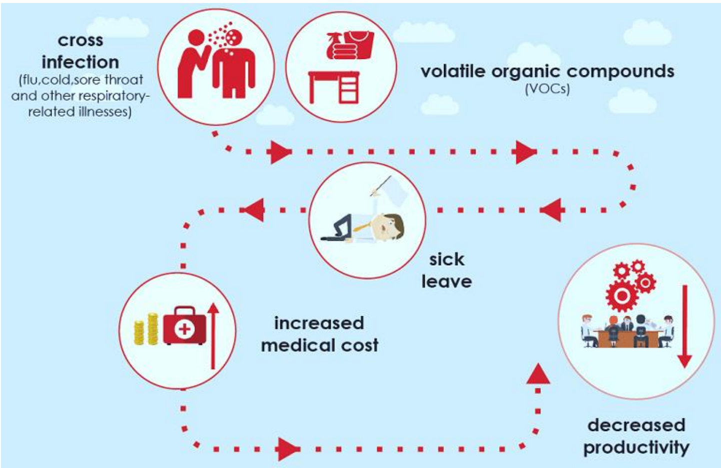


The evaluation of indoor air quality presents a challenging task. The time-varying constituents of indoor air quality (IAQ) encompass both physical and chemical factors, such as temperature, relative humidity, and airborne contaminants. The variables in question are influenced by a range of factors, including the external environment, the materials used in construction, the building's structural design, the

HVAC system, the layout of indoor spaces (including furnishings, furniture, and equipment), and the patterns of occupant productivity. The variables in question are subject to the influence of variations and interactions, and are characterised by a high degree of interconnectedness, as noted by Szczurek et al. (2015). To enhance the quality of indoor air, one may either augment ventilation or diminish air pollution. According to Zhang et al. (2022), the process of ventilation serves to eliminate indoor pollutants such as carbon dioxide. Ventilation rates serve as effective indicators of indoor air quality. Increased ventilation rates have been shown to enhance the quality of indoor air. According to Kamaruzzaman et al. (2017), there exists a correlation between inadequate indoor air quality and the manifestation of Sick Building Syndrome (SBS) symptoms, as well as decreased productivity. Studies conducted in Europe have established a correlation between ventilation rates that fall below 10 Ls-1 (litre per second) and the onset of Sick-Building Syndrome and other health-related complications (Clements-Croome & Baizhan, 2000; Lee et al., 2022). Elevated rates of ventilation have the potential to augment energy consumption within the constructed milieu.

Figure 11

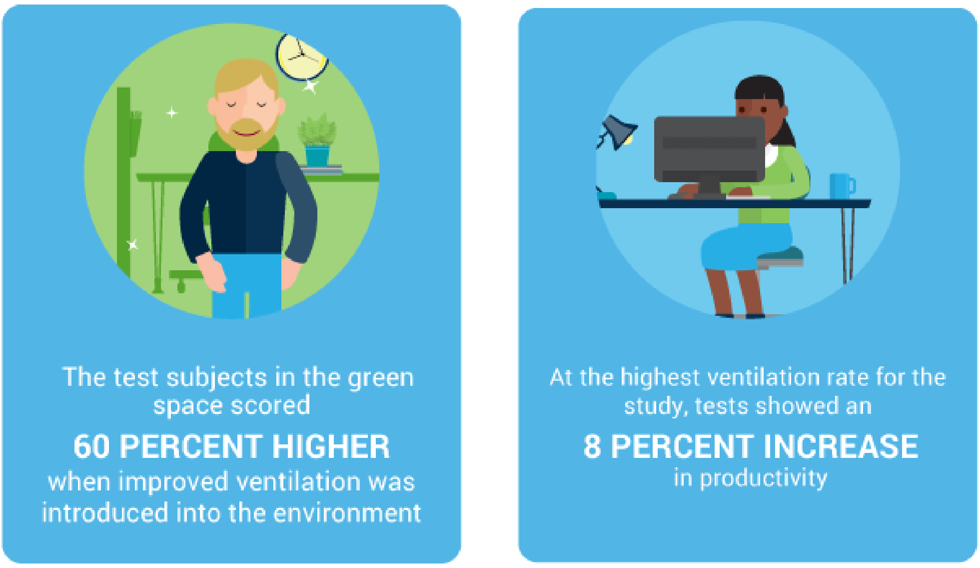
Sick Building Syndrome and How It Leads to Decrease in Productivity (Medklinn,2022)



According to research conducted by Nasrollahi et al. (2007), improved IAQ would increase occupant productivity, which would benefit both the occupants and the building as a whole. According to Lii et al. (2006), Higher ventilation rates in a building can yield financial advantages ten to sixty times higher than its yearly energy and maintenance expenditures. There are several ventilation systems used to control the rate of airflow in buildings. Naturally ventilated systems, hybrid/mix mode systems, and air-conditioned systems are among them. According to studies, mixed-mode heating and cooling systems deliver higher air quality and use less energy than traditional HVAC systems. (Tharim et al., 2017).

Figure 12

Demonstration of Increased Productivity Due to Improved Ventilation Rates (Piers, 2015)



According to Putra and Chandra's (2015), the utilization of air conditioning, with or without humidification, is significantly more probable to result in one or more symptoms of Sick Building Syndrome (SBS) (30-200%) in comparison to natural ventilation, as indicated by Sakellaris et al. (2016b). According to Bluyssen et al. (2016), careful consideration of the regional climate, building characteristics, and occupants' behaviors and preferences is crucial when selecting an appropriate ventilation system. Mechanical ventilation systems are commonly utilized in regions with high temperatures. Conversely, Personalized Ventilation (PV) systems exhibit potential utility in regions with high temperatures and humidity levels, such as Abuja, Nigeria, where occupational activities are prevalent. Personalized ventilation can serve as a supplementary system to the primary air conditioning system, resulting in potential energy savings of 15% to 30%. The authors of the publication cited are Al Horr et al. and the work was published in 2016. The provision of immediate fresh air to the vicinity in which individuals are inhaling is facilitated. According to Savelieva et al. (2019), the integration of photovoltaics and central air conditioning can facilitate the management of poor indoor air quality. A correlation has been observed between an increase in indoor air pollution and a decrease in work productivity. According to Thach et al. (2020), Indoor contaminants such as volatile organic compounds (VOCs) and formaldehyde are common in the indoor environment. According to Wolkoff (2013), The presence of chemical and biological volatile organic compounds (VOCs/MVOCs) in the atmosphere has a direct impact on the indoor air quality. Volatile organic compounds (VOCs) can originate from both anthropogenic and biogenic sources. Volatile organic compounds (VOCs) emanate from natural sources such as oceans, volcanoes, and forests. Volatile organic compound (VOC) emissions are also attributed to human activities in the industrial sector, petrochemical industry, and vehicular emissions, as noted by Panagiotaras et al. (2014).

According to the study conducted by Panagiotaras et al. (2014), volatile organic compound (VOC) emissions are not solely attributed to indoor cooking and smoking activities. Volatile organic compounds (VOCs) are also emitted by carpet, furniture, paint, and cleaners. The levels of volatile organic compounds (VOCs) are comparatively elevated in recently constructed buildings as opposed to those that have been in existence for a longer period of time. According to Thach et al. (2020), research indicates a decrease in the concentration of volatile organic compounds within the indoor settings of the majority of buildings over a period of time. According to Wolkoff (2013) and Panagiotaras et al. (2014), the majority of volatile organic compounds are characterized by their unpleasant odour and irritant properties. Coulby et al. (2020) have established regulations and norms within the industry regarding the acceptable levels of contamination. Volatile organic compounds (VOCs) exhibit a diverse array of physical and chemical characteristics. The complexity of the issue makes it challenging to establish comprehensive sampling and testing protocols for volatile organic compounds (VOCs). The selection of sampling techniques is contingent upon the substances under investigation, with a particular emphasis on physiological factors (Panagiotaras et al., 2014; Ortiz & Bluyssen, 2022). The identification and mapping of volatile organic compounds (VOCs) in a given region is a challenging task due to the variability in individual responses to various substances.

According to Panagiotaras et al. (2014), the prevalent methods for sampling and analysing indoor air are TO and IP. In 1988, Fanger introduced the Olf and Decipol units as a means of quantifying indoor pollutants and identifying their sources, including but not limited to furniture and ventilation systems. The term "olf" refers to the rate at which pollutants are emitted into the atmosphere. The level of pollution emitted by an individual is comparable to the average amount of pollution released into the atmosphere. Building materials are believed to emit between 0.1 and 0.2 olf/m2. Decipol is a metric that reflects the perception of air quality by the general public. A Decipol is a unit of measurement used to quantify an individual's respiratory emissions resulting from the inhalation of 10 litres per second of uncontaminated air. An equation utilising Decipol units was developed by Kosonen and Tan (2004) and Fanger (1988) to estimate the quantity of displeased building inhabitants as a function of their perceived air quality.

Factors of Indoor Air Quality

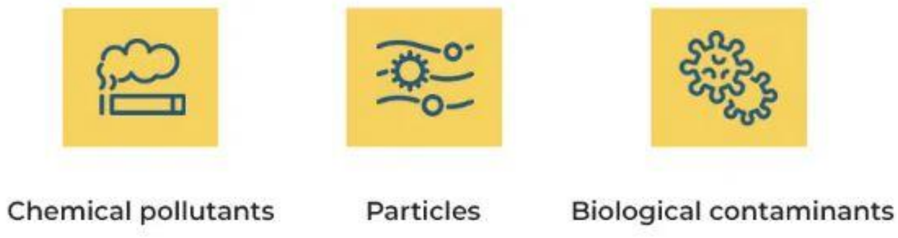
The concept of indoor air quality cannot be generally defined because of the numerous elements that influence the type, levels, and effects of contaminants in the air. Several factors contribute to indoor air quality, such as potential sources of pollutants or odours, the design, upkeep, and functioning of ventilation systems, moisture and humidity levels, and the perceptions and sensitivities of individuals occupying the building. Additionally, there exist a multitude of factors that can impact an individual's level of comfort with regards to the quality of the indoor air. In order to regulate the quality of indoor air, it is imperative to implement three fundamental strategies. The initial measure towards mitigating pollution is regulating the origins of pollutants. This objective can be achieved through various means such as evacuation of individuals from the premises, installation of physical obstructions, modification of air pressure dynamics, or imposition of usage restrictions. Subsequently, the subsequent measure involves the attenuation of the harmful substances, succeeded by the implementation of a ventilation system to eliminate them from the edifice. Employ filtration techniques to eliminate harmful substances from the atmosphere.

Management of Pollutant Sources

Pollutants can originate from various sources, both external and indoor. These sources encompass a range of activities and factors such as building maintenance, pest control, housekeeping, remodelling or renovation work, the introduction of new furnishings or finishes, and even the day-to-day activities of occupants. Mitigating people's contact with contaminants stemming from these factors is a fundamental aim of any indoor air quality initiative. Several significant categories of pollutants include:

Figure 13

Three Main Pollutant Sources (Shineservices,2019)



Chemical Pollutants

Chemical pollutants are sourced from various origins such as tobacco smoke, emissions from building products (including workplace furnishings, furniture, wall and carpeting, cleaning products and consumer goods), inadvertent chemical spills, and combustion byproducts such as carbon monoxide and nitrogen dioxide.

Figure 14

Chemical Pollutants Found in the Office (Matthew Micheletty,2018)

Particles

Particles are substances that exist in either solid or liquid form and possess a low enough density to remain suspended in the air. The most sizable particles can be observed with the naked eye when illuminated by sunlight entering a room. Nevertheless, minuscule and imperceptible particles pose a greater risk to human health. Airborne particulate matter can infiltrate a building through outdoor sources or can be generated by indoor processes such as woodworking, plasterboard sanding, printing, copying and smoking.

Figure 15

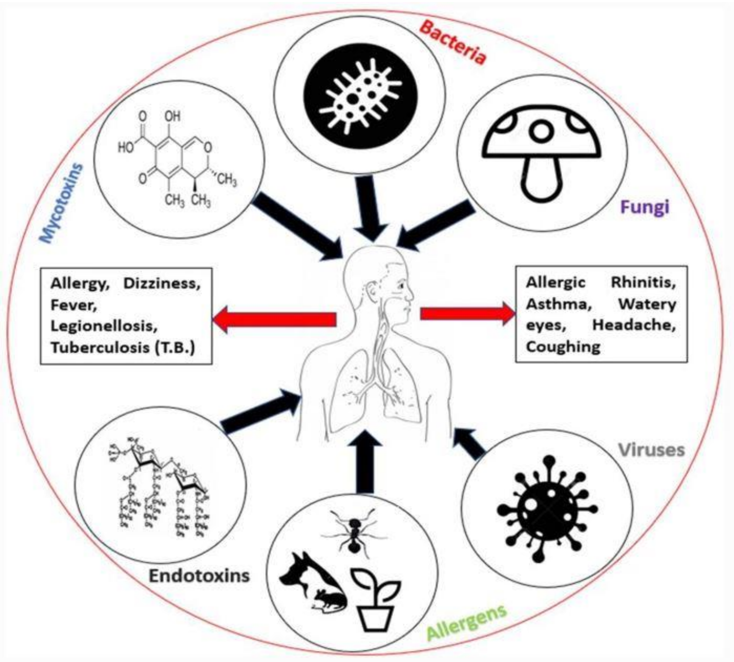
Common Sources of Particles that Contaminate the Indoor Air Quality (Andrew, 2019)

Biological Contaminants

Insufficient cleaning and maintenance, Human activity causes water spills, insufficient humidity management, condensation, and the entry of germs, viruses, fungi (such as mold), allergies, and pollen, infiltration, or ventilation can lead to significant growth of these microorganisms. Individuals who exhibit an allergic response experience symptoms upon exposure to indoor biological pollutants, which is a significant contributing factor to the high incidence of asthma attacks among the Nigerian population.

Figure 16

Biological Contaminants and their Effects on the Human Body (*Pradeep, 2021*)



Design, Maintenance, and Operation of Ventilation Systems in Buildings

In order to uphold superior air quality, it is imperative to take into account the HVAC system, architecture, and pollution management of the building. According to Fengxian et al. (2022), HVAC systems encompass both the apparatus utilised for heating, cooling, and ventilation within a structure, as well as the ductwork responsible for filtering and purifying the air. The aforementioned systems have the potential to influence the transportation and elimination of pollutants. Heating, ventilation, and air conditioning (HVAC) systems have the potential to emit pollutants. According to Lin et al. (2013), the growth of mould in drip pans or air ducts can occur in the absence of moisture control, when ventilation air filters become soiled or damp. Effective management of indoor air quality encompasses:

Ventilation System Design

When designing an HVAC system, it is crucial to take into account the anticipated number of occupants as well as the quantity of machinery present in the building. Modifications to the heating, ventilation, and air conditioning (HVAC) system may be requisite in instances where the rooms within a structure are utilised for purposes other than their initial intended function. In the event of a conversion of a warehouse into a residential space, it may be imperative to make alterations to the heating, ventilation, and air conditioning (HVAC) system.

Outside Air Supply

Adequate ventilation is essential in any workplace to mitigate the impact of pollutants emanating from equipment, building materials, furniture, goods, and occupants. This may be accomplished by maintaining a sufficient amount of air from the outdoors via the HVAC system. The level of comfort experienced by individuals is contingent upon the distribution of air.

Figure 17.

Window Design for Outside Air Supply of the National Assembly (Author, 2023)

Outdoor Air Quality

The presence of external air pollutants, including but not limited to carbon monoxide, pollen, and dust, can potentially affect the quality of indoor air due to their infiltration into a building's ventilation system. A significant proportion of the particles present in the external supply air can be effectively trapped through the correct installation and regular maintenance of filters. In order to regulate gaseous or chemical pollutants, it may be necessary to utilise filtration equipment of a more intricate nature.

Space Planning

The quantity of air that flows within an enclosed space is influenced by variables such as its arrangement and the quantity of occupants present. Placing a computer in close proximity to a thermostat or HVAC control device may result in an overcooling of the room due to the thermostat's misinterpretation of the temperature as excessively high. Impeding the flow of air through supply or return air registers via furniture or partitions may impact the indoor air quality.

Equipment Maintenance

The maintenance of the HVAC system is a crucial factor that determines the quantity and quality of air in a building. Effective building management entails establishing regular preventive maintenance protocols to ensure optimal functionality of HVAC systems. Implementing regulations on highly polluted routes. Contaminants have the potential to disperse throughout a structure via various pathways such as stairwells, lift shafts, wall cavities and utility chases. Certain sources may require specific measures such as specialised ventilation or other forms of control.

Post-Occupancy Evaluation

Post-Occupancy Evaluation is a systematic approach utilised to assess the performance of a building subsequent to its occupancy, with the aim of enhancing its utility and functionality. Post-Occupancy Evaluation (POE) can provide valuable insights into the practical usage of buildings and suggest potential enhancements to align with the requirements of their inhabitants.

The primary objective of Performance-Oriented Engineering (POE) is to assess the efficacy of design techniques in fulfilling the requirements of occupants. According to Crawford and Stephan's (2017) study, the integration of feedback from building users during the design phase can result in improved building performance and outcomes. Post-Occupancy Evaluation (POE) can aid in identifying unanticipated issues that may have arisen during the design phase, such as concerns pertaining to noise, lighting, or thermal comfort (Aksamija & Behzadan, 2019).

There are various methodologies that can be employed to conduct a post-occupancy evaluation (POE), including but not limited to surveys, interviews, observations, and environmental monitoring. According to Zeiler (2014), the selection of a research method is contingent upon the research questions that necessitate resolution, as each method has its own advantages and disadvantages. Surveys and environmental monitoring are two methods that can be employed to gather information regarding the satisfaction and preferences of a building's occupants, as well as objective data pertaining to indoor air quality, thermal comfort, and utilization of energy.

Figure 18

POE Evaluation Process (Author, 2023)

POE data may be utilized to guide a variety of design decisions and building management techniques. For example, if tenants notice illumination concerns, the lighting design may need to be adjusted to increase visual comfort. Similarly, if energy consumption is higher than planned, the HVAC system may need to be adjusted to maximize energy performance (Hensen et al., 2019).

Work Productivity

Work productivity is an important facet of organizational success that has piqued the interest of scholars, employers, and employees. There are many variables that can affect how productive an employee is at work, including organisational, individual, and work environment variables. Researchers have also investigated the influence of indoor environmental quality (IEQ) on work efficiency in recent years, with an emphasis on elements such as thermal comfort, air quality, and illumination.

Several research have established a link between IEQ and job productivity. Hedge et al. (2004) discovered, for example, that better air quality and thermal comfort resulted in a 6% increase in productivity. Furthermore, Wargocki et al. (2015) discovered that enhanced lighting conditions resulted in a 10% improvement in productivity. These data imply that having a comfortable and healthy work environment might boost productivity dramatically.

Individual characteristics such as stress, job satisfaction, and motivation, in addition to IEQ, have been proven to influence work productivity. According to research conducted by Judge et al. (2001), job happiness is closely connected to work productivity, with pleased employees being more productive than dissatisfied ones. Similarly, Latham and Pinder (2005) discovered that motivation was a major predictor of labor productivity in their study. These findings emphasize the significance of addressing individual characteristics in order to improve job productivity.

Work productivity has also been found to be influenced by organizational characteristics such as leadership and organizational culture. Schneider et al. (2013) discovered that a favorable organizational culture increased work productivity whereas a bad organizational culture decreased work productivity. Avolio et al. (2009) discovered that transformative leadership was positively connected with job productivity in their study. These findings imply that addressing organizational characteristics might also help to increase job productivity.

Aside from these considerations, technology improvements have been demonstrated to have an influence on job productivity. For example, Cheng and Furnham (2014) discovered that using smartphones and other mobile devices enhanced job productivity. Similarly, Greenberg and Pierscionek (2013) discovered that using electronic health records in hospital settings enhanced labor productivity. These findings imply that adopting new technology can help to increase job productivity.

It should be noted, however, that the link between employee productivity and these elements is complicated and nuanced. For example, although some studies have discovered a favorable relationship between job productivity and technological improvements, others have discovered a negative relationship, with employees feeling more stress and distraction as a result of the usage of technology (Mark et al., 2014). Similarly, while better IEQ has been shown to boost job productivity, the link between individual IEQ characteristics and work productivity may differ depending on the environment (Lee et al., 2019).

Work productivity is a multidimensional concept influenced by a variety of elements such as IEQ, individual characteristics, organizational factors, and technology improvements. While various studies have established a favorable relationship between these qualities and job productivity, it is critical to examine the context as well as the potential trade-offs associated with each element.

Occupant Health and Well-being

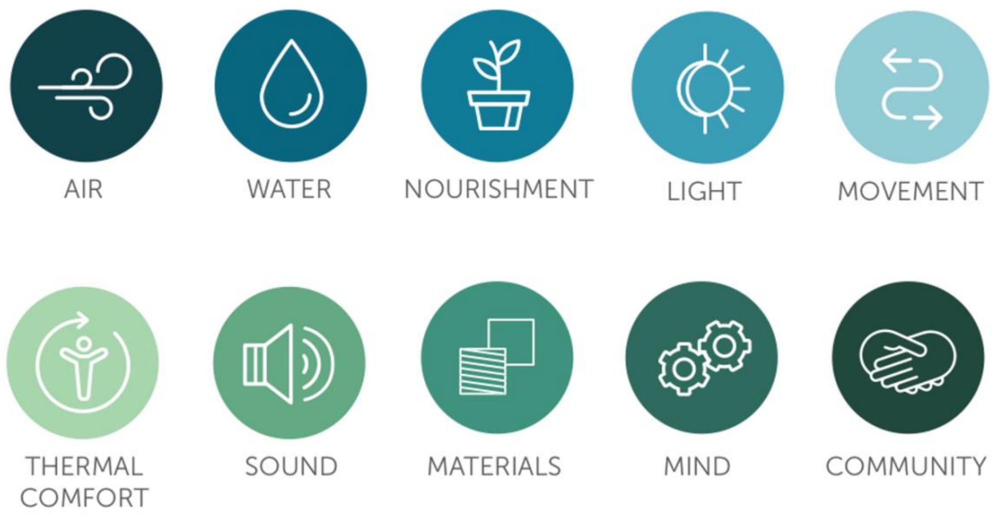
The health and well-being of occupants are critical components of a sustainable built environment. The quality of indoor environmental conditions in buildings may have a substantial influence on the health and well-being of building occupants. As a result, there is an increased interest in developing building design solutions that promote healthy and comfortable interior settings. This review of the literature gives an overview of the major elements influencing occupant health and well-being in buildings, as well as the numerous tactics that may be used to promote healthy indoor environments.

The indoor environmental quality (IEQ) significantly impacts the well-being and contentment of individuals occupying a building. The term Indoor Environmental Quality (IEQ) pertains to the degree to which a given space satisfies specific criteria for factors such as air quality, thermal comfort, lighting, and acoustics. According to Wargocki et al. (2015), there exists a correlation between inadequate indoor air quality and a range of health concerns such as respiratory complications and allergies. Thermal discomfort can cause stress, decreased productivity, and other health issues. Poor lighting can cause eye strain and headaches, while loud music might induce tension and hearing difficulties. Improving IEQ is thus a critical technique for boosting occupant health and well-being.

To increase IEQ and promote occupant health and well-being, a variety of building design solutions may be used. The first strategy is to build with low-emission materials. VOCs (volatile organic compounds) emitted by building materials can cause respiratory difficulties and other health concerns. As a result, utilizing low-emission building materials can enhance indoor air quality while also promoting occupant health and well-being (Gormley et al., 2015). The second technique is to make sure there is enough ventilation. Proper ventilation may aid in the removal of contaminants and the maintenance of excellent indoor air quality. The third method is to make advantage of natural light and vistas to the outside. Natural light and outside vistas have been found to promote occupant health and well-being (Heschong Mahone Group, 2003). The fourth technique is to make certain that suitable acoustic design is used. Because noise may lead to stress and other health issues, effective acoustic design is critical for optimizing occupant health and well-being.

Figure 19

Concepts to Consider for Occupants Wellbeing in a Building (Well v2, 2020)



Indoor thermal comfort is another important aspect influencing occupant health and well-being. Thermal discomfort has been linked to stress, decreased productivity, and other health issues in studies (Fanger, 1970). As a result, it is critical to keep interior temperatures within a comfortable range. Thermal comfort standards created by the ASHRAE are extensively utilized in building design (ASHRAE, 2017). The standard suggests a winter temperature range of 68°F to 76°F and a summer temperature range of 73°F to 79°F. Thermal comfort design is critical for improving occupant health and well-being.

Aside from IEQ and thermal comfort, building design may have an influence on occupant health and well-being via influencing physical activity levels. Sedentary lifestyles have been linked to a variety of health issues, including obesity, diabetes, and cardiovascular disease (Katzmarzyk et al., 2009). As a result, physical activity-inducing building design solutions can improve occupant health and well-being. Providing stairs instead of elevators, for example, can stimulate physical exercise, while walking routes and bike racks can encourage active transportation.

The health and well-being of building occupants are critical components of a sustainable built environment. The quality of indoor environmental conditions in buildings may have a substantial influence on the health and well-being of building occupants. As a result, solutions for building design that encourage healthy and comfortable interior environments are crucial. Improving indoor environmental quality (IEQ), guaranteeing thermal comfort, and encouraging physical activity are all critical techniques for boosting occupant health and well-being in buildings.

Factors that Affect Occupant Comfort and Productivity

A lot of personal and environmental factors, as well as those that directly affect how much pollution people are exposed to, can affect how people feel about the air quality. Some of these things affect both the amount of pollution and how people feel about the air quality.

a. Unpleasant smells.
b. Temperature -- too hot or cold.
c. Air flow and movement – excessively cold or stuffy.
d. Heat or glare from sunlight.
e. Glare from ceiling lights, especially on monitor screens.
f. Overcrowding of furniture.
g. Workplace or household stress.
h. Sentiments regarding the geographical placement, occupational milieu, illumination, and embellishment of the workplace.
i. Work space ergonomics, including height and location of computer, and adjustability of keyboards and desk chairs.
j. Levels of Noise and disturbance.
k. Selection, location, and use of office equipment.

Indoor Air Quality: A Shared Responsibility

Inadequate HVAC design has the potential to impact the quality of indoor air. The HVAC system's management and the inflow of outside air may be managed by the building's administration. Typically, lessees and inhabitants of a building bear the responsibility of procuring and utilising materials and commodities for restoration purposes. The maintenance and cleanliness of a building necessitate the collaboration of both management and employees. The aforementioned factors render the maintenance of indoor air quality a frequent responsibility. The implementation of strategies for managing indoor air quality holds significance, as stated by Wang et al. (2014). Additional variables, such as the response of individuals with high susceptibility to indoor air pollution or outdoor air conditions, remain beyond our control. It is imperative to bear in mind that inadequate indoor air quality in any building can be attributed to system malfunction, substandard maintenance, or actions of building occupants (Esfandiari et al., 2017). It is important to note that a significant number of purported indoor air quality concerns are, in fact, related to issues of comfort, such as extreme temperatures, humidity levels, or air circulation. Several symptoms, such as headaches, can be attributed to non-structural factors.

Theoretical Framework

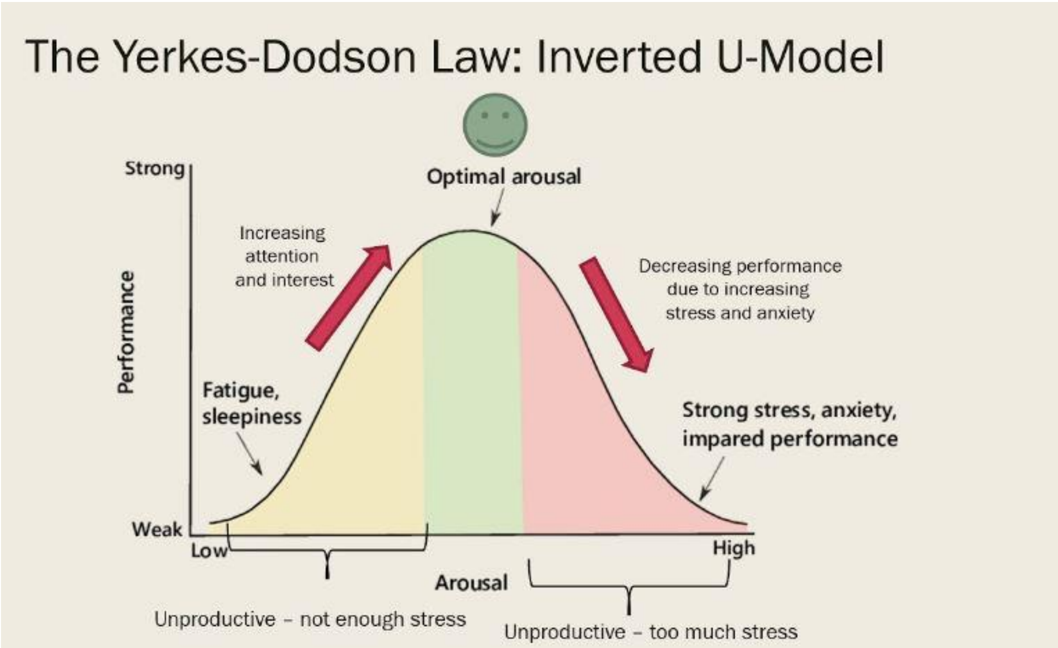
The present study elucidates five theoretical frameworks that explicate the correlation between indoor environmental quality and employee productivity. The aforementioned theories elucidate the subject of inquiry through diverse viewpoints, thereby promoting understanding.

The Arousal Theory

The Arousal Theory examines the impact that arousal has on performance in addition to the physiological reactions that are elicited by various forms of environmental stimulus. Productivity in the workplace is at its peak for occupants when they are at an intermediate degree of arousal, but it declines as the amount of arousal is raised or lowered. The Yerkes-Dodson law establishes a correlation between the level of arousal and an individual's performance. The aforementioned inverted-U relationship exhibits slight variations contingent on whether the assessment of productivity is conducted on tasks that are facile or arduous. Empirical research has provided support for this theory, as evidenced by the preference of individuals for moderate stimulation (Al Horr et al., 2016b). Additionally, certain cultures have been observed to flourish in environments that present moderate challenges. This theory was developed by anthropologists and sociologists. These findings can be explained in part by the correlation between a rise in the temperature of the surrounding environment and an increase in arousal levels. A higher level of arousal initially results in improved performance; but, when the level of arousal continues to rise, it eventually leads to over-arousal, which in turn results in decreased performance. In a similar vein, it has been demonstrated that invasions of one's personal space result in higher levels of arousal (Middlemist, Knowles, & Matter, 1976) as well as declines in performance (Evans & Howard, 1972).

Figure 20

Inverted U-Model of The Yerkes-Dodson Law (think360studio, 2021)



The Behaviour Constraint Theory

The actual or imagined limitations imposed on an organism by its environment are the primary subject categorized as behavior constraint theory. This theory proposes that the surrounding environment possesses the potential to direct, constrain, or restrict an occupant's activity (Stokols, 1978). The reactance hypothesis proposed by Brehm (1966) served as the foundation for the development of the behavioral constraint model. This theory asserts that people have a fundamental urge to retain their behavioral freedom. It is said that an environment is restrictive when it prevents a person from achieving his or her goals due to some inhibiting factors. Some aspects of the working environment, such as the temperature in the office or the location of the company, as well as other aspects, such as inclement weather, may be perceived by employees as factors limiting their freedom. When faced with such a predicament, the occupant feels helpless and out of control. According to Wortman and Brehm (1975), an individual occupant will stop making instrumental efforts and will instead enter a helpless condition if failures or a loss of control continue for a prolonged period of time without any prospects of recovery. This is the conclusion that can be drawn from the research of Wortman and Brehm. Allen and Greenberger (1980), who have conducted extensive research in this area, postulated that if a person's attempts in the past to change his or her social environment have been unsuccessful, the individual may try to change his or her physical environment before giving up and admitting helplessness. It is essential to a person's day-to-day existence to feel as though they have some measure of control over their surroundings, as this is beneficial to their health. Individuals are friendlier and more willing to lend a hand when they have a sense of mastery over the circumstances in which they find themselves (Glass & Singer, 1972; Moser & Levy-Leboyer, 1985).

On the other side, the perception that one is losing control has a negative impact on both one's conduct and one's overall well-being and health (Barnes, 1981). Averill (1973), discussed three distinct types of control: behavioral control, cognitive control, and decision control. The first type, behavioral control, gives the subject the opportunity to change upsetting environmental events; the second type, cognitive control, uses reappraisal techniques to make the environment seem less threatening; and the third type, decision control, gives the subject the opportunity to select the best available option. The behavioral constraint model was adopted in this study because it is highly effective in describing and understanding human behavior, particularly with regard to the control component.

The Adaptation-Level Theory

According to the postulations of this theory, each of us has a minimum threshold for a particular level of external stimulus. A slight increase or decrease in this threshold can suggest a concentration of arousal, overload, underload, or stress. Behavioral changes will occur if the input load is greater than our capacity for adaptation. Helson (1964) and Wohlwill (1974) were the two authors who contributed the most to the promotion of this theory. All environmental psychologists highlight the connection between persons and their surroundings; however, adaptation-level theorists place their attention squarely on the processes of adaptation and change, which make up this connection. To ensure their survival, individuals can either adjust to the prevailing circumstances or modify their engagement with the surroundings. The physiological responses of piloerection, muscle rigidity, heightened motor activity, and vasoconstriction are adaptive mechanisms that manifest in reaction to alterations in the surrounding temperature. These responses are also commonly referred to as "goose pimples." Wohlwill (1974) defined three different types of stimulation in addition to the three factors of intensity, diversity, and patterning. These three types are, movement, social, and sensory stimulation. An optimal or intermediate degree of arousal or stimulation is desired for the best responses and work performance. For example, if aloofness and gregariousness are the two extremes of a scale measuring social contact, then a person may favor either of them at some moment in time based on the amount of exposure that they are receiving. The working young population of today surely draws its motivation solely from this hypothesis for their desire to spend some time alone, whether at a tranquil resort or in a remote place.

An additional advantage of using this strategy is that it takes into account individual differences in adaptation level. Adaptation level refers to the degree of stimulation or arousal that a person has become accustomed to and either anticipates or wants in a given circumstance. This methodology explains why two persons respond differently to the identical indoor environmental quality.

However, there might be some differences in the best level depending on the history of each individual and how close they are to a certain region. For instance, a someone who walks into a bangle factory for the first time would find the heat and temperature unbearable, yet the workers there are quite tolerant of it. Those who come from mountainous regions and then move to lowland areas have a greater capacity for withstanding the cold than those who were born and raised in those regions. This change in optimal level is referred to as adaptation. Wohlwill (1974) defined adaptation as a quantitative change in the distribution of affective or judgmental reactions along a stimulus continuum. Adaptation is the outcome of sustained exposure to a stimulus and can be seen as a change in distribution. According to Dubos (1980), adaptation is the process that enables people to change how they perceive their environment, as well as the coping mechanisms that they use in order to deal with the challenges that are caused by that environment. This process is known as adaptation. The fundamental summary of this theory, as well as the reason for its adoption in this thesis is that it explains why each occupant must bear a certain amount of weight in order to adapt to the many stimuli that present in their environment and consequences of exceeding individual weight. If the stimulus load is greater than the level at which adaptation takes place, an occupant's behavior with regard to their employment will alter. Because of this shift in behavior, it's possible that the workforce's productivity will decrease as a result.

The Environmental Stress Theory

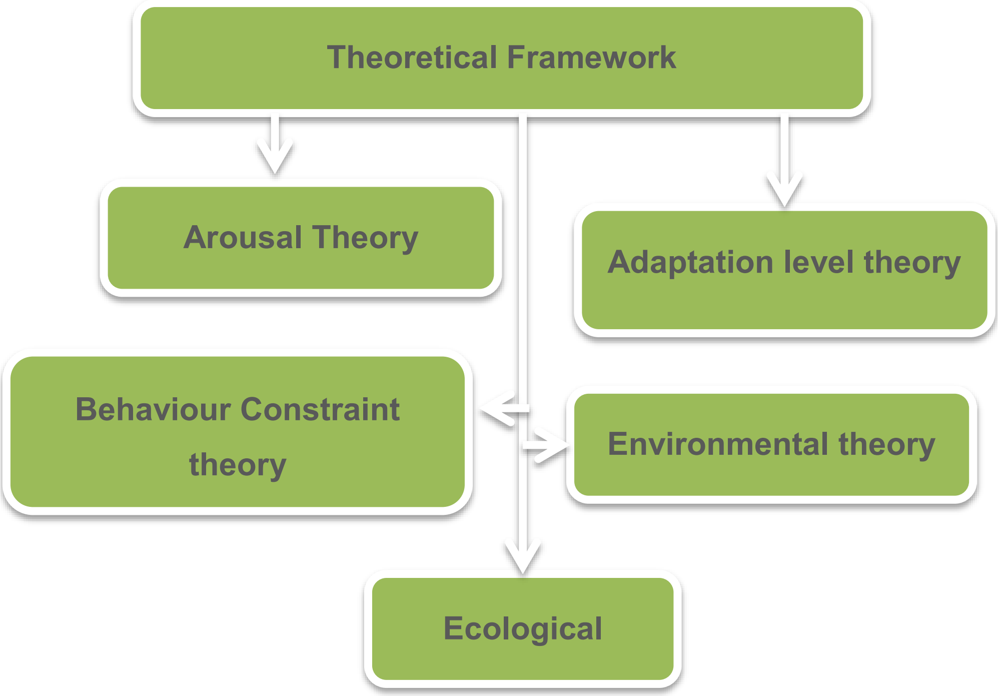
The environmental stress theory investigates the effect of external conditions on an individual's biological adaptability. Stress is a change in the reaction of the mind and body to any event that induces a change. This change could be positive, negative, or monotonous. Individuals experience stress when the demands of their environment surpass their capacity for coping. Coping is the process of regaining control over a stressful or limiting environment. According to the psychological stress model, exposure to environmental factors like temperature or crowding can elicit a variety of physiological, emotional, and behavioral responses, all of which have the potential to bring about a number of unfavorable outcomes (Lazarus, 1996). The environmental situation or stimulation is the stressor, and the related behavior is the stress reaction. The involvement of physiology, emotion, and cognition as mediators in the organism-environment interaction is emphasized by stress theories. The organism is receiving information about the environment through its senses, and this information can trigger a stress response if the organism's exposure to the environment is greater than some ideal threshold. The organism subsequently reacts so as to alleviate the stress. A portion of the stress reaction is innate. Initially, a variety of physiological systems are altered as a result of the stressor's alarm response. The organism then develops resistance as it strives to combat the stressor. Eventually, as coping resources become expended, weariness sets in (Selye, 1956). Negative repercussions, such as performance deficits, psychosomatic complaints, and psychological or physical breakdown, might be noticed, however, if the individual is unable to deal with the stress in a productive manner. The environmental stress model is helpful in understanding the impact that stress has on workplace productivity as well as the behavior of occupants of the office. It also provides a complete analysis of the combined and individual effects of environmental stressors, such as room temperature, on the behavior of people who are in the space.

The Ecological Theory

Ecological theorists, such as Barker (1968), place a significant amount of importance on the organism-environment-fit idea. Some behaviors are supported by environments that are either purposefully created or that develop over time. Barker is credited with coining the term "behavior settings," which are evaluated according to the compatibility between the interdependent environmental elements and the behaviors that are observed. The ecological theory states that there is a symbiotic link between an occupant and their environment, which means that people and their environments are interdependent on one another. The environment exerts a direct influence on human behavior and responses, and even very modest changes or modifications to the latter can result in noticeable shifts in the former. The process by which individuals interact to and react to their surrounding environment is referred to as ecological perception. It paints a picture of a mutually beneficial relationship between species and the environments in which they live. According to this theory, the environment is nothing more than a representation of itself, and it is the individual's perception that paves the way for further investigation into the surroundings (Clayton & Myers, 2009). This theory arrives at the conclusion that there is an interdependent and reciprocal link between the environment and the productivity of its occupants, and it makes this assumption in the process of drawing that conclusion.

Figure 21

Theoretical Framework (Author, 2023)



Related Research

Relationship Between Indoor Environmental Quality (IEQ), Occupant's Satisfaction, and Productivity in an office building in Malaysia

This study was carried out in an office block located in the central region of Kuala Lumpur, Malaysia. A sample of 120 individuals occupying a green-rated office block were requested to express their preferences by means of a seven-point Likert scale, which measures their level of agreement and satisfaction. The research conducted by Zulkefli Mansor et al. (2019) revealed a robust association between the Indoor Environmental Quality (IEQ) of an office building, the contentment of its occupants, and their efficiency, particularly with regards to visual comfort.

Figure 22

The Trx Exchange Tower in Malaysia (Tower Info, 2016)

Findings: the research made key findings which are;

I. Improved Indoor Environmental Quality (IEQ) has been found to have a substantial positive impact on occupant satisfaction and efficiency, particularly in environmentally friendly workplace buildings.

II. Among the different factors that influence IEQ, visual comfort has been found to have the most significant correlation with occupant satisfaction and productivity.

III. The research shows that occupants of the office building in the study had a high level of satisfaction with IEQ factors such as thermal comfort, lighting, and acoustics, but were less satisfied with the cleanliness and air quality of the building.

IV. Additionally, the study found that occupants who perceived higher levels of IEQ were more likely to report higher productivity levels.

Recommendations;

a. To enhance occupant satisfaction and work efficiency in the workplace, building owners and managers should prioritize improving visual comfort.
b. Regular maintenance of building systems like air conditioning and ventilation can lead to better air quality and greater occupant satisfaction.
c. The use of green building practices and materials can also contribute to better Indoor Environmental Quality (IEQ) in office buildings.
d. Building managers should consistently evaluate occupant satisfaction with IEQ and utilize the feedback to determine areas for enhancement.

The Impact of Indoor Environmental Quality on Occupants' Health and Productivity in a Green-Certified Office Building in Beijing

In this investigation, Beijing, China's green office building's occupant health and productivity were compared to IEQ. Through surveys and interviews, they gathered information on the building's thermal comfort, lighting, acoustics, indoor air quality, occupant health, and worker productivity. According to the study's findings, there is a link between occupant health and productivity and IEQ. In particular, it was discovered that better thermal comfort and air quality were positively associated with occupant health, while the right lighting levels were positively associated with workplace productivity. The authors came to the conclusion that improving IEQ in office buildings can significantly affect occupant health and productivity and that obtaining a green certification can be a useful strategy for promoting and achieving IEQ improvements (Jingyi Sun et al., 2020).

Figure 23

Parkview Green Office Building Beijing (Arch Daily, 2022)

Figure 24

An Interior Section of Parkview Green Office Beijing (Arch daily,2022)

Findings; the research made key findings which are;

I. In a green certified office building in Beijing, China, researchers discovered a favorable link between IEQ and occupant health and productivity.
II. It was discovered that improved air quality and thermal comfort were favorably connected with occupant health.
III. Appropriate lighting levels were discovered to be favorably related to workplace efficiency.
IV. According to the study, improving IEQ in office buildings can have a considerable influence on occupant health and productivity.
V. Green certification may be a powerful tool for promoting and achieving IEQ improvements in commercial buildings.

Recommendation: Based on the findings of the study, here are some of the recommendations that were made;

I. In order to maximise occupant health and productivity, building owners and managers should prioritise enhancing IEQ parameters such as air quality, thermal comfort, and lighting.
II. Green certification may be a powerful tool for promoting and achieving IEQ improvements in commercial buildings.
III. Building inhabitants should be enlightened on the significance of IEQ factors and encouraged to play a proactive part in creating and sustaining a healthy and productive indoor environment.
IV. When designing and managing office spaces, building developers and operators should take into account the specific needs and preferences of occupants.

CHAPTER III
Methodology

This section's goal is to explain the study's design and methods employed to investigate the impact of indoor environmental quality on the occupational efficiency of inhabitants in the Nigerian National Assembly. The study aims to examine the methods used for data collection, presentation, and analysis in order to achieve the study objectives. To achieve the objectives of the study, a mixed methodology was utilized. The methodology included both qualitative and quantitative methods, with a combination of literature review and questionnaire survey. The literature review provided a comprehensive understanding of the existing research on indoor environmental quality and its impact on work productivity, while the questionnaire survey was used to collect subjective data from occupants in the National Assembly.

The research methodology utilized a descriptive and quantitative approach. It employed a well-designed questionnaire survey to gather data on occupants' perception of indoor environmental quality and its impact on their work productivity. The administration of the questionnaire to individuals employed in the National Assembly facilitated the acquisition of data that has the potential to illuminate the relationship between Indoor Environmental Quality (IEQ) and workplace productivity.

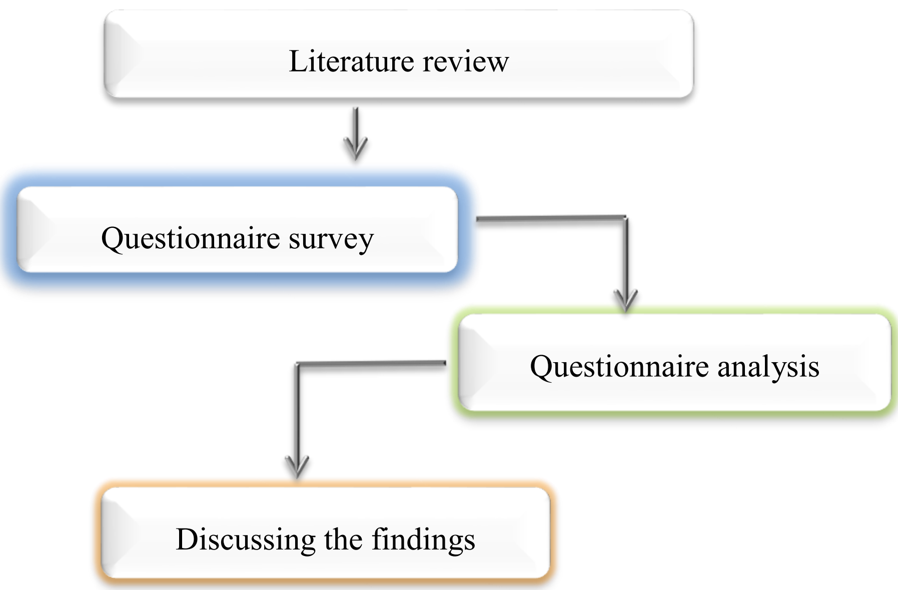
The outcomes of the employed methodology have yielded a comprehensive comprehension of the impact of indoor environmental quality on the occupational efficiency of the occupants of the National Assembly. The study's results will be presented and analyzed in the following chapters.

Research Design

A scientific study's plan is its research design. It consists of research approaches, tools, and techniques. It helps to detect and handle potential issues that may arise during the research and analysis process (Trochim et al., 2015). This investigation employed a questionnaire research design. The term "survey research" refers to a certain kind of research methodology in which the primary way data is gathered is through the use of questionnaires and polls (Zikmund, 1988). In this research approach, the survey research design was employed to acquire a deeper understanding of individual or group viewpoints on the on-going subject.

Figure 25

Research Design (Author, 2023)



Population and Sample

The employees in the Senate Directorate Nominal Roll makes up the population for this study. At the moment, there are about 600 people on the National Assembly Senate Directorate's nominal staff list. The Senate Directorate staff were chosen using the convenience sample approach. A total of 203 participants who are employees working in the National Assembly building in Abuja, the capital city of Nigeria, participated in this study. This number of participants were recruited using the convenience sample approach. According to Sedgwick's (2013) this sampling is a random sampling approach that includes choosing a sample from the population group that is most easily accessible. Prior to participating in the survey, participants must give their consent.

Data Collection Tools

The questionnaire was used as a data collection instrument. In order to collect data from respondents for a survey or statistical analysis, this instrument consisted of a series of questions (or other forms of prompts). Typically, a survey instrument employed in research will encompass a combination of structured and unstructured queries. Individuals have the liberty to express themselves to varying degrees when responding to open-ended inquiries, as they are not confined to a specific format or length. Respondents had a selection of predefined answers to pick from.

Data Collection Procedures

For this study, an online survey was utilized as the primary data collection method. The survey questionnaire was divided into four sections, which included demographic information, Occupancy, Activity and Control Over the Environment, Indoor Environmental Quality, and productivity. Prior to administering the survey, the questions were carefully drafted, and a feedback system was established, the relevant authorities at the survey site were contacted, and a consultant from within the National Assembly volunteered to handle the survey operations. This technique of conducting surveys over the internet is the method that is most ideally suited for surveys that require a sizeable sample size and/or a sample whose members are dispersed across a large geographical area (Evans & Mathur, 2005). This is also less expensive than sending out surveys through mail. One of the process's limitations is that participants must have computer skills and internet-capable devices in order to conduct the survey online (Nayak & Narayan, 2019).

Data Analysis Procedures

This research used the SPSS program to conduct a descriptive analysis of the questionnaire responses. The Pearson product-moment correlation coefficient was employed to evaluate the hypotheses. The Pearson correlation coefficient quantifies the degree of a straight-line connection existing between two different factors. The correlation is represented by the symbol 'r' which quantifies the degree of deviation of the data points. This correlation is a statistical method that aims to determine the most optimal line of fit for two variables' data. The analysis of the data is presented in tables and detailed explanations are provided in addition to the tables presented.

Figure 26

Pearson Correlation Coefficient Value(s) (Dewie, 2016)

Correlation Coefficient Value (r)	Direction and Strength of Correlation
-1	Perfectly negative
-0.8	Strongly negative
-0.5	Moderately negative
-0.2	Weakly negative
0	No association
0.2	Weakly positive
0.5	Moderately positive
0.8	Strongly positive
1	Perfectly positive

Reliability & Validity

After a careful construction, the instrument was sent to the thesis supervisor who is considered an expert to critique and validate if the right component appropriate for providing answers to the research questions have been properly captured and presented in the right format. Peer-review strategy and input from experts in the faculty was greatly considered as dependable elements in ensuring consistency of study goals through the statements rendered in the questionnaire, thereby arriving at reliable data.

CHAPTER IV
Findings and Discussion

The current chapter presents the results of the survey and conducts an in-depth analysis of the obtained data with the aim of addressing the research questions posed in the study. This chapter is broken up into four parts. First, a brief background of the place of study, followed by a discussion on questionnaire distribution. The answers to the research questions are presented in the third section, and the null hypotheses that were developed are put to the test in the fourth section.

Case Study of Nigeria National Assembly Office Building

The Senate and the House of Representatives comprise the National Assembly's political structure. The political composition of each chamber is determined by Sections 47 through 51 of the Constitution and provisions in the Houses' Rules and Standing Orders. The administrative structure of this "bureaucracy" is overseen by the National Assembly's chief administrative and accounting officer or clerk. He is assisted by the National Assembly's Deputy Clerk. The Clerks of the Senate and the House of Representatives are in charge of managing the legislative activities of their respective chambers. They oversee the activities of both houses and carry out political directives. The National Assembly's Clerk and Presiding Officers report to the two clerks.

For the purposes of this thesis, the National Assembly Complex will serve as the case study. The complex serves as the National Assembly's legislative chamber in the Federal Republic of Nigeria. The Department of Public Building, FCDA, Abuja, awarded the contract to ITB Nigeria on February 18, 1996, and it was completed in 1999 for approximately $35.18 million. Abuja, the Three Arms Zones of the Federal Capital Territory, was the location of the Complex. The National Assembly's Legislative and Senate Chambers are housed in a building with a domed roof and a gross floor area of 40,000 square metres. The structural element consists of both precast and cast-in-place concrete. Installations of electrical and mechanical components include central air conditioning, CCTV, access control, and fire detection and suppression systems.

Figure 27

National Assembly Complex Abuja (Getty Image, 2019)

Figure 28

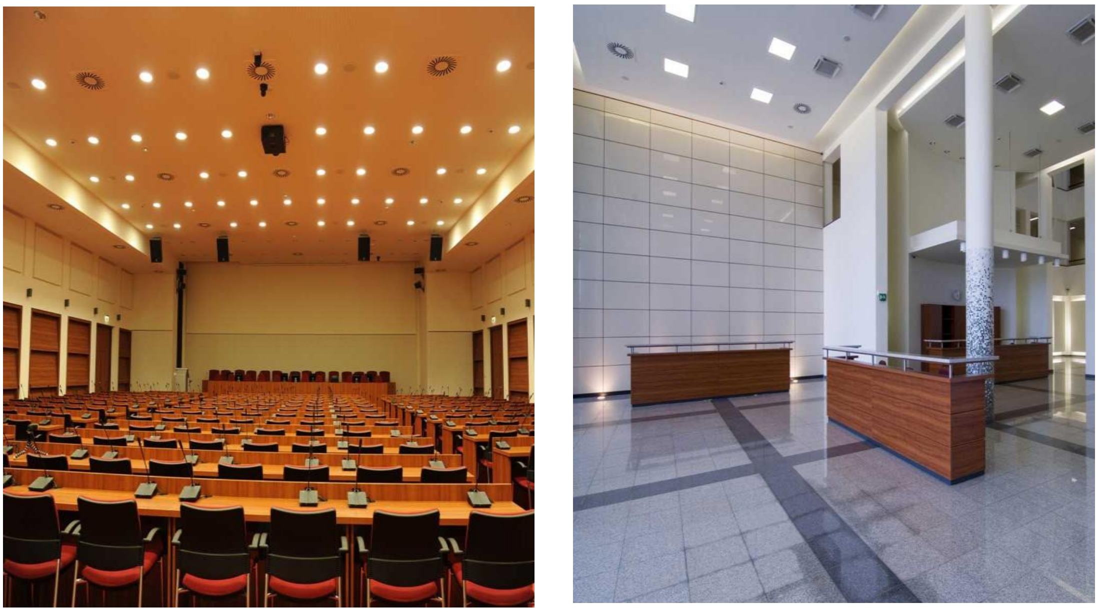
Entrance to The National Assembly Complex (Getty Image,2019)

Figure 29

Windows Position of the National Assembly building (Getty Image,2019)

Figure 30

Interior of The National Assembly Building (Getty Image, 2019)



Questionnaire Distribution

An electronic structured questionnaire was used in this study to elicit responses. It was made available to the respondents through email and social media private pages, after obtaining their consent. This electronic survey lasted a period of 43 days during which the forms were sent and received. The researcher expected over 400 responses from the occupants of the National Assembly. However, a total of 274 responses were received. A total of 203 were sorted valid for analysis while a total of 71 responses were invalid. Invalid responses comprised of forms that had no demographic data; incorrectly filled, double entry, and incomplete filling. The proportion of replies based on legitimate cases, excluding missing or incorrect data, is referred to as the valid percent. Cumulative percent displays the percentage running total as each response or category is added, offering insight into the cumulative distribution. These statistics, used together, aid in analyzing the distribution and relative relevance of the dataset's categories.

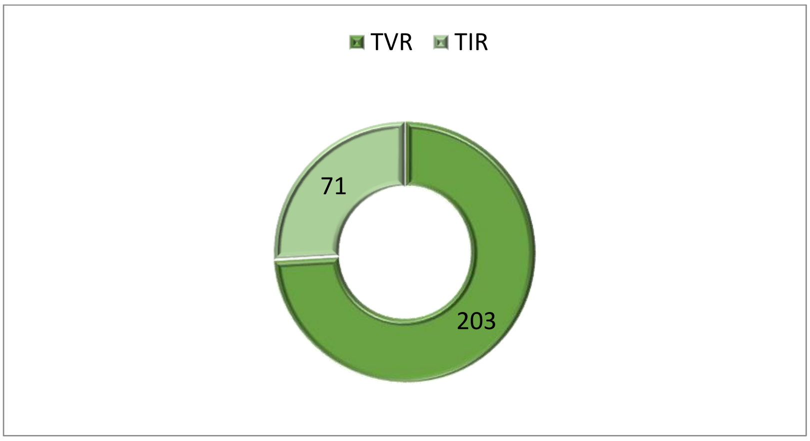
Table 1.

Questionnaire Responses

	Frequency	Percent
Total valid responses	203	74
Total invalid responses	71	26
Total responses received	274	100

Figure 31

Total Valid Response and Total Invalid Response Chart (Author,2023)



Demographic Information

Table 2.

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	Female	100	49.3	49.3	1.5
	Male	100	49.3	49.3	50.7
	Total	203	100.0	100.0	100.0

Table 2 shows a female representation of 49.3% and a male representation of 49.3%. The coincidence in gender equality could be due to high number of invalid votes that would have allowed a difference in gender.

Table 3.

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	20-29	54	26.6	26.6	1.5
	30-39	78	38.4	38.4	28.1
	40-49	51	25.1	25.1	66.5
	50-59	17	8.4	8.4	91.6
	Total	203	100.0	100.0	100.0

Table 3 displays the participant ages. The study revealed that 26.6% of those who participated were between the ages of 20-29 years, while 38.4% belong to the age group of 30 and 39 years. 25.1% of the participants were aged between 40 and 49 years, and 8.4% were aged between 50 and 59 years. The tabular representation illustrates a higher count of individuals belonging to the young adult age group as compared to the older adult age group.

Table 4.

Education Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	Masters	107	52.7	52.7	1.5
	Ph.D.	1	.5	.5	54.2
	High school	17	8.4	8.4	54.7
	Undergraduate degree	75	36.9	36.9	63.1
	Total	203	100.0	100.0	100.0

The table 4 above shows the level of education of the participants. A total of 52.7% have obtained a master's degree, a total of 0.5% have obtained a doctorate, 8.4% had secondary education, while 36.9% have obtained a undergraduate degree. The results shows that respondents are educated, with most respondents obtaining a master's degree.

Table 5.

Employment Duration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	0-5 years	91	44.8	44.8	1.5
	6-10 years	6	3.0	3.0	46.3
	11-15 years	87	42.9	42.9	49.3
	Above 15 years	16	7.9	7.9	92.1
	Total	203	100.0	100.0	100.0

Table 5 gives an insight into the duration of employment for enrolled participants. A total of 44.8% have been employed for a period of 0-5 years, a total of 3% have been employed for 6-10 years, 42.9% have been employed for 11-15 years while 7.9% have been employed in the National Assembly as civil servant for a period of above 15 years.

Analysis of Research Questions

Research Question 1: How does Indoor Air Quality (IAQ) influence occupants' work productivity?

The analysis of Research Question 1 focuses on examining the impact of indoor air quality (IAQ) on occupants' work productivity. This analysis will utilize data collected through the questionnaire survey to provide insights into the relationship between IAQ and work productivity. There are four independent variables related to indoor air quality that were used in the questionnaire, their analysis is shown in the following tables below.

Office occupants are the first factor evaluated for the analysis. Office occupants are an important aspect to consider when analyzing the link between IAQ and productivity. Because various people are sensitive to different IAQ agents, their productivity may be affected differently. The number of people in an office area can have an effect on the concentration of carbon dioxide, which is a measure of indoor air quality. High carbon dioxide levels can cause impaired cognitive function, tiredness, and headaches, all of which can reduce productivity. The survey questionnaire questioned the number of office occupiers, and the results are presented in table 6.

Table 6.

Office Occupants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	3-5	108	53.2	53.2	1.5
	5-10	6	3.0	3.0	54.7
	Less than 3	55	27.1	27.1	57.6
	More than 10	15	7.4	7.4	84.7
	None	16	7.9	7.9	92.1
	Total	203	100.0	100.0	100.0

According to the data presented in Table 6, it is evident that the number of occupants in an office can have a considerable influence on the quality of air in the workplace. The survey responses indicate that the majority of offices surveyed (53.2%) have 3-5 occupants. This suggests that a significant proportion of offices may have a moderate number of individuals working together, potentially leading to increased levels of carbon dioxide (CO_2) and other pollutants in the air. Furthermore, a notable percentage of offices (27.1%) reported having less than 3 occupants. In such cases, the smaller number of individuals in the office could potentially result in improved air quality due to a reduced concentration of CO_2 and other pollutants. Conversely, a smaller proportion of offices (7.4%) indicated having more than 10 occupants, which implies a higher density of workers and, consequently, an increased likelihood of diminished air quality. Interestingly, a small percentage of offices (7.9%) reported having a single occupant. In such instances, the air quality may largely depend on factors unrelated to occupant density, such as the ventilation system, cleaning practices, and the presence of potential indoor pollutants.

The location of windows is the second factor examined in this analysis. This is due to the fact that it can influence the quantity of natural ventilation and sunshine that enters the area, which can affect the concentration of IAQ agents as well as the mood and circadian cycles of the inhabitants. However, the placement of windows might have a detrimental impact on IAQ and productivity. For example, if windows are positioned in a way that allows outdoor pollutants such as traffic exhaust or industrial emissions to enter, this can contribute to poor IAQ and decreased productivity due to discomfort and irritation. Based on this, occupants were asked to rate the level of comfortability with the positioning of the windows in their various offices. The outcomes of their answer are shown in table 7 below.

Table 7.

Position of Windows

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		17	8.4	8.4	
	Comfortable	95	46.8	46.8	8.4
	Very comfortable	1	.5	.5	55.2
	Slightly comfortable	76	37.4	37.4	55.7
	Uncomfortable	1	.5	.5	93.1
	Very uncomfortable	1	.5	.5	93.6
	Slightly uncomfortable	12	5.9	5.9	94.1
	Total	203	100.0	100.0	100.0

According to the data presented in Table 7 above, it appears that the positioning of office windows can have an impact on the comfort level of workers. According to the survey findings, a sizable proportion of respondents (46.8%) were comfortable with the position of the office window. This suggests that the current window placement in their respective offices is generally satisfactory and contributes to a positive working environment. Furthermore, a small percentage of respondents (0.5%) reported being very comfortable with the position of their office windows. This suggests that these individuals find the window placement particularly favourable, potentially due to factors such as natural lighting, outside view, or adequate ventilation. On the other hand, a notable percentage of respondents (37.4%) indicated that they were slightly comfortable with the window position. This implies that while they may not have major issues with the window placement, there might be some room for improvement to enhance their comfort further. It is worth noting that a small proportion of respondents (0.5%) reported feeling uncomfortable with the position of their office window. This indicates that for these individuals, the window placement may have a negative impact on their comfort and potentially affect their overall well-being and productivity. Similarly, another 0.5% of respondents reported being very uncomfortable with the window position, suggesting a more significant level of discomfort. It is important to address such concerns to create a more favourable work environment for these individuals.

Lastly, 5.9% of respondents reported feeling slightly uncomfortable with the position of the office window. Although this percentage is relatively small, it indicates that there is a subset of workers who have some reservations or concerns regarding the window placement in their offices.

The number of individuals present in a given office space can significantly impact IAQ and subsequently influence occupants' productivity levels. Higher occupancy density in an office space can lead to increased carbon dioxide (CO2) levels. As occupants exhale CO2, elevated concentrations can accumulate in poorly ventilated areas. The number of occupants in a shared office space in the National assembly offices are presented in the table 8 below.

Table 8.

Office Space

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	1	37	18.2	18.2	1.5
	10	1	.5	.5	19.7
	11	5	2.5	2.5	20.2
	12	1	.5	.5	22.7
	14	1	.5	.5	23.2
	15	2	1.0	1.0	23.6
	2	8	3.9	3.9	24.6
	3	74	36.5	36.5	28.6
	4	10	4.9	4.9	65.0
	5	34	16.7	16.7	70.0
	6	5	2.5	2.5	86.7
	7	16	7.9	7.9	89.2
	8	5	2.5	2.5	97.0
	9	1	.5	.5	99.5
	Total	203	100.0	100.0	100.0

According to the data presented in Table 8 above, it is evident that there is a variety of office sizes available for occupants to share. The responses from the survey indicate that the most common office size, shared by the highest percentage of respondents (36.5%), is suitable for accommodating three people. This suggests that a significant proportion of offices surveyed are designed to comfortably house a small group of individuals, potentially promoting collaboration and efficient space utilization.

Furthermore, a notable percentage of respondents (18.2%) reported occupying offices that are suitable for a single person. These smaller-sized offices may be conducive to focused and individual work, providing privacy and a sense of personal space. The data also shows that there are offices designed to be shared by different numbers of occupants. For example, 16.7% of respondents mentioned that their office is suitable for accommodating five people, indicating a slightly larger shared space compared to the three-person offices.

Additionally, a smaller percentage of respondents reported occupying offices suitable for sharing among seven people (7.9%), four people (4.9%), and two people (3.9%). These office sizes suggest a range of collaborative spaces where occupants can work together in teams of varying sizes. The survey results also indicate that there are offices designed for larger groups of people. For instance, 2.5% of respondents reported occupying offices that can be shared by 11 or 8 people, suggesting a more spacious and potentially open workspace environment.

Lastly, a small percentage of respondents (1.0%) mentioned that their office can accommodate up to 15 people. These larger-sized offices may be intended for larger teams or departments, promoting collaboration and interaction among a significant number of occupants.

Table 9.

IAQ Agents

		Frequency	Percent	Valid Percent
Valid		3	1.5	1.5
	Food	4	2.0	2.0
	Food, Cleaning products	4	2.0	2.0
	Food, Cleaning products, outside sources.	13	6.4	6.4
	Food, Perfume, Cleaning products.	25	12.3	12.3
	Food, Perfume, Outside sources.	4	2.0	2.0
	Other people.	15	7.4	7.4
	Other people, Cleaning products.	12	5.9	5.9
	Other people, Cleaning products.	1	.5	.5
	Other people, Outside sources.	6	3.0	3.0
	Outside sources.	2	1.0	1.0
	Perfume, Outside sources.	1	.5	.5
	Perfume, Outside sources, Paintings.	1	.5	.5
	Photocopiers.	2	1.0	1.0
	Photocopiers, Cleaning products, outside.	1	.5	.5
	Tobacco smoke.	22	10.8	10.8
	Tobacco smoke, Food, Cleaning products.	4	2.0	2.0
	Tobacco smoke, Food, Other people.	15	7.4	7.4
	Tobacco smoke, Food, Outside sources.	4	2.0	2.0
	Tobacco smoke, Other people.	15	7.4	7.4
	Tobacco smoke, Perfume.	1	.5	.5
	Tobacco smoke, Photocopiers.	17	8.4	8.4
	Tobacco smoke, Photocopiers, Printers.	12	5.9	5.9
	Tobacco smoke, Printers.	4	2.0	2.0
	Tobacco smoke, Food, Carpet/furniture	15	7.4	7.4
	Total	203	100	100

It is clear from the data in table 9 above that there exists various agents that influence the quality of indoor air, as reported by the respondents. The top five most occurring agents, based on the highest response percentages, are as follows:

Food, Perfume, Cleaning products, and Outside sources (12.3%), this category represents a combination of factors such as food odors, perfume scents, cleaning product emissions, and pollutants originating from outside sources. These agents can contribute to the degradation of indoor air quality, potentially causing discomfort or allergic reactions for some individuals. Tobacco and smoke (10.8%) Tobacco smoke is a well-known contributor to poor indoor air quality. The presence of tobacco smoke can lead to a range of health issues and discomfort for both smokers and non-smokers in the vicinity. It is important to implement effective strategies to minimize or eliminate tobacco smoke indoors. Tobacco smoke, photocopiers (8.4%), This category refers to the combined presence of tobacco smoke and emissions from photocopiers. Photocopiers can release volatile organic compounds (VOCs) and other pollutants, which, when combined with tobacco smoke, can further exacerbate indoor air pollution and negatively impact air quality. Tobacco smoke, other people (7.4%) is another category that represents the influence of tobacco smoke originating from other individuals in the indoor environment. Second-hand smoke is a concern for non-smokers as it can have detrimental effects on their health and contribute to poor indoor air quality. Food, cleaning products, outside sources (6.4%) is the last category and it highlights the impact of food-related odors, emissions from cleaning products, and pollutants from outdoor sources. Cooking odors, volatile compounds from cleaning agents, and outdoor pollutants entering the indoor space can affect the overall air quality and potentially cause discomfort or allergic reactions.

Table 10.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Office Occupants	203	1	6	3.09	1.367
IAQ agents	203	1	25	13.75	7.635
Office Space	203	1	15	8.29	3.664
Windows position	203	1	7	3.00	1.483
Valid N (list wise)	203				

The findings of this study highlight four aspects of air quality that have an impact on the amount of work accomplished by occupants. The number of people working in an office, the presence of contaminants in the indoor air, the size of the office space, and the location of windows are some of these considerations. The standard deviation of these factors is presented in Table 11, illustrating both a vast and a close range of variation with respect to the central value (mean). Two of the components showed a large range of variation (office occupants and window position), but two of the other factors (IAQ agents and office space) had a narrow range of variation. This suggests that work productivity, while influenced to some degree by these four elements, is far more influenced by the agents that impact indoor air quality and the size of the office. Agents that affect the quality of the air within an office building, such as food, cleaning chemicals, smoke, perfumes, and paintings can have a significant impact on the productivity of the people who work there. In addition to this, the size of the workplace, the number of people working in the office, and the location of the window can all have an impact on the quality of the air, which in turn has an impact on the amount of work that gets done. The implications of this finding covered in the following chapter.

Research Question 2: How does thermal comfort in office buildings influence occupants work productivity?

The analysis of Research Question 2 seeks to investigate the link connecting thermal comfort in office buildings and the productivity of their inhabitants. Three independent variables which are cold level, heat level and Noise level were determined through the data collected from the questionnaire survey and they will be utilized to analyse this research question.

The first variable analysis conducted to test the impact of thermal comfort on occupants' productivity is the Cold levels, which refers to the perception of coldness in the indoor environment. The temperature in the office space plays a significant role in determining thermal comfort. When the temperature is too cold, it can have adverse effects on occupants' well-being and productivity. In table 11 below the participants response to the cold level temperatures in the office are presented.

Table 11.

Cold Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	1.5	1.5	
	Dissatisfied	50	24.6	24.6	1.5
	Neutral	19	9.4	9.4	26.1
	Satisfied	17	8.4	8.4	35.5
	Very dissatisfied	25	12.3	12.3	43.8
	Very satisfied	89	43.8	43.8	56.2
	Total	203	100.0	100.0	100.0

According to the information presented in Table 11 above, it is evident that cold level temperature in the offices has a significant impact on the satisfaction of the participants, which can, in turn, affect their work productivity. The responses indicate the following distribution:

Dissatisfied: 24.6% of the participants expressed dissatisfaction with the cold level temperature in their offices. This suggests that a considerable portion of the participants felt that the temperature was too cold for their comfort, potentially leading to discomfort and possibly impacting their productivity.

Neutral: 9.4% of the participants indicated a neutral response towards the cold level temperature. This suggests that they neither found it excessively cold nor satisfactory, which may indicate that they were relatively unaffected by the temperature in terms of their work productivity.

Satisfied: 8.4% of the participants reported being satisfied with the cold level temperature. This implies that they found the temperature to be acceptable and comfortable for their work environment, which could positively impact their work productivity.

Very Dissatisfied: 12.3% of the participants expressed being very dissatisfied with the cold level temperature in their offices. This indicates a higher degree of dissatisfaction compared to the participants who were simply dissatisfied. Such a response suggests that these individuals found the temperature significantly uncomfortable, which could potentially have a negative impact on their work productivity and overall well-being.

Very Satisfied: The majority of participants, accounting for 43.8%, reported being very satisfied with the cold level temperature. This implies that a significant proportion of individuals found the temperature to be ideal and conducive to their work environment. When employees are very satisfied with the cold level, it can contribute to their overall comfort, potentially leading to increased work productivity.

Heat levels pertain to the perception of warmth or high temperatures in the office environment. Similar to cold levels, excessively high temperatures can significantly affect thermal comfort and productivity. When the temperature is too hot, individuals may experience fatigue, difficulty concentrating, and reduced cognitive performance, for these reasons this research chose the heat levels as the second variable to test against productivity and the results of the occupant's response to the heat levels in their office are presented in table 12 below.

Table 12.

Heat Level

		Frequency	Percent	Valid Percent
Valid		18	8.9	8.9
	Dissatisfied	56	27.6	27.6
	Neither satisfied nor dissatisfied	12	5.9	5.9
	Satisfied	55	27.1	27.1
	Slightly dissatisfied	17	8.4	8.4
	Very dissatisfied	5	2.5	2.5
	Very satisfied	40	19.7	19.7
	Total	203	100.0	100.0

According to the results presented in Table 12, It is clear that the heat level temperature in the workplaces has a substantial influence on participant happiness., which can, in turn, affect their work productivity. The responses indicate the following distribution:

Dissatisfied: 27.6% of the participants expressed dissatisfaction with the heat level in their offices. This suggests that a significant portion of the participants felt that the temperature was too warm for their comfort, potentially leading to discomfort and possibly impacting their productivity.

Neither Dissatisfied nor Satisfied: 5.9% of the participants indicated a neutral response, neither being dissatisfied nor satisfied with the heat level. This suggests that they did not have strong feelings about the temperature, indicating that it may not have significantly impacted their work productivity.

Satisfied: 27.1% of the participants reported being satisfied with the heat level. This implies that they found the temperature to be acceptable and comfortable for their work environment, which could positively impact their work productivity.

Slightly Dissatisfied: 8.4% of the participants expressed being slightly dissatisfied with the heat level. This indicates a mild level of dissatisfaction compared to those who were dissatisfied. Such a response suggests that these individuals found the temperature somewhat uncomfortable, which could have a slight negative impact on their work productivity and overall well-being.

Very Dissatisfied: 2.5% of the participants expressed being very dissatisfied with the heat level. This indicates a higher degree of dissatisfaction compared to those who were simply dissatisfied. Such a response suggests that these individuals found the temperature significantly uncomfortable, which could potentially have a negative impact on their work productivity and overall well-being.

Very Satisfied: 19.7% of the participants reported being very satisfied with the heat level. This implies that a significant proportion of individuals found the temperature to be ideal and conducive to their work environment. When employees are very satisfied with the heat level, it can contribute to their overall comfort, potentially leading to increased work productivity.

Noise levels refer to the presence of unwanted sounds in the office space, including external noise from traffic, machinery, or internal noise from conversations and equipment. High noise levels can have detrimental effects on occupants' well-being and productivity. Minimizing noise disturbances promotes a sense of calm, improves concentration, and supports higher productivity levels among office occupants. The responses obtained from the occupants based on the noise levels of their office space in the National assembly are presented in table 13 below.

Table 13

Noise Level

		Frequency	Percent	Valid Percent
Valid		3	1.5	1.5
	Dissatisfied	89	43.8	43.8
	Neutral	32	15.8	15.8
	Satisfied	62	30.5	30.5
	Very dissatisfied	5	2.5	2.5
	Very satisfied	12	5.9	5.9
	Total	203	100.0	100.0

It is clear from the results reported in Table 13 that the level of noise in the office has a significant impact on the satisfaction of the occupants, which can affect their work productivity. The responses indicate the following distribution:

Dissatisfied: The majority of participants, accounting for 43.8%, expressed dissatisfaction with the level of noise in the office. This suggests that a significant portion of the occupants found the noise levels to be disruptive and potentially hindering their concentration and productivity.

Neutral: 15.8% of the participants indicated a neutral response, neither being dissatisfied nor satisfied with the noise level. This suggests that they did not have strong feelings about the noise levels, indicating that it may not have significantly impacted their work productivity.

Satisfied: 30.5% of the participants reported being satisfied with the noise level in the office. This implies that they found the noise levels to be acceptable and conducive to their work environment, which could positively impact their work productivity.

Very Dissatisfied: 2.5% of the participants expressed being very dissatisfied with the noise level. This indicates a higher degree of dissatisfaction compared to those who were simply dissatisfied. Such a response suggests that these individuals found the noise levels significantly disruptive and potentially detrimental to their work productivity and overall well-being.

Very Satisfied: 5.9% of the participants reported being very satisfied with the noise level. This implies that a small but significant proportion of individuals found the noise levels to be ideal and conducive to their work environment. When employees are very satisfied with the noise level, it can contribute to their overall comfort, potentially leading to increased work productivity

Table 14.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Cold level	203	1	6	4.37	1.722
Heat level	203	1	7	3.85	1.978
Noise level	203	1	6	3.06	1.199
Valid N (list wise)	203				

In the process of determining how the level of thermal comfort in an office building influences the productivity of its occupants, the table 14 above provides a descriptive analysis of the responses that were obtained. The level of noise has a mean of 3.06 with a spread level of 1.19; the level of cold has a mean of 4.37 with a spread level of 1.7; the level of heat has a mean of 3.85 with a spread level of 1.97. The evidence presented in table 14 demonstrates a close spread, which suggests that respondents agree to a significant extent that these thermal factors affect productivity in their workplace, with cold level having the most significant impact. Productivity drops significantly when the temperature in the office is too low. Work productivity is negatively impacted when the temperature is excessively hot, and it is also negatively impacted when there is an excessive amount of background noise in an office setting. The implication of decreased work productivity is covered in the following chapter.

Hypotheses Testing

To further prove our findings, a hypotheses test was carried out using the Pearson correlation test. The evaluation of all findings results are presented below.

H1: There is no significant relationship between indoor air quality and occupants' work productivity.

The present study involved conducting a hypothesis test to ascertain the adequacy of evidence to reject the null hypothesis (H1) and support the hypothesis that is not null, which posits a significant association between indoor air quality and work productivity. The Pearson correlation test was employed to compare the dependent variable, work productivity, with the independent variables, namely office occupants, IAQ agents, windows position, and office space.

Table 15.

Correlations of indoor air quality variables

	Work Productivity	Office Occupants	IAQ agents	Windows position	Office Space
WorkProductivity	1	.170*	.321**	.081	.220**
OfficeOccupants	.170*	1	-.126	.288**	-.073
IAQagents	.321**	-.126	1	-.668**	.555**
WindowsPosition	.081	.288**	-.668**	1	-.291**
Office Space	.220**	-.073	.555**	-.291**	1

Findings as shown in Table 15 demonstrate that there is a correlation between factors that affect the quality of the air inside a building and worker productivity. According to the findings of the Pearson correlation test, there is a significant link (.170) between the amount of work accomplished in an office and the number of people working there. There is a correlation between work productivity and the constituents of indoor air quality that is positive (.321**). Work productivity has also been shown to have a positive relationship with the position of windows (0.81), as well as the size of office space (0.220**). The table below gives a quick summary for this hypothesis.

Table 16.

Summary of Hypothesis One

Independent variable name	Correlation value	Result	Null hypothesis	Condition
Office Occupants	0.170	Positive	There is no substantial link between indoor air quality and occupants' work productivity.	Rejected
IAQ agents	0.321**	Positive		
Window position	0.081	Positive		
Office Space	0.220**	Positive		

Table 16 summarizes the results for Hypothesis One, which examines the relationship between indoor air quality (IAQ) and occupants' work productivity. The findings indicate the following:

i. Office Occupants: The number of occupants in the workplace has a positive connection (0.170) with work productivity. The null hypothesis is rejected, suggesting a significant relationship.

ii. IAQ Agents: IAQ agents and work productivity have a substantive positive connection (0.321**).

iii. Window Position: There is a positive correlation (0.081) between window position and work productivity, although the relationship is relatively weak.

iv. Office Space: Office space and work productivity have a notable positive connection at (0.220**).

In summary, the results indicate that the number of occupants, IAQ agents, window position, and office space have a positive relationship with work productivity.

H2: There is no relationship between thermal comfort in office buildings and work productivity.

The second hypothesis is being tested using work productivity as the dependent variable to test against the independent variables used in this thesis which are cold level, heat level and noise level. The result of this test is present in table 17 below and the summary of the hypothesis is giving in table 18 below.

Table 17.

Correlations of Thermal Comfort Variables

	Work Productivity	Cold level	Heat level	Noise level
Work Productivity	1	.147*	.061	-.079
Cold level	.147*	1	.050	-.263**
Heat level	.061	.050	1	.495**
Noise level	-.079	-.263**	.495**	1

Table 17 demonstrates the nature and degree of the relationship between work productivity and thermal comfort. It aims to clarify how thermal comfort influences the productivity of occupants. The results indicate a weak correlation between work productivity and heat level (0.061) and a strong correlation between work productivity and noise level (-0.079). Work productivity correlates positively with temperature (0.147), heat (0.061), and noise (-0.079). The null hypothesis is accepted based on the evidence presented in Table 17. The summary of this examination is shown in table 18 below.

Table 18.

Summary of hypothesis two

Independent variable name	Correlation value	Result	Null hypothesis	Condition
Cold level	0.147	Positive	There is no relationship between thermal comfort in office buildings and work productivity.	Accepted
Heat level	0.061	Weak		
Noise level	-0.079	Negative		

Table 18 summarizes the results for Hypothesis Two, examining the relationship between thermal comfort cold level, heat level and noise level with work productivity. The findings indicate the following:

i. Cold Level: There is a positive correlation (0.147) with work productivity, but the null hypothesis is accepted, indicating no significant relationship.

ii. Heat Level: There is a weak positive correlation (0.061) with work productivity.

iii. Noise Level: There is a negative correlation (-0.079) with work productivity, but the relationship is not significant.

In summary, the results suggest that thermal comfort cold level, heat level and noise level have limited or no meaningful impact on work productivity in office buildings.

CHAPTER V
Discussion

The implications of the findings from this study are discussed throughout this chapter. This is done with the intention of putting the findings of this study in their proper place among another empirical research.

Discussion for Findings 1

According to the evidence that was presented in the previous chapter, the work productivity of occupants can be affected by factors related to indoor air quality such as the size of the office space, the number of people working in the office, the position of the office window, as well as indoor air quality agents such as food, paintings, perfumes, office cleaning agents, tobacco smoke, and other factors. Hameed et al. (2009) and Haynes (2008) both came to similar conclusions, and this result backs up their findings. Both of these studies offer empirical support for the hypothesis that office space has an effect on the level of employee productivity. Respondents highlighted perfume, cleaning agents, and even air fresheners as examples of silent and significant agents that affect the quality of indoor air.

The introduction of potentially harmful pollutants by these air agents can have an impact on the quality of the air inside buildings. Increased levels of volatile organic compounds (VOCs) in indoor air have been linked to the use of air agents such as perfume, cleaning agents, and air fresheners. These VOCs include formaldehyde, acetaldehyde, benzene, toluene, ethyl benzene, and xylenes. These volatile organic compounds are often difficult to detect in the air, but they are known to cause irritation to the eyes, nose, and throat, in addition to contributing to headaches and nausea. The fragrance composition plays a crucial role in determining the quantity and variety of volatile organic compounds (VOCs) that are emitted into the atmosphere, surpassing the significance of the air freshener type. The comprehensive identification of constituents in air fresheners is a challenging task, if not an unattainable one, due to the absence of mandatory disclosure of the complete inventory of components by manufacturers.

Air fresheners have the potential to introduce volatile organic compounds (VOCs) and other pollutants into the atmosphere. This can occur through direct emissions from the air fresheners themselves, as well as through the formation of secondary reaction products resulting from the interaction of the freshener chemicals with pre-existing atmospheric constituents, such as ozone. Air freshener emissions have the potential to undergo reactions with naturally-occurring indoor air compounds, such as ozone, resulting in the formation of secondary pollutants, including formaldehyde. The production of secondary pollutants is subject to the influence of various factors, including but not limited to the composition of air fresheners, their concentrations, and patterns of usage.

The utilization of air fresheners has the potential to elevate the levels of air pollutants to which individuals are exposed. Exposure to these substances, even at low concentrations, has been linked to various detrimental health outcomes. Substance exposure can cause migraine headaches, asthma exacerbations, respiratory impairments, dermatological manifestations, and neurological complications. Substance-vulnerable people suffer more from these negative effects. The presence of both noxious and agreeable scents may serve as an indicator of potential hazards to human well-being. At times, individuals may detect the presence of specific chemicals in the atmosphere prior to their attainment of hazardous concentrations. According to the participants' opinions, the persistent presence of odour in the atmosphere has a negative impact on their overall quality of life and subjective feeling of wellness.

The potential for health symptoms to arise from environmental odour is contingent upon both individual and environmental factors. Various factors such as age, gender, health status, and the concentration and nature of the substance in the surrounding environment may play a significant role. Consequently, given that the productivity of workers is contingent upon their mental, emotional, psychological, and physical well-being, any impairment resulting from exposure to indoor air pollutants can impede their capacity to perform tasks, thereby exerting a detrimental impact on productivity.

Discussion for Findings 2

The findings of research question two indicate a positive correlation between cold temperature and occupant work productivity, as supported by empirical evidence. Less is known about the impact of low temperatures and cold thermal sensations on productivity. Merely a limited number of research works (Wyon, 1996; Berglund et al., 1990) have investigated the correlation between warm temperatures and cold temperatures. There exists a wealth of information regarding the impacts of temperatures that deviate significantly from the standard range observed in office buildings, whether they be excessively low or excessively high. The correlation between manual dexterity in cold environments and hand functionality has been established. The temperature of an individual's hands and fingers can have an impact on their performance in manual dexterity tests. This temperature is contingent upon the body's thermal equilibrium.

In low temperature conditions, vasoconstriction occurs in the peripheral blood vessels, resulting in decreased blood flow to the hands. This physiological response leads to a reduction in the temperature of the hands prior to a decrease in the core body temperature. At indoor air temperatures ranging from 20 to 22 degrees Celsius, there is a decline in manual dexterity. According to the findings of Meese et al. (1984), there were notable reductions in finger strength and speed in various tests such as pegboard, screw plate, block treading, and knot-tying. Additionally, the participants exhibited decreased performance in pencil rolling tasks with varying degrees of retardation. The experimental results indicate that a decrease in ambient temperature from the reference value of 24oC to 18oC resulted in a reduction of performance ranging from 5% to 15% across all tests. The manual dexterity of the hands and fingers is a crucial aspect not only for physical labour but also for contemporary office work, where a considerable amount of work is performed on computer systems. Nonetheless, it is not feasible for us to establish a quantitative correlation between diminished finger dexterity and the efficacy of word processing in a professional setting. According to Humpreys et al. (1999), there exist notable inter-individual differences in the relationship between finger temperature and ambient temperature. According to the data, it can be observed that a significant proportion of individuals exhibit finger temperatures that are almost equivalent to the ambient globe temperature when the temperature falls below 24oC, which is the threshold beyond which temperature can impact hand dexterity. The efficiency of word processing activities can be influenced by the manual dexterity of the fingers. At present, there exists a dearth of information pertaining to the aforementioned relationship.

CHAPTER VI
Conclusion and Recommendation

Conclusion

The level of performance that an organization's employees are capable of delivering on is directly proportional to the success of the organization in terms of its goals. Because of this, if the performance of the occupants continues to improve, then the performance of the company will also continue to improve, and vice versa. As a result, it is absolutely necessary to make certain that each and every employee delivers a performance that is commendable whenever they are given a task. It is essential to ensure that employees are happy with the conditions of their workplace in order to produce work of a quality that will meet and exceed the expectations of their employer. It is necessary to consider the indoor air quality in order to provide good environmental quality in a building. This includes ventilation and thermal comfort, which can be achieved by ensuring that the HVAC system is operating correctly and that the temperature is at a level that is appropriate for the people who live in the building. This is due to the fact that an extremely high or low temperature will have an effect on the indoor air quality, which will then have an effect on the performance of the employees.

Additionally, if the level of indoor air quality in a building does not meet the needs and requirements of the occupants, several SBS symptoms will occur and affect them, such as headache, irritated eyes or nose, blocked nose, and so on; as the syndrome infects the building occupants, they will feel ill, and their desire to come to work will decrease because they know that as soon as they enter the building, they will be infected with the syndrome and become ill. Because of this, as employees become less enthusiastic about coming to the office, their productivity will suffer because they will not be as focused on delivering their work; if they continue to complete their tasks in a manner that is only half-hearted, it will eventually affect their psychology, which could lead to high levels of stress.

As a result of this, as employees become less enthusiastic about coming to the office, their productivity will suffer because they will not be as focused on delivering their work. This circumstance will also have an impact on the performance of the company, as the correlation between the stress levels of the occupants and their levels of work performance and productivity, as well as the performance of the company, is inversely proportional. In addition, it was found that the occupants' level of comfort and health, SBS symptoms, satisfaction with indoor ventilation, and comfort level are the primary factors that influence the psychological state of the occupants. Based on the results obtained, it can be concluded that occupants' work productivity and stress levels are higher and lower, respectively, the more satisfied they are with the indoor air quality of the building. IAQ is essentially one component of the indoor environmental quality (IEQ). During the research, the occupants of the buildings were surveyed regarding the IEQ satisfaction of the buildings. According to the findings, it can be deduced that office occupants are more productive at work and experience less stress when they are satisfied with the indoor air quality of the structure. In contrast, poor indoor air quality significantly decreases office workers' productivity and performance.

Recommendation

Given the aforementioned, it is imperative to increase consciousness regarding the work environment, particularly in emerging economies like Nigeria where there exists a potential hazard to health. Apart from the impact on the operational effectiveness and ecological soundness of a structure, it is imperative to thoroughly contemplate the welfare of its occupants. Merely creating a structure that provides comfort is inadequate. Despite popular belief, literature suggests that "green" building plans do not automatically ensure a safe, healthy environment for occupants. This study recommends the following:

i. Architects and engineers must take into account several factors, including sick building syndrome, thermal conditions, and interior and exterior designs, to ensure that newly constructed buildings adhere to the requisite standards for optimal indoor air quality.
ii. In order to uphold and sustain favorable indoor air quality, it is imperative to engage in ongoing monitoring of the actions of individuals occupying the space.
iii. It is imperative that architects and engineers consider the potential issues related to inadequate indoor air quality and associated health concerns that may arise

within occupational environments. The design and construction of buildings should take into consideration the impact of workers' complaints, increased sick leave, absenteeism, and decreased productivity, with the aim of mitigating these occurrences and enhancing productivity.

iv. It is imperative to establish a well-defined system for measuring performance in both public and private organizations, which can furnish precise data. Additionally, an IAQ protocol that facilitates prompt assessment of IAQ issues is crucial to safeguarding the future of workplaces.

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APPENDICES

Appendix A

NEAR EAST UNIVERSITY

SCIENTIFIC RESEARCH ETHICS COMMITTEE

05.01.2023

Dear Ahmad Tijjani Mohammed

Your application titled **"The Impact of Indoor Environmental Quality on Occupants Work Productivity; Indoor Air Quality and Thermal Comfort in Office Buildings in Abuja, Nigeria"** with the application number NEU/AS/2022/183 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Prof. Dr. Aşkın KİRAZ

The Coordinator of the Scientific Research Ethics Committee

Appendix B

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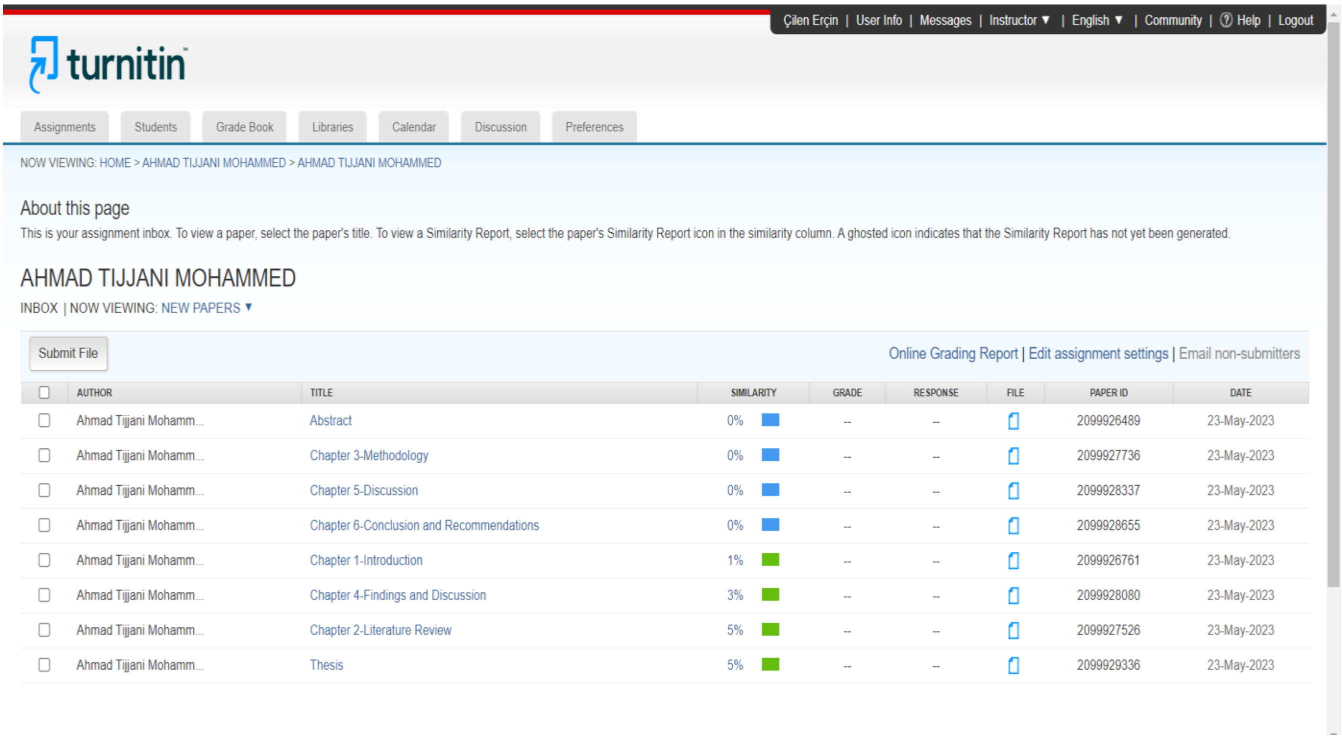

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