EVALUATION OF THE INDOOR AIR QUALITY AND ELETRICAL ENERGY CONSUMPTION IN THE 200 HOUSING UNIT ESTATE, LOKOJA, KOGI STATE

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ABSTRACT

Indoor air quality is one of the most significant factors affecting the health and well-being of occupants. The assessment of the overall comfort of the environment places foremost attention to human health. The study aimed at Evaluation of Indoor Air Quality and Electrical Energy Consumption of the residential building in 200 housing unit estate Lokoja, Nigeria, following the ASHRAE standard guide, with a view to ascertain the current level of indoor air parameter with relation to energy consumption. The study employs the use of experimental reading, using air visual and electrical energy monitoring device in determine indoor air parameter such as temperature, particulate matter PM2.5 CO_2, relative humidity, temperature and setting the device at 2hr interval, 1m away from the walls of the building for 24hrs per day. Descriptive and inferential statistics were used for analyzing the acquire mean with SPSS file, Pearson's correlation was used to determine the relationship between indoor air quality and electrical energy consumption. Findings revealed that the CO_2, PM2.5 and relative humidity are within the set's standard of ASHARF, but temperature exist set limit of the study area. Furthermore, correlation relationship between the average operative IAQ and the average energy consumption is perfectly negative where the Pearson's correlation coefficient, r, is equal to -0.126 (p-value < 0.01) which indicates moderate and significant correlation. Therefore, the study recommends the use of HVAC, Fan Force Ventilation, dehumidification and further study on indoor air quality and electrical energy consumption.

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ACRONYMS AND THE FULL MEANING

ACGIH	AMERICAN CONFRENCE OF GOVERMENTAL INDUSTRIAL HYGIENISTS
ASHRAE	AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING SYSTEM
BRI	BUILDING RELATED ILLNESSES
COPD	CHRONIC OBSTRUCTIVE PULMONARY DISEASE
(CO_2)	CARBON DIOXIDE
CO	CARBON MONOXIDE
CVD	CARDIOVASCULAR DISEASE
EIA	ENERGY INFORMATION ADMINISTRATION
HCHO	FORMALDEHYDE
HVAC	HEATING VENTILATION AIR-CONDITIONS SYSTEM
IAQ	INDOOR AIR QUALITY
IDPH	ILLINOIS DEPARTMENT OF PUBLIC HEALTH
IEE	INSTITUTE OF ENVIRONMENTAL EPIDEMIOLOGY
KWH	KILLO WATT PER-HOUR
NIOSH	NATIONAL INSTITUTE OF OCCUPATIONAL AND HEALTH
NVOC	NON-VOLATILE ORGANIC COMPOUNDS
OSHA	OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
PM	PARTICLE MATTER
ROI	RETURN ON INVESTMENT
SBS	SICK BUILDING SYNDROME
SVOC	SEMI VOLATILE ORGANIC COMPOUNDS
TVOC	TOTAL VOLATILE ORGANIC COMPOUNDS
USEPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
USGBC	US GREEN BUILDING COUNCIL
VOC	VOLATILE ORGANIC COMPOUNDS
VVOC	VERY VOLATILE (GASEOUS) ORGANIC COMPOUNDS
WHO	WORLD HEALTH ORGANISATION

CHAPTER ONE

1.1 INTRODUCTION

1.2 BACKGROUND TO THE STUDY

Indoor air quality is one of the most significant factors affecting the health and well-being of people (Daccaro *et al.,* 2017) as exposure to bioaerosols, containing airborne microorganisms and their by-products, can result in diseases including respiratory disorders and other adverse health effects (Gorny & Dutkiewicz 2012; Fracchia *et al.*, 2016). Clean air is a basic requirement for life and healthy living. The quality of air in homes, offices, schools, day care centers, public buildings, health care facilities and other private and public buildings where people spend over 85% of their time daily is crucial for healthy living and people's well-being. The assessment of the overall comfort of the environment places foremost attention to human health. The negative impact of the built environment on the health of users is a matter of concern, which points to some design or technical flaws in the building (Akanmu *et al.*, 2020).

The National Health and Medical Research Council (NHMRC) define indoor air as 'air within a building occupied by people of varying states for a period of at least one hour. Buildings covered by this definition include homes, schools, restaurants, public buildings, residential (NHMRC, 2010). Indoor air refers to non-industrial closed indoor environments, including dwellings, establishments open to the public, care and education settings, health care and medical- social establishments, and means of transportation. Living, staying, visiting, studying or working in these indoor environments can lead users or occupants to report discomfort or health issues (Ogedengbe & Onyuanyi, 2017).

Indoor air quality can be defined as the totality of attributes of indoor air that affect a person's health and well- being (Oluwole *et al.*, 2013).

Air pollution has been a serious environmental problem for many years and is becoming a greater issue globally. Particulate matter in ambient air presents a risk to human health, particularly after prolonged exposure. Exposure to air pollutants has been reported to cause health effects, genetic structure alterations, weaken immune system, asthma, headache, dry eyes, nasal congestion, nausea, and fatigue depending on the type of pollutants, amount of pollutants, frequency of exposure and associated toxicity of specific pollutants (Sukhsohale *et al.*, 2012; Moschandreas & Sofuoglu 2014, Padhi *et al.* 2019). Natural ventilation and indoor air quality in millions of houses are often poor, resulting in the prevalence of airborne disease transmission (Cohen *et al.*, 2014). The International Agency for Research on Cancer (IARC) revealed that worldwide 223,000 lung cancer deaths in 2010 resulted from air pollution (IARC, 2013; WHO, 2017).

According to the World Health Organization (WHO), more than two-thirds of the global estimates of mortality from indoor air pollution occur in Southeast Asia and sub-Saharan Africa (WHO, 2017). In Nigeria, specific activities such as talking, sneezing, coughing, walking, washing and toilet flushing as well as the use of biomass cooking fuels, unsanitary waste disposal techniques and other activities which release gaseous and particulate pollutants into the outdoor and indoor environments readily generate airborne biological particulate matter (Madukasi *et al.*, 2010; Smith, *et al.*, 2014).

Considering the adverse effect of poor IAQ in residential buildings in Africa and Nigeria in particular, the current study embarked on an evaluation of domestic practices that may jeopardize public health. The study aims to proffer solutions that would reduce and possibly eliminate the risks of IAQ by studying the underlying causes of IAQ in the 200 housing unit estate Kogi state, located in Lokoja local government, Nigeria.

1.3 Statement of the Problem

Exposure to air pollutants has been reported to cause health effect genetic structure alterations, weaken immune system, asthma, headache, dry eye, nasal congestion nausea and fatigue depending on the type of pollutants, amount of poulltants, frequency of explosive and associated toxicity of specific pollutants (Anifowose *et al.*, 2016).

The construction industry faces a problem in reducing buildings' environmental impacts, such as energy usage and corresponding greenhouse gas emissions, while maintaining indoor settings that are safe and healthy for occupants. This overarching goal is frequently mentioned in the context of green or sustainable building discussions. A variety of programs, regulations, rules, and other initiatives are in place or in the works to encourage, and in some cases mandate, the design and construction of green or sustainable structures (**American Society of Heating, Refrigerating and Air-Conditioning Engineers ASHRAE**, 2009; U.S. **Green Building Council** USGBC, 2009; International Code Council ICC, 2010).

The WHO (2012) expressed that indoor air pollution in developing countries is linked to increased health risks; this is also true for urban areas in developing countries due to indoor-to-indoor source of air pollution.

1.4 Research Questions

i. What are the state and trend of IAQ in the residential buildings at the 200 housing units estate Kogi state, Lokoja?

ii. What is the state and trend of IAQ established relationship between the existing benchmark by ASHRAE and the residential buildings at the 200 housing units estate Kogi state, Lokoja?.

iii. To what extend would the proffer trends be beneficial to the residential buildings at the 200 housing units estate Kogi state, Lokoja for the present and future with implications for good indoor energy and the use of energy in the buildings?

iv. What are the effects of energy consumption in the residential building with respect to indoor air quality?

1.5 Aim and objectives of the Research

The research aimed at evaluation of indoor air quality and electrical energy consumption of the residential buildings in the 200 housing unit estate. With a view to ascertain the present state and compare with existing standard (ASHRAE, 2009).

1.6 Objectives

The objectives of the study are to:

i Determine the state and trend of IAQ of the residential buildings at the 200 housing units estate Lokoja

ii Compare the state and trend with the existing benchmark in the estate.

iii Determine the electrical energy consumption and its relationship with IAQ.

1.7 Significance of the Study

Academically, enhanced IAQ helps to improve visual acuity, reduces distractions, improves thermal comfort levels, and contributes to the health and wellbeing of occupants in the built environments, which in turn reduces diseases and sickness and improves performance of occupants (Corgnatti *et al.,* 2007; De Giuli *et al.,* 2012; Lee *et al.,* 2012). The study is therefore undertaken with a view to improving the environments for conducive and health well-being of the residents in the 200 housing unit estate Kogi state located in Lokoja. The study was conducted in order to represent local satisfaction of the occupants in the 200 housing unit estate Kogi state located in Lokoja regarding the quality of indoor air inside the building due to impact of the surroundings. The result of the study will help the residents of the community to gain the appropriate information necessary for them to be aware of building related syndromes that are common around the built environment. It will help the residents in improving the indoor air quality through measuring and enhancing pollutants levels by applying strategies of controlling the source, improving the current ventilation systems and providing air cleaners where necessary in future development.

1.8 Justification for the Study

Because of the complicated interaction between indoor air quality and outdoor climatic conditions, as well as the effects of climate change, a paradigm shift is required to create structures which not only are comfortable and healthy for inhabitants, but likewise viable.

It is widely assumed that greater energy usage is the only way to improve IAQ, This may be true in some weather circumstances where enhanced dilution ventilation improves IAQ, however there are other ways that can both improve IAQ and save energy (Levin & Teichman, 1991; Persily & Emmerich, 2012). Source control (such as choosing low-off-gassing construction materials, furnishings, and maintenance products and limiting occupants' use of fragranced or scented products), air cleaning (both particulate and gas phase), increasing ventilation efficiency (such as using displacement air distribution for cooling), and using outdoor ventilation can all improve indoor air quality (which, in mild weather conditions, reduce energy usage while increasing ventilation rate). Other strategies include demand controlled ventilation (for example, using carbon dioxide sensors), dynamic reset (for example, adjusting outdoor air rates based on real-time measurement of supply airflow in variable air volume systems), and using dedicated (decoupled) ductwork (particularly effective in hot and humid climates).

1.9 Scope of the Study

This study was restricted to selected residential buildings in Lokoja Kogi State. This study focuses on evaluation of the indoor air quality in the 200 housing estate Kogi state, Lokoja. Measuring the indoor air parameter carbon dioxide (CO_2), temperature, relative humidity, particulate matter 2.5 (ppm 2.5). The data collection are within the conducted 22 selected buildings in 200 housing unit estates that will represent the population.

The study did not cover other problem that is not considered as one, each building is given a careful reading. The result of the study will be applicable only to the population area of study and will not be used as a measure to other buildings; the main source of data will be the experimental reading with air visual anode monitoring.

1.10 Limitation of the Study

The research is basically concerned with evaluation of the indoor air quality and electrical energy consumption in the 200 housing unit estate Kogi state, Lokoja. Taking reading for just the indoor parameter, measuring the indoor air parameter are carbon dioxide (CO_2), temperature, relative humidity, particulate matter 2.5 (ppm 2.5).

CHAPTER TWO

2.1 LITERATURE REVIEW

2.2 The Concept of Indoor Air Quality (IAQ)

"Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants," according to the United States Environmental Protection Agency USEPA (2016). Indoor air quality (IAQ) is defined by the ASHRAE IAQ Guide, as the "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction" (ASHRAE, 2016). IAQ as a measure of air freshness enhances the health, comfort and wellbeing of indoor occupants. Air pollution phenomenon has been attracting attention in especially developed countries due to the links established between the natural environment and human health and economic implications (De Longueville *et al.,* 2010). Similarly it attracts attention due to the findings that 25% to 33% of global disease burden is attributed to environmental factors (Smith *et al.,* 2014).

Indoor environmental quality (IEQ) refers to the quality of thermal comfort, health, and well- being that a buildings environment can offer to the occupants and/or users. The level of IEQ depends on many complex interconnected parameters. These parameters have been reported to include the design and operation of building systems that control thermal comfort, indoor air quality (IAQ), acoustics, and illuminance. The assessment of the overall comfort of the environment places foremost attention to human health. The negative impact of the built environment on the health of users is a matter of concern, which points to some design or technical flaws in the building. Studies have shown evidence that there is a direct and consistent connection between the indoor environment and human well-being. This relationship usually presents both short-term and long-term effects on people (Akanmu *et al.,* 2020) reported that poor IEQ of a building can affect the comfort, health, and productivity of the occupants. Alike, poor IEQ has been implicated in psychological and other building-related illnesses that are not immediately obvious. Understanding the sources of indoor environmental discomfort and their adequate handling can often help prevent many problems ahead of time, during a design process.

Indoor air can be much more contaminated than outdoor air, contrary to conventional opinion. Most people associate air pollution with smog, ozone, haze in the air, or a noxious odor from a nearby chemical factory. However, the air inside houses, businesses, and other structures can be significantly more contaminated than the air outside (Bluyssen & De Richemont, 2010). Lead (in house dust), formaldehyde, fire retardants, radon, microscopic dust mites from moulds, and even volatile compounds from fragrances used in conventional cleaners are all common contaminants present in the air inside homes. Some pollutants are carried into the home via a new mattress or furniture, carpet cleaners, or a coat of paint on the walls, according to Bluyssen & De Richemont, (2010).

One of the top five environmental concerns is poor indoor air quality (IAQ) (USEPA, 2016). Improving indoor air quality in buildings can have a significant impact on occupant health. Pollutants in the air of a building can cause dizziness, migraines, and aggravate allergies and asthma. While cleaning and vacuuming can help to improve indoor air quality, it will not solve IAQ issues on its own. Good indoor air quality has a slew of advantages. It improves staff health, employee productivity, and occupant pleasure, reduces absenteeism, improves learning and student achievement, and promotes a more favorable customer experience. (Lavin & Higgins, 2006). Advantages of a good Increased return on investment (ROI) and bottom-line economics have also been linked to IAQ (ASHRAE, 2009).

Although the problems associated with poor IAQ have been extensively documented and are widely available, many building design and construction decisions are made without considering the potentially significant effects of bad IAQ. Ventilation has been a major architectural factor for as long as man has been systematically building his dwelling. In the previous 12 centuries, public knowledge and concern about indoor air quality (IAQ) has progressively grown, and it is now a major consideration in the design and construction of any livable facility. “In most situations, IAQ is still not a high-priority design or building management concern relative to function, cost, space, aesthetics, and other features such as location and parking,” (ASHRAE, 2009).

Industrial activities release major pollutants into the environment thereby causing air, water and land pollution, as well as noise. Industrial pollution is thus a threat to both human, animal and plant life and it affects the aesthetic quality of the environment. Noise, which could stress related illness and diseases such as cancer, kidney failure nervous disorders, leukemia, mental retardation, hearing failure or total deafness is a fallout of industrial pollution (Ogedengbe and Onyuanyi, 2017). Industrialization came into play and was seen initially as a sign of development but bore with it more complicated problems. Major activities during production process involve the use of chemical whose bye-products constitute industrial waste that are sometimes discharged carelessly into the environment through pipes, drains, air and land and find their way into water used for drinking, fishing and other purposes.

Traffic flow in the urban centers has been a contributory factor influencing air pollution and this occurrence has reached the critical level in many cities (Höglund & Niittymäki, 2000). Understanding the relation between vehicle emissions and traffic control measures is an important step toward reducing the potential for global warming, smog, ozone depletion, and respiratory illness. The clean air which was naturally meant to support human health and wellbeing has been contaminated by various chemicals emitted into them from natural and anthropogenic sources thereby causing major health risk to human dwelling in that vicinity and windward side of the pollution sources. According to Oderinde *et al.*, (2016) transport is a vital part of modern life whereby there is opportunity to travel short and long distances for personal development and professional activities. More importantly, the economic development of entire regions depends on the easy access to people, goods and services assured by contemporary transport technology because of its flexibility (Oderinde *et al.*, 2016; WHO 2017). In general, transportation improve overall accessibility in terms of business, education, employment and services; and reduce transportation costs (travel time, vehicle operating costs, road and parking facility costs, accident and pollution damages) to increase economic productivity and development. Unfortunately, these positive aspects are closely associated with the hazards to the environment and human health caused by road transport (WHO 2012). Motor vehicles, including non-road vehicles, now account for 75 percent of carbon monoxide emissions nationwide (USEPA, 2016).

2.3 Sources of Indoor Air Pollutants

Because different pollutant sources have varied properties, such as toxicity and dangerousness, the level of alarm will vary. The pollutant emitting capability, that is, how much pollutant does the source emit, the dangerous nature of the emissions, the closeness of inhabitants to the pollution source, and the purifying capabilities of the aeration scheme are some of the aspects to consider. The following are some common sources of indoor air pollution:

a) **Building Site or Location:** The proximity of buildings to indoor pollutant sources can have a great influence on the air quality of the indoor spaces. For example, residential of commercial buildings located near highways and thoroughfares, construction sites, industrial and chemical plants may experience higher particulates and other pollutants levels. (European Commission, 2003).

b) **Building Design:** It is unsurprising that poorly built buildings, in terms of IAQ, will experience higher indoor air pollution due to a lack of ventilation, which traps pollutants inside the structure. Unstable or weak foundations, leaking roofs, poorly planned facades, and poorly constructed window and door openings could all be examples of poor design, allowing pollutant or water penetration. Outside air intakes near sources of pollutants (e.g., idling automobiles, combustion products, garbage bins, etc.) or where building exhaust re-enters the building can be a persistent supply of pollutants. (European Commission, 2003).

c) **Building Systems Design and Maintenance:** Broken down HVAC systems leave buildings vulnerable to outdoor pollutants which can find their way into the building from outside pollutant sources such as; particulates, exhaust from vehicles, smoke etc. In addition, changes to the building design or use should also incorporate changes or adjustments to the air-conditioning and mechanical ventilation system to accommodate the new changes either in temperature, humidity, or airflow.

d) **Renovation Activities:** Dust and paint odors are prevalent during renovations. As a result, it is critical to isolate ducts and ventilation channels, as well as the air condition and mechanical ventilation system, and to install barriers to prevent dust and system.

e) **Local Exhaust Ventilation and Occupant activities:** Kitchens, motor garages, maintenance shops, barbershops and beauty salons, restrooms, laundry, and trash rooms, among other places where high pollutant activities take place, should be well ventilated.

d) **Building materials and furnishings:** Pollutants from factories and manufacturing plants contaminate building materials and household furnishings. This furniture could be made of pressed wood, which emits particles into the air, lowering indoor air quality. Building materials, on the other hand, can break down over time and release pollutants, or cause mold to grow on walls and ceilings due to a disturbance, such as moisture, degrading indoor air quality. The introduction of new building materials such as cement and corrugated iron sheet has impacted on the architecture of the built environment in the country. Furthermore, with the increasing revenue from oil, came a gradual departure from the traditional construction methods and materials to modern ones. Likewise, the fact that none of the traditional building materials was company manufactured, processed or fabricated, diminished their prospect of being further developed (Agboola & Zango, 2014). Buildings are now designed and constructed across the regions of Nigeria with modern western-style materials, due to their advantages over the traditional ones and the improved purchasing power of many citizens.

2.4 Common Types of Indoor Air Contaminants in Houses

The common type of indoor air contaminants found in hospitals indoor environments are carbon monoxide (CO), carbon dioxide (CO_2), total volatile organic compounds (TVOCs), formaldehyde (HCHO), and Particulate matter (WHO, 2016). .

2.3.1 Carbon monoxide (CO)

Carbon monoxide is a colorless, odourless, tasteless, and odorless toxic gas created by incomplete fuel combustion. CO is an inert gas that easily penetrates from the outside without being depleted by physical or chemical processes other than dilution through air exchange. It can be removed from the interior air, whether from outside or within sources, and replaced with fresh, CO-free air. Because of its stability, it is frequently used as an indoor tracer for air exchange measurements (Wanner, 2013). Incineration constituents such as coal or gas heaters, gas stoves, and water heaters all be sources of CO. High quantities of CO can also enter buildings from outside vehicle emissions. Tobacco smoking is another type of CO pollution that is only present for a short time. Carbon monoxide poisoning can exacerbate angina, decrease mobility, and ultimately result in death (WHO, 2016).

2.3.2 Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is an odourless and colourless gas that is a significant product of human respiration and is used as a key indicator for evaluating indoor air quality and ventilation system effectiveness. In the absence of additional sources (example, burning fuel), human CO_2 emissions account for a significant share of indoor CO_2 pollution (Wanner, 2013). Apart from human respiration, the largest source of CO_2 is combustion, which includes kerosene, gas, and wood or coal-fired equipment.

2.3.3 Total volatile organic compounds (TVOCS)

Chemical compounds that have at least one carbon and one hydrogen atom in their molecular structure are referred to as organic compounds. Very volatile organic compounds (VVOC), volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), and non-volatile organic compounds (NVOC) are the different types of organic molecules. The details of these compounds are shown in Table 2.1.:

Table 2.1: Classification of indoor organic compounds by volatility

Description	Abbreviation	Boiling point range (°C)
Very volatile (gaseous) organic Compounds	VVOC	0 to 50-100
Volatile organic compounds	VOC	50-100 to 240-260
Semi volatile organic compounds (pesticides, polynuclear aromatic compounds, plasticizers)	SVOC	240-260 to 380-400
Non-volatile organic compounds	NVOC	

Source: (WHO, 2016)

TVOCs are mostly found and emitted from building materials, furnishings and clothing, Potable water, combustion appliances, Paints and associated supplies, consumer and commercial products, carpets, adhesives and many others (BCA, 2010). VOC exposure has the potential to cause both immediate and chronic health consequences. Individuals with asthma and respiratory problems, such as nocturnal dyspnea, are more vulnerable to low-dose VOC exposures than others. Low levels of VOCs can also cause fatigue, headaches, drowsiness, and confusion.

2.3.4 Formaldehyde (HCHO)

Formaldehyde is a colorless gas with a strong odor and flammability that reacts quickly at ambient temperature. Although interior levels are higher due to the presence of more emitting sources, Inhalation, ingestion, and skin contact are the three major procedures for the human body.

Inhalation of formaldehyde has negative health consequences (sensory irritation, focus distraction, lachrymation, coughing, mortality, and so on). It can be found in a variety of products, including insulation, ceiling tiles, particle board, plywood, furniture, and more. Studies have shown that large amounts of formaldehyde exposure can induce cancer or other disorders in experimental animals (mice or rats) (WHO, 2016). Inhalation or direct contact with formaldehyde can cause negative health effects. Table 2.2 lists a variety of acute health effects linked to various formaldehyde concentrations.

Coughing, sneezing, and slight eye irritations are common symptoms of formaldehyde exposure of less than 1 ppm, however these symptoms usually go away quickly after exposure (Hines, 2015).

Table 2.2: Acute health effects from formaldehyde exposure

Formaldehyde concentration(ppm)	**Observed health effects**
<0.05	None reported
0.05-1.5	Neurophysiologic effects
0.05-1.0	Odour threshold limit
0.01-2.0	Irritation of eyes
0.10-25	Irritation of upper airway
5-30	Irritation of lower airway and pulmonary Effects
56-100	Pulmonary edema, inflammation, pneumonia
>100	Coma, death

Source: (Hines, 2015)

2.3.5 Particulate matter (PM)

Particle Matter is a term that describes a mixture of very small solid and liquid particles prevalent in the air, both indoors and outdoors, that can be damaging to one's health. Because the particles themselves are of varied sizes, some are one-tenth the width of a strand of hair, assessing particle pollution is difficult. Many are considerably smaller; some are so little that only an electron microscope can see them. Individual particles are invisible due to their small size, but combined they appear as a haze, which arises when millions of particles distort the distribution of sunlight. This means that humans are unaware when particles are inhaled, despite the fact that it is so harmful that it can shorten life. Natural defences assist people in coughing or sneezing larger particles out of our bodies, but they do not keep out smaller particles (those that are smaller than 10 microns in diameter, or about one-seventh the diameter of a single human hair). These particles become lodged in the lungs, whereas the tiniest can pass through the lungs and into the bloodstream.

Particles are divided into three sizes by researchers: coarse, fine, and ultrafine. PM10-2.5 particles are coarse particles with a diameter of 2.5 microns to 10 microns. PM2.5 refers to fine particles with a diameter of 2.5 microns or less.

Ultrafine particles have a diameter of less than 0.1 micron and are small enough to pass through lung tissue and into the bloodstream, where they circulate alongside oxygen molecules. Ones of any size can be hazardous to one's health, while smaller particles can penetrate deeper into the organs, (Al-Salem & Khan, 2010)

PM0.1 – particulate matter having a diameter smaller than 0.1 microns (100 nm).

PM10 – particulate matter having a diameter smaller than 10 microns.

PM2.5 – particulate matter having a diameter smaller than 2.5 microns.

In recent years, studies carried out such as to assess the levels of criteria air pollutants in cities of Rivers State, including Port Harcourt, and their probable association with air borne diseases, provide evidence of correlation. Adoki, (2012) carried out air quality survey in four different locations in Rivers state at varying distances (60, 100, and 500 m) from emission source. Conferring to his findings, virtually all the samples complied with (Department of Petroleum Resources (DPR)) guidelines for annual average apart from SOx and NOx whose annual means surpassed specification at only one location. Non-conformity occurred mostly in the dry season. During that season, the levels of the pollutants were disposed to be higher in the evenings and sustained through the early hours of the morning. In all four locations, suspended particulate matter (SPM) conformed to specification of 230ug/m; with highest annual mean being 129ug/m. Like with NOx and SOx, season significantly influenced their concentrations (Adoki, 2012). Nwachukwu *et al*, (2012) in their survey of a 5-year

(2003 to 2007) epidemiological data discovered that the level of all the criteria air pollutants in Rivers State was significantly higher than the WHO specification. They were able to prove that air pollution was associated with air related morbidities and mortalities in the state. Amongst the air-related morbidity assessed, including cerebrospinal meningitis (CSM), chronic bronchitis, measles, pertussis, pulmonary tuberculosis, pneumonia, and upper respiratory tract infection (URTI), pneumonia was the most prevalent for all of the years that were studied, and was responsible for the highest number of deaths in 2005.

2.3.6 Sahara dust

Northern part of Nigeria trade winds flows over Sub-Saharan Africa from late November to March carrying with it dry dust. Northern Nigeria is faced with perennial pollution from the deposits of the Sahara desert dust that blows during the months of November to February every year (Okunola *et al.*, 2012). This phenomenon however, has not received the necessary attention it deserves (De Longueville *et al.*, 2010). Stormy activities in the depression of Chad Basin raise a large amount of dust into the atmosphere and transport some over West Africa to the Gulf of Guinea, depositing, re-suspending and re-depositing along the transport path. The Harmattan winds are often found in Nigeria, Benin, Togo, Ghana and the Cote D'voire, and the quantity and the impact of the dust is greater in the Northern parts of these countries and that the dust particles become finer in size as they move further south (Uduma & Jimoh, 2013). Being a country in West Africa, Nigeria is one of the countries most exposed to desert dust because of its proximity to the main emission source area and its location with regard to the dominant trade winds. Among the atmospheric aerosols, mineral dust produced from wind-blown Sahara dust is one of the largest contributors to the global aerosols loading (contributes about 58% of the global Harmattan emission). It has strong impacts on human health, agriculture, micro-climate, visibility and the ecosystems of a large area of West Africa, and even on the global environment (Tanaka & Chiba, 2006). When inhaled these particles evade the natural defences of the respiratory system and lodge deep in the lungs causing serious health complications (De Longueville *et al.*, 2010). It has become common especially in Northern Nigeria, for people to experience nasal congestion, cough, muscular aches and pains, painful watery eyes, and unusually high body temperature during the more dusty Harmattan periods. It was only in 1998 that the Nigerian government set up an agency (Environmental Protection Agency - EPA) for the protection of external environment, through regulating, controlling and monitoring environmental pollution in the country, however, no reference was made to the inconveniences caused by the Sahara desert dust to the public (Chineke & Chiemeka, 2009). It has been observed that the dust from the Sahara also travels long distances even outside the African continent, making it a global problem. The presence of the Sahara desert dust and its effects have been reported by many researchers to reach as far as Western Europe and the Americas (Chineke & Chiemeka, 2009; Ginoux *et al.,* 2012). Uduma & Jimoh, (2013) studied Harmattan dustand hospitalization data, the results confirm a correlation between Harmattan dust impact and human health in Kogi.

2.4 Indoor Air Quality and Occupants' Wellbeing

Indoor allergies and irritants require special attention in this decade and beyond because we're spending more time indoors and these irritants can't easily exit because modern homes are airtight (Bluyssen & De Richemont, 2010). Every day, most people spend roughly 90% of their time indoors, whether at home, at work, or at school (Jacobs, *et al.,* 2007). This means that occupant well-being must be attained in terms of indoor air quality, thermal, visual, and acoustical comfort. Similarly, pollution levels are 2 to 5 times greater indoors than outside, according to USEPA measurements, regardless of whether the buildings are in rural or highly industrial settings. Other recent scientific investigations have raised concerns about the air quality inside our homes and businesses (Waterfurnace, 2016).

Over the last 50 years, the fast development of new construction materials, furniture, and consumer products has resulted in an increase in new chemicals in the built environment. (Weschler, 2009). Weschler discovered that the number of chemicals created and used in household and building items, such as construction materials, interior finishing materials, cleaning agents, furnishings, computers and office equipment, printers, and supplies, has increased dramatically in recent years.

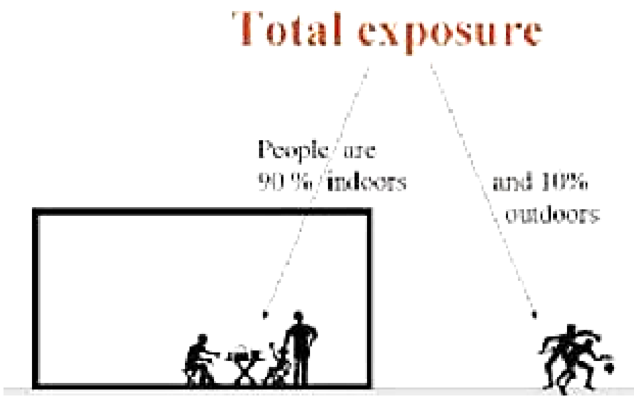

Figure 2.1: Time typically spent indoors and outdoors. Source: European Commission (2003)

Indoor air pollution is not a new problem. On the subject of IAQ, there is more than enough written data dating back over a century. Poor IAQ is thought to be a major cause or aggravating factor in the following disorders, according to WHO (2016):

a) Allergic and asthma symptoms
b) Lung cancer
c) Chronic obstructive pulmonary disease (COPD)
d) Airborne respiratory infections
e) Cardiovascular disease (CVD)

f) Odour and irritation (SBS symptoms)

g) Stress

2.5 Indoor Air Quality (IAQ) and Energy Use

Nigeria, unlike wealthy countries, faces a number of environmental, social, and economic issues, including a lack of electricity, a poor waste disposal system, air, water, and noise pollution, unemployment, and a lack of water supplies, to name a few (Stanley, Mbamali, Zubairu, Bustani, Andrew & Joshua, 2010). Buildings use a lot of energy and are considered to be one of the most energy-intensive economic sectors. Because buildings are affected by their surroundings and vice versa, it is critical to pay attention to the environmental quality of inside spaces. When attempting to achieve environmental quality in indoor areas, three aspects must be considered: building physics, energy use, and outdoor conditions. Because buildings have such a lengthy life period, spanning decades or even centuries, the European Commission (2003) emphasizes that "all decisions taken at the design stage have long term implications on the energy balance and the environment." Previously, it was thought that good indoor air quality and energy efficiency were mutually exclusive. That is, because buildings consume a lot of energy through their HVAC systems, achieving acceptable indoor air quality requires a significant investment in energy. However, it has been demonstrated by (Bluyssen & De Richemont, 2010) that this does not have to be the case: good indoor air quality may be achieved without spending a lot of money on energy if the building and HVAC systemare planned in such a way that the ventilation of the areas is maximized. Today's challenge is to establish the perfect balance between good indoor air quality and high energy efficiency, (European Commission, 2003).

2.6 Strategies for Achieving a Good Balance between Good Indoor Air Quality (IAQ) and the Rational Use of Energy in Office Buildings

According to the USEPA (2016), “Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Indoor air can be much more contaminated than outdoor air, contrary to conventional opinion. Most people associate air pollution with something outside the home: smog, ozone, haze in the air, or a noxious Odour from a nearby chemical plant. However, theair inside houses, businesses, and other structures can be significantly more contaminated than the air outside (Bluyssen & De Richemont, 2010). Lead (in house dust), formaldehyde, fire retardants, radon, microscopic dust mites from moulds, and even volatile compounds from fragrances used in conventional cleaners are all common contaminants present in the air inside homes. Some pollutants are carried into the homevia a new mattress or furniture, carpet cleaners, or a coat of paint on the walls, accordingto Bluyssen & De Richemont (2010). One of the top five environmental concerns is poor indoor air quality (IAQ) (USEPA, 2016). Improving indoor air quality in buildings can have a significant impact on occupant health. Pollutants in the air of a building can cause dizziness, migraines, and aggravate allergies and asthma. While cleaning and vacuuming can help to improve indoor air quality, it will not solve IAQ issues on its own. Good indoor air quality has a slew of advantages. It improves staff health, employee productivity, and occupant pleasure, reduces absenteeism, improves learning and student achievement, and promotes a more favourable customer experience (Lavin & Higgins, 2006). The advantages of improved indoor air quality have also been linked to higher returns on investment (ROI) and bottom-line economics (ASHRAE, 2009).

Although the problems associated with poor IAQ have been extensively documented and are widely available, many building design and construction decisions are made without considering the potentially significant effects of bad IAQ. Ventilation has been a major architectural factor for as long as man has been systematically building his dwelling. In the last century, public knowledge and concern about indoor air quality

(IAQ) has progressively grown, and it is now a major consideration in the design and construction of any livable facility. "In most situations, IAQ is still not a high-priority design or building management concern relative to function, cost, space, aesthetics, and other features such as location and parking," ASHRAE (2009).

2.7 Ventilation and Energy Use in Office Buildings

Residential building ventilation is one part of a well-thought-out plan for creating and maintaining a comfortable and healthy interior air environment. Avoiding the installation of things with known high pollutant emissions inside the home environment is the first step in controlling indoor air pollution. It's followed by local exhaust in areas where excessive pollutant emissions can't be prevented, such as kitchens, toilet rooms, and bathrooms (wet rooms), and it's followed by whole-building controlled mechanical ventilation to dilute leftover interior pollutants with fresher outdoor air, (Rudd & Lstiburek, 2000).

Because the ventilation air is thermally conditioned, that is, heated, chilled, and dehumidified or humidified, ventilation consumes energy. The running of ventilation fans in mechanically ventilated buildings wastes energy as well. As the amount of ventilation air provided grows, the capacity of heating and cooling equipment must also be raised. As a result, ventilation rates have frequently been reduced, notably during the energy crisis of the early 1970s, in order to save money on equipment and energy. Buildings have also gotten more airtight, especially in colder climates, reducing ventilation air flow through the building envelope. The ventilation rates chosen for buildings must strike a balance between ventilation's energy consumption and the known or theorized health and comfort benefits of ventilation, (Rudd, *et al.,* 2013).

2.8 Energy Efficiency and Sustainability

In developed countries, energy consumption in both residential and commercial buildings is dominated by space heating, cooling, air conditioning and lighting, as shown in Figure 1.

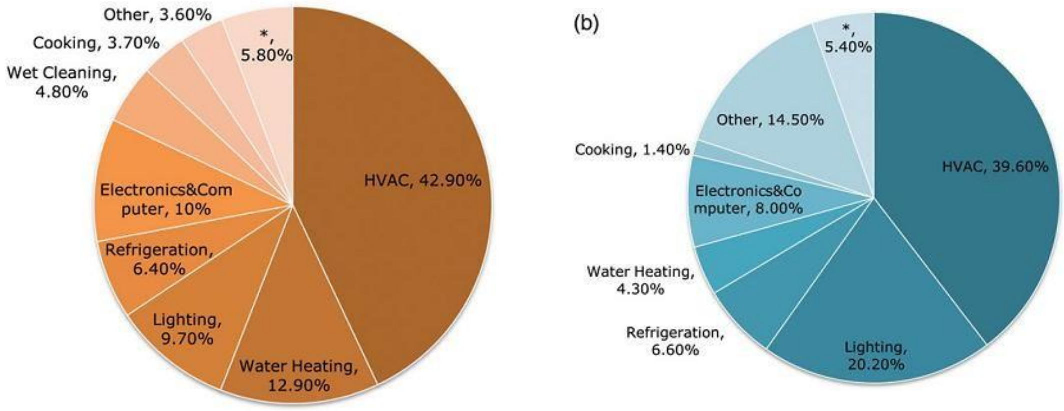

Figure 2.2: (a). Residential buildings total energy end use (2010).(b).Commercial sector building energy end use.

Because of the usage of air conditioning systems in buildings for occupant comfort, energy consumption in commercial and private buildings in the EU exceeded 435 Mtoe (40.3%). Lighting energy usage rises as well, becoming a considerable portion of total energy consumption in buildings (European commission, 2003). Various analytical and practical investigations on air conditioning systems using solar energy to drive desiccant and adsorption/absorption have been carried out to increase the energy efficiency of air conditioning systems (Choudhury, Chatterjee, & Sarkar, 2010). Though these systems have a significant potential for energy savings because they can replace high electrical energy and thus fossil fuel use, their cost-effectiveness can be improved further if they are used in conjunction with correct control measures.

2.8.1 Required minimal and maximal ventilation rates of residential buildings

Tightening the building envelope can also help to reduce energy losses due to uncontrolled infiltration. However, appropriate ventilation must be delivered in a controlled manner to meet the needs of the inhabitants in terms of health and comfort. There are currently no widely accepted figures for this minimum level of adequate ventilation. For example, between 1981 and 1989, the amount of ventilation requirements in the ASHRAE 62 standard tripled (from 2.5 to 7.5 litters per second and person), partially because moderate smoking was permitted in the 1989 standard but not in the 1981 standard. Heating and cooling buildings, as well as providing other building services such as lighting, account for a major share of national economies and the global energy balance. Depending on the climate, socioeconomic status, and structure of energy use in a country, the percentage used for heating and cooling in European countries ranges from 20 to 80 percent of total energy use.

2.9 Indoor Air Quality Standards and Guidelines

The following are the national or mandatory standards and guidelines for Carbon monoxide (CO), Carbon dioxide (CO_2), Total Volatile Organic Compounds (TVOCs), Formaldehyde (HCHO) and Particulate matter (PM):

1. **Carbon monoxide (CO):** According to the AHSRAE standard, carbon monoxide exposure shall not exceed 9 ppm for an eight-hour time weighted average airborne concentration (ASHRAE, 2007). The World Health Organization (WHO) recommends a threshold of 10 parts per million (ppm) (WHO, 2016). The National Institute of Occupational and Environmental Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) recommend a threshold level of 35 ppm (NIOSH, 2004; OSHA, 2011);

nevertheless, MAK (MAK, 2000) recommends 35 ppm and ACGIH recommends 25 ppm. (ACGIH, 2005).

2. **Carbon Dioxide (CO_2):** ASHRAE standard 62.1(ASHRAE, 2007) recommend a threshold limit of 1000 ppm for carbon dioxide for an eight-hour time weighted average airborne concentration. The other threshold limits are 5000 ppm (ACGIH, 2005; MAK, 2000; NIOSH, 2004) and 10,000 ppm (OSHA, 2011).
3. **Total Volatile Organic Compounds (TVOCs):** TVOC concentrations shall not exceed 1.0 mg/m^3 according to ASHRAE Standard 62-1989R. (ASHRAE, 2007). Essentially, TVOC concentrations might be regulated to be less than the 0.2 mg/m3 no-effects criterion. In addition, ASHRAE recommends a comfort range of 0.2 mg/m3 for TVOCs, whereas multifactorial exposure ranges, discomfort ranges, and toxic ranges are (0.2 – 3 mg/m^3), (3 – 25 mg/m^3), and (>25 mg/m^3), respectively (ASHRAE, 2007).
4. **Formaldehyde (HCHO):** The recommended limit for an 8-hour time–weighted average airborne concentration exposure for formaldehyde is 0.1 ppm (DOSH, 2005). The other threshold limits are 0.3 ppm(ACGIH, 2005; MAK, 2000), 0.016 ppm (NIOSH, 2004) and 0.75 ppm (OSHA, 2011).
5. **Particulate Matter (PM):** ASHRAE maximum exposure limit for PM2.5 is 35µg/m^3 and PM10 is 150µg/m^3 (EPA, 2016). The threshold limits for other international standards are 10 mg/m^3 (ACGIH, 2005) and 4 mg/m^3 (NIOSH, 2004).

2.10 Building Illnesses

The term 'symptoms of diagnosable illnesses or causes that may be diagnosed and attributed directly to airborne building contaminants' is used to describe Building

Related Illnesses (BRI). Coughing, chest tightness, chills, fever, and muscle aches are all symptoms of BRI. After leaving the facility, occupants may require extended recovery time.

Building-related illnesses are that which occur in non-residential and non- industrial structures. Infectious, immunologic, and allergic disorders, as well as a diverse set of work-related symptoms such as skin irritation, mucous membrane irritation of the eyes, nose, and throat, headache, weariness, and difficulties concentrating, are among the diseases. BRI has been linked to both physical environment (e.g., indoor air quality) and mental factors. The ill building syndromes include BRI symptoms that are linked to the physical environment of specific buildings(SBS), (Stephen, *et al.,* 2008).

2.10.1 Sick building syndrome

Sick building syndrome is defined by the Institute of Environmental Epidemiology (IEE, 1996) as an excess of work-related irritations of the skin and mucous membranes, as well as other symptoms (such as headache and weariness) experienced by residents in dwellings or modern office buildings. The following symptoms are most typically associated with sick building syndrome, according to the World Health Organization (WHO) (2016):

1. Eye, nose and throat irritation;
2. Sensation of dry mucous membranes and skin;
3. Erythematic;
4. Mental fatigue;
5. Headaches;
6. High frequency of airway infection and coughs;
7. Hoarseness, wheezing, itching and unspecified hypersensitivity;
8. Nausea and dizziness.

Symptoms of sick building syndrome typically afflict 20% or more of a building's occupant population, as contrast to building-related disease, which typically affects only a few residents. (Spengler & Sexton, 1983; Samet, 1993).

2.10.2 Building related illnesses

The type of sickness caused by a contaminant in a building is determined by the contaminant present. Exposure to bio-aerosols, for example, can produce humidifier fever and hypersensitivity pneumonitis, whereas Legionnaires' disease is caused by exposure to the legionella bacterium (Spengler& Sexton, 1983; Samet, 1993). When the person leaves the building, the symptoms do not go away. Tracing the sickness to a specific contaminant and removing the source from the building is the most effective mitigation technique for building-related illness. When researching an interior air quality problem, distinguishing between these two types of ailments induced by indoor surroundings can be difficult. A further issue is that both illnesses can occur in the same building, and a building-related illness or sick building syndrome may be mistaken for the other. These classifications are useful in assisting in the identification of the problem, but the most important priority, above classification, is the alleviation of health and indoor air concerns. When signs of diagnosable sickness are detected and can be directly attributable to airborne building pollutants, the term "building related illness" (BRI) is used.

2.11 Benefits of Good IAQ

The European Commission (2003) lists a number of advantages for ventilation in future rural and urban building developments in order to ensure good indoor air quality and occupant satisfaction. According to the commission, the current and future generations of building occupants will be safe and productive because adequate indoor air quality will improve their health and well-being.

i. Optimise energy use and save cost with comfort and productivity
ii. Minimize indoor and outdoor exposures to pollutants and other agents with adverse health effects
iii. Decrease life-cycle costs by avoiding adverse health effects, energy waste and unnecessary costs for operation, maintenance and rehabilitation of buildings
iv. Avoid the use of rare materials and encouraging a sensible recycling of other material
v. Avoid the use of materials and substances hazardous to the environment.
vi. Not cause unwanted side-effects like noise, draught, added air pollutants, or spreading indoor or outdoor generated pollutants.
vii. Help to maintain building and city designs and structures that are vital to social and economic values and social networks among individuals
viii. Help to preserve historical buildings and environments as well as respecting local architectural traditions in a cautious and aesthetic balance with new building and system designs.
ix. Design and operating buildings and systems so that they make sensible use of climate and natural forces and can be adapted (over centuries) for shifting demands.

CHAPTER THREE

3.1 RESEARCH METHODOLOGY

3.2 Research Design

This research involved field survey and extensive literature review. Field survey which involved the measurements of indoor air quality and electrical energy consumption parameter, particulate matter ppm2.5, relative humidity temperature and carbon dioxide (CO_2) for indoor air quality. And also a careful measurement of the electrical energy consumption in KWh. The field measurements data was obtained by using appropriate scientific equipment, air visual anode monitoring device and wireless energy monitoring device. Also, an extensive literature review was carried out to obtain in-depth knowledge of the subject area. According to Akanmu *et al.,* (2020), the methodology employed for the assessment of these IAQ descriptors followed prescriptions of international standards ASHRAE standard 55 and ISO 7730.

A research procedure was designed as shown in Fig. 3.1 and was adequately followed to accomplish the objectives of the study.

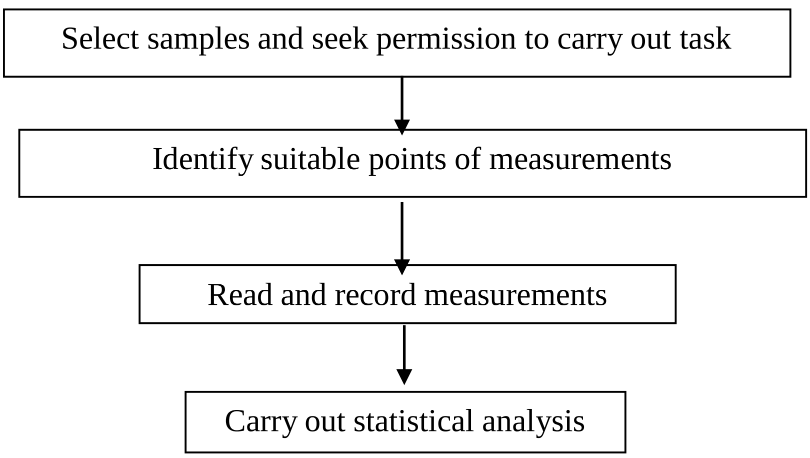

Figure: 3.1 Flow diagram for the Research procedure

3.3 The Study Area

Lokoja, the research region, is located between latitudes 7°45'N and 6°45'E. Lokoja is the administrative capital of Nigeria's Kogi State. State and federal roadways connect it to the rest of the country. It is also close to the junction of the River Niger and the River Benue; the location is sandwiched between a water body and a hill, namely the River Niger and Mount Patti, which streamlines the settlement and has a modifying impact on the climate. The climate is divided into two seasons: wet and dry. The Guinea Savannah Region has an AW type climate, according to Koppen's classification. The annual rainfall is between 1016mm and 1524mm with the mean annual temperature of 27º7'C (NPC, 2006).

3.4 Population, Sample Size and Sampling Techniques

3.4.1 Population

The survey population of this research work was based on residential buildings with specific focus on selected residential building in Lokoja Kogi State. The selected residential in Lokoja, Kogi State makes the population of the study.

3.4.2 Sample size and sampling technique

The equation given by (Singh and Masuku 2014) of sample size determination is used to determine appropriate sample size, based on the population of the selected buildings; this gives the sample size for the assessment of the indoor air quality and energy consumption of the office buildings within the area.

The equation is as follows:

The formula: n = $\frac{N}{1+ a^2N}$ …………………………………….. (1)

Where:

n = sample size

N = population size;

α = alpha (1.96) by substituting the size of the population

*95% confidence level of (1.96) was assumed, and substituting into equation 3.1, the sample size obtained was as follows:

$$\frac{N}{1+ a^2N} = \frac{200}{1+(1.96^2)(200)} = \frac{200}{1+8}$$

$$\frac{200}{9} = 22.2 \text{ nos.} \approx 22 \text{ nos.}$$

The sample size for the assessment of the indoor air quality and energy consumption of the houses within the estate was 22. Simple random sampling technique was used to select the houses within the selected estate for the study.

3.5 Data Collection Equipment and Procedure

3.5.1 Data collection equipment

The equipment that were used for the collection of data included; measurement that access Indoor Air Quality and Energy consumption.

3.5.1.1 Equipment

Measurements were carried out using the following equipment in the selected houses within the estate:

i. Indoor Air Quality Visual Monitor

ii. Wireless Energy monitor

i. Indoor Air Quality Visual Monitor

Indoor Air Quality Visual Monitor is a multi-meter tester that may be carried about (Plate 3.1). Build custom IFTT applets to trigger other smart devices. Professional grade, extremely accurate indoor air quality monitoring system laser sensor technology delivers highly exact indoor readings for Particulate matter 2.5 and CO_2. It uses the world's largest network of air quality monitoring stations sensor to display real-time local outdoor air quality data, as well as indoor temperature and relative humidity, and indoor and outdoor air quality compared side by side on a bright 5" screen. It was used to measure the indoor air quality from the study area. It measures and calculates the following parameters:

i. Particulate matter 2.5 (PM2.5)
ii. Carbon dioxide (CO_2)
iii. Relative Humidity
iv. Temperature

The Indoor Air Quality Monitor Measures Particulate matter in the range 0.3 - 2.5µm, Carbon dioxide (CO_2) in the range 400 – 10,000 ppm, Temperature in the range 10 - 40ºC and Relative Humidity 0 – 95%.

Plate I: Indoor Air Quality Visual Monitor

ii. Wireless Energy monitor

The second instrument used in the study is Wireless Energy monitor (EW4500) (Plate 3.2). This meter is portable and equipped with Triple display showing; your current electricity usage, your accumulated electricity usage over any period of time and Your per hour usage. The Wireless Energy monitor displays the hour/minutes, Day/Month and Year.

Plate II: Electronic Instrumentations.

Source: www.efergy.com

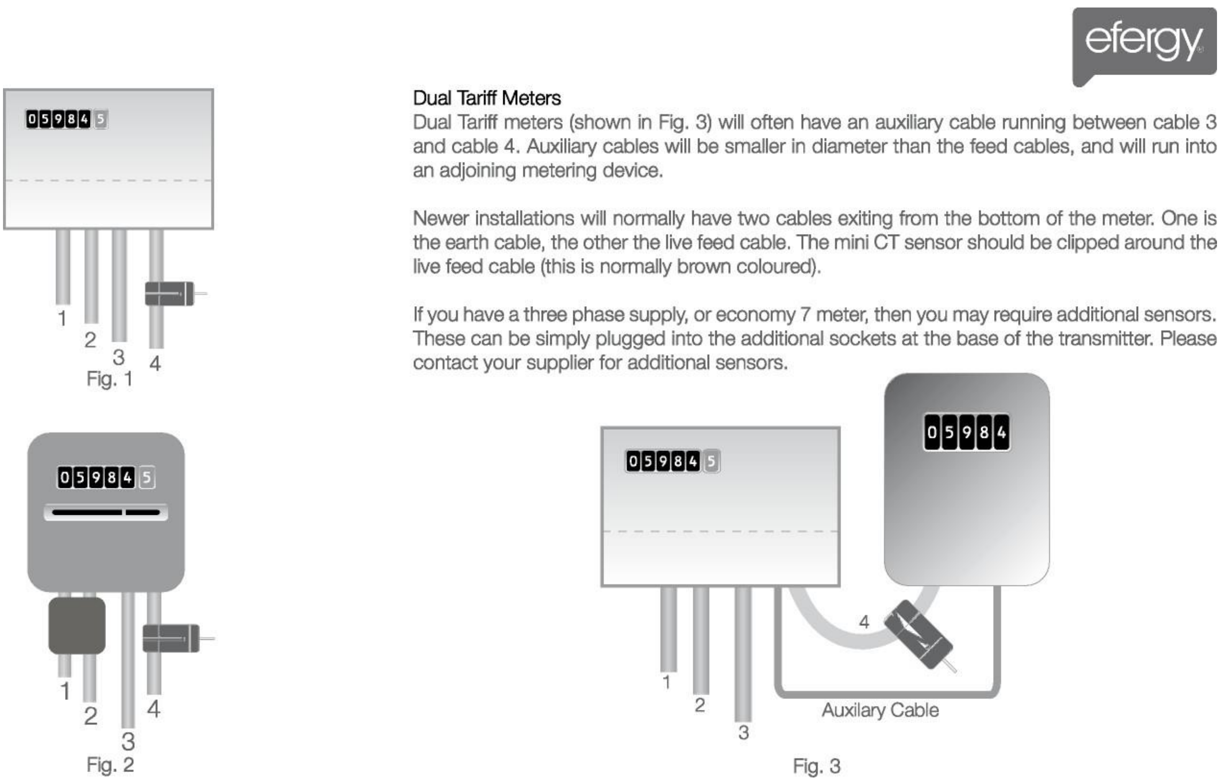

Plate III: Wireless Energy Monitor

Source: www.efergy.com

3.5.2 Data collection procedure

The following are the procedures carried out in other to archive the objectives of the study.

3.5.2.1 Experiment

Data was collected by adhering to the experimental procedure described below.

Steps: The following are the six steps that was followed to carry out the experiment in the selected houses:

i. Sampling Locations: this includes the selected houses to be sampled.

ii. Sampling Session: Sampling times was selected in an attempt to collect data during potential high activity. The two (2) time windows (Sampling Sessions) include:

   a. Morning time (Session 1): approximately 8:00-10:00 a.m.

   b. Evening time (Session 2): approximately 4:00-6:00 p.m.

iii. Calibration of the Equipment: The Indoor Air Quality Visual Monitor and Wireless Energy monitor was calibrated according to the manufacturer's instructions.

iv. Positioning of the Equipment: The Indoor Air Quality Visual Monitor was placed away from all walls, openings and corners. The equipment was placed at different sampling points within each space in the various selected houses. Watts Clever Wireless Energy monitor was connected to the selected house meter.

v. Documentation of Results: The resulting value was documented on a sampling form.

The Precision Requirements: The Indoor Air Quality Visual Monitor calibrate in 200 seconds for start-up of the analyzer and 60 seconds recalibration for new measurement. Watts Clever Wireless Energy monitor calibrate automatically before the start of new measurement. This was done to ensure accuracy of results.

3.6 Data Analysis

To compare the contaminants' means and significant levels, descriptive and inferential statistics were used. For analysis, the acquired means were combined into a single SPSS file.

3.6.1 Descriptive statistics

Descriptive statistics was used to summarize the mean, frequency and standard deviation of pollutant and particle concentration. Simpler interpretation of the data was acquired using descriptive statistics, and the data was presented in a more comprehensible manner.

3.6.2 Inferential statistics

The Pearson Correlation was used to determine whether there is any linear relationship between the indoor air quality and the energy consumption in the selected houses within the estate. A Probability value (p-value) of ($p<1.96$) was used for all analyses. It was used to show how pairs of variable are related and how strongly the variables are related. The application of statistical techniques was led by the following criteria:

i. The null hypothesis
ii. The p-value for the selected test statistic
iii. The level of probability used is 1.96

When p-value is less than the significance level (α), then, the variables are statistically related. Therefore, the decision rule all conditions recorded in this study was thus;

If p-value < α, we reject the hypothesis, otherwise we do not reject it.

The three null hypotheses postulated for this study were tested using simple regression and multiple regressions. Simple regression was used to evaluate if two null hypotheses would be rejected or not rejected, regardless of whether the other hypotheses were considered. Each hypothesis addresses the link between each independent and dependent variable independently. The final null hypothesis was tested using multiple regressions because it examined the combined effects of the two independent variables. Below are the null hypotheses:

i. There is no relationship between the independent variable (Temperature) and dependent variable
ii. There is no relationship between the independent variable (Carbon dioxide) and dependent variable.
iii. There is no relationship between a linear combination of the independent variables and dependent variable.

3.6.3 Case study of residential building

The estate 500 housing units considered in this case was constructed in 2004 with over 200 housing units and housing occupant in the year 2007. It relies on grid electricity supply of energy use.

Furthermore, the grid electricity use is metered and billed in kWh using prepaid meter.

CHAPTER FOUR

4.1 RESULTS AND DISCUSSIONS

4.2 Data Presentation and Analysis

This chapter of the study presents the results of the data collected and analyzed relative to the indoor air quality of the 200 housing unit estates in Lokoja metropolis, Kogi state. At the time of the field work 22 houses were conducted, which includes 4 key indoor air quality indicators including Particulate matter2.5 (µg/m^3), Carbon dioxide (CO_2), Temperature (ºC), Relative Humidity (%) and electrical energy reading in KWh. This section first presents the results gathered from the actual spot measurement procedures using the monitoring equipment – Direct Sense-IAQ Visual Monitor and Wireless Energy Monitor. Here, descriptive statistics are used to present and analyze the results, which include chart showing the average particulate matter 2.5 (µg/m^3), carbon dioxide (CO_2), temperature (ºC) and relative humidity (%) during 4-hours observation for each 22 houses, (ASHRAE, 2007)

4.3 Results and Discussion

This section only presents the actual findings and results gathered from the data collected.

4.4 Average Concentration Level of Particulate Matter

Figure 4.1 shows the average concentration level of particulate matter2.5 in 22 houses located in 200 housing unit estate in Lokoja, Kogi state. The data shows that particulate matter2.5 as per average values, of particulate matter2.5 were within the limit of ASHRAE standard for particulate matter 2.5 which should not be more that 35µg/m^3 particulate matter 2.5 is a major product of pollutant that are combination of very small solid and liquid particles in air both indoor and outdoor that can be damaging to one health. Detailed minimum and maximum of particulate matter2.5 values of the houses can be found in Appendix A.

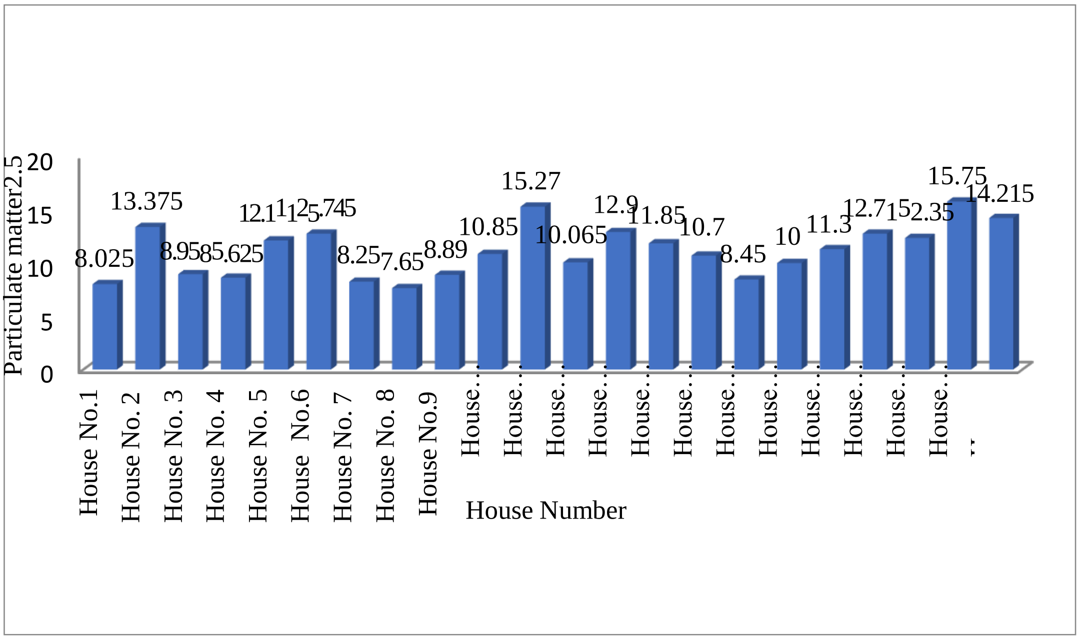

Figure 4.1: Average particulate matter2.5

4.4.1 Average concentration level of carbon dioxide (co_2) ppm

Figure 4.2 shows the average concentration level of carbon dioxide (CO_2) ppm in 22 houses located in 200 housing unit estates in Lokoja, Kogi state. The data shows that Carbon dioxide (CO_2) ppm as per average values, of carbon dioxide (CO_2) ppm are within the limit in house number 1 to house number 22, when compared with Alumnus Department of Public Healthy (Illinois Department of Public Health IDPH, 2003) guide for indoor air quality. Based on the data, house number 2 has highest average CO_2 concentration level amongst the 22 house spaces, with concentration level of 777ppm. House number 1, 3, 7, 8, 17, 18, 20 and 21 have relatively high average CO_2 concentration levels ranging between 612ppm and 755ppm. While house number 4, 6, 9, 10, 11, 12, 13, 14, 15, 16, 19 and 22 have relatively low average CO_2 concentration levels ranging between 411.5ppm and 525.5ppm.

Carbon dioxide (CO_2) is a major product of human respiration and is utilized as an important indictor to evaluate indoor air quality, as well as the performance of ventilation systems. By generally-accepted standards set forth by the ASHRAE, the accepted level for carbon dioxide should be below 1000ppm. The findings of the concentration levels of carbon dioxide at the 22 houses showed that there was adequate air circulation for all the building spaces, wherein all buildings where field work was conducted have below 800ppm concentration levels. Therefore, the 22 houses passed the recommended level established by other standards such as the OSHA, in which the current OSHA standard for carbon dioxide is 5000 ppm as an 8-hour time-weighted average concentration (Mallinger, 2015). Detailed minimum and maximum of particulate matter2.5 values of the houses can be found in Appendix A

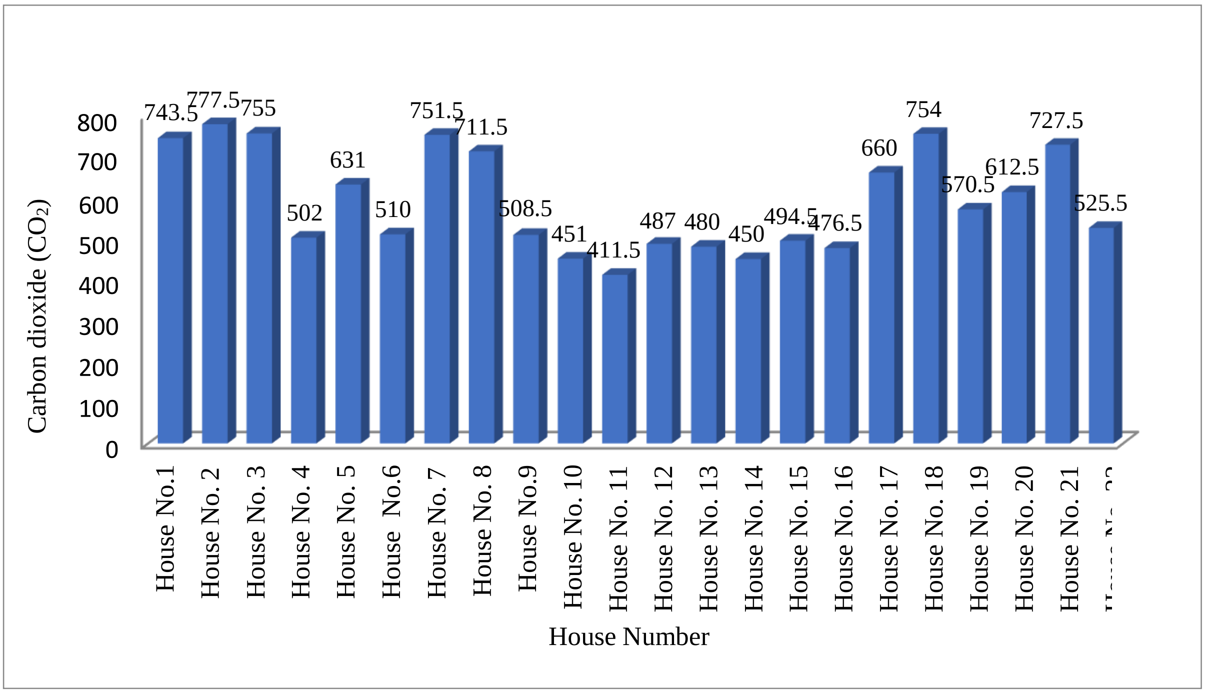

Figure 4.2: Average concentration level of Carbon dioxide (CO_2) ppm.

4.4.2 Average level of temperature (^{O}C)

Figure 4.3 shows the average level of temperature (^{o}C) in 22 houses located in 200 housing unit estates in Lokoja, Kogi state. Based on the result below, it indicates that house number 8, 9 and 12 have temperature within the ASHRAE standard range while the remaining houses were within comfortably cool in the morning and comfortably warm in the evening. According to the result, observed temperature at house number 7 was much higher compared to other average temperature levels at other houses with an observed average temperature of 30.75^{o}C. when comparing with limits of (IDPH) high temperature and relative humidity measured could cause discomfort dehydration and enhance the growth of molds, fungi and bacteria which could adversely affect occupants health (Davis, 2003). Detailed minimum and maximum of temperature (^{o}C) values of the houses can be found in Appendix A.

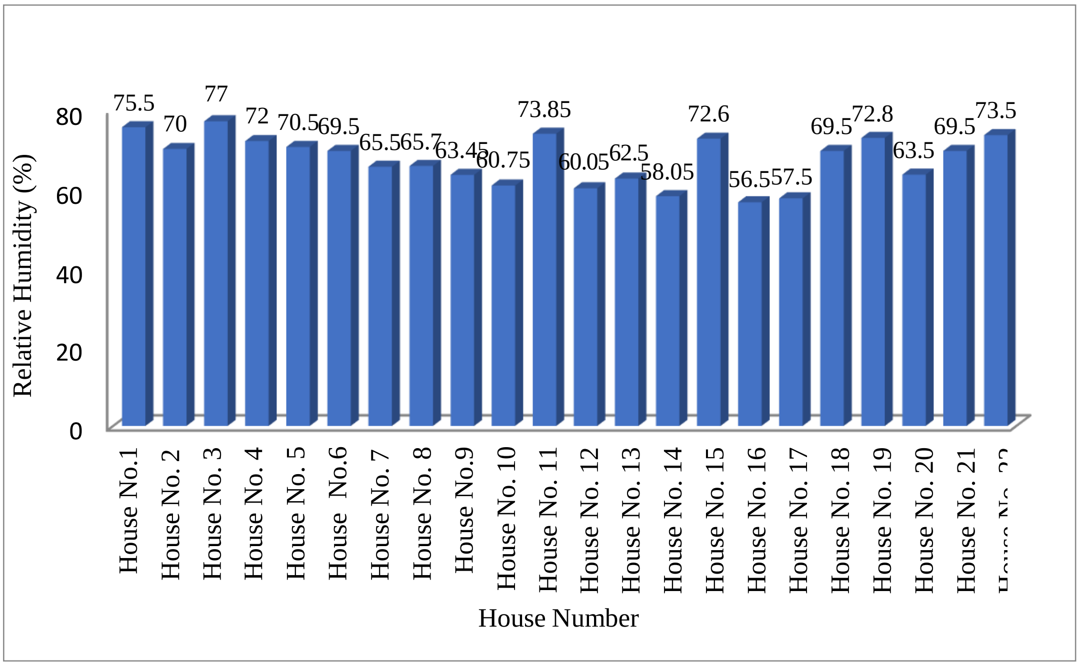

Figure 4.3: Average level of Temperature (^{o}C)

4.4.3 Average relative humidity (%)

Figure 4.4 shows the average Relative Humidity (%) at the 22 housing unit estates located at Lokoja Kogi state. Accordingly, house number 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,12, 13, 15, 18, 19, 20, 21 and 22 have higher relative humidity (%), meaning that these houses contained higher amount of moisture in the air compared to what the air could hold at their respective temperature levels while house number 14, 16 and 17 have normal required relative humidity, meaning that these houses contained accurate amount of moisture in the air compared to what the air could hold at their respective temperature. According to ASHRAE standards, acceptable temperature and relative humidity ranges for indoor environments is 20-27°C and 30-60%. Findings showed that all 22 spaces at Building A and B have temperatures within the ASHRAE standard range.

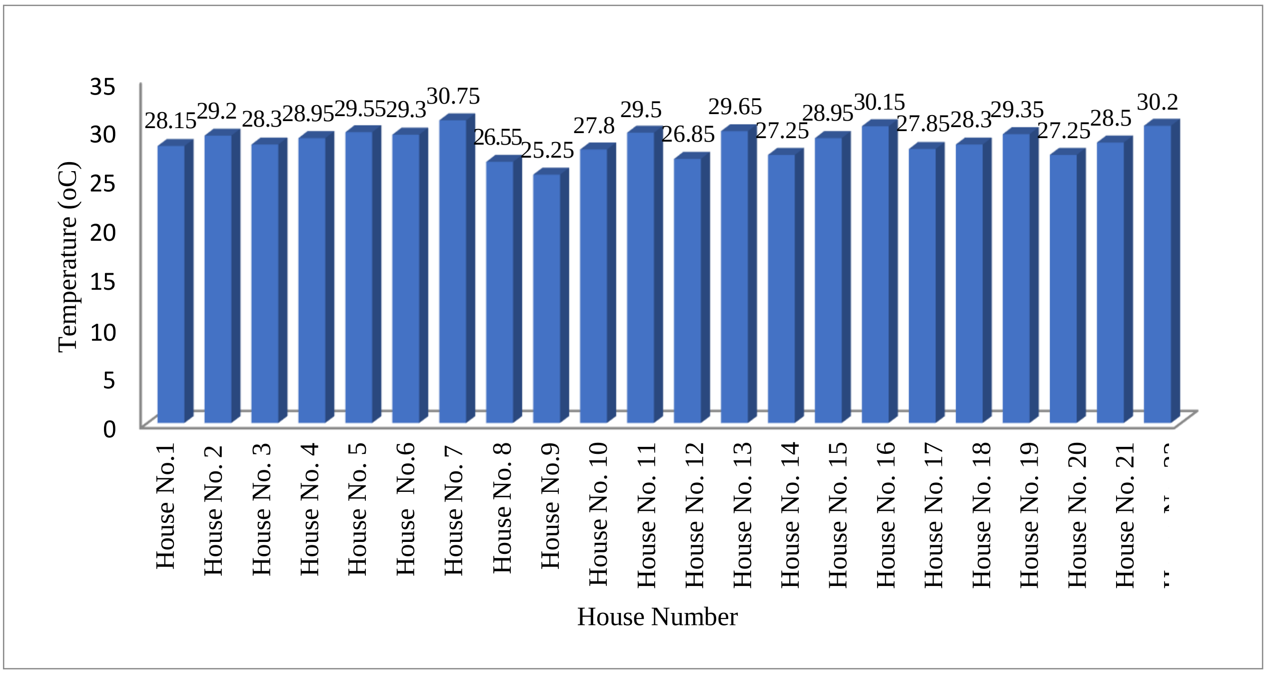

Figure 4.4: Average Relative Humidity (%)

4.4.4 Average energy consumption (KWH)

Figure 4.5 shows the average energy consumption at the 22 housing unit estates located at Lokoja Kogi state. It was observed that there was a substantial increase in energy consumption and a rise in the associated IAQ; particulate matter2.5, carbon dioxide CO_2 temperature and relative humidity during the evening session while at morning session the average energy consumption in the buildings were low. This implies that the IAQ indictors were low therefore the occupants do not to make use of the thermal comfort equipment because the indoor environment is conducive.

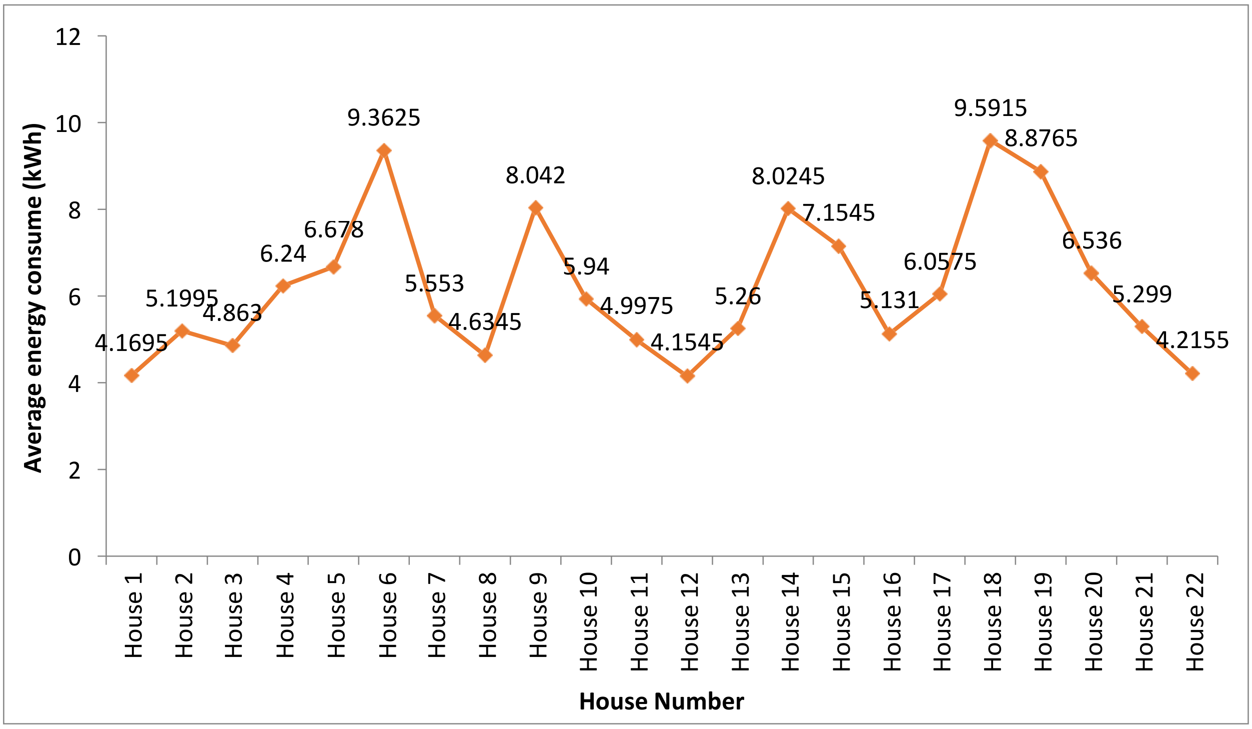

Figure 4.5: Average Energy Consumption (kWh)

Figure 4.5 shows the average energy consumption at the 22 housing unit estates located at Lokoja Kogi state. thus there was a substantial increase in energy consumption and a rise in the associated IAQ; particulate matter2.5, carbon dioxide CO_2 temperature and relative humidity during the evening session while at morning session the average energy consumption in the buildings were low. This implies that the IAQ indictors were low therefore the occupants do not to make use of the thermal comfort equipment because the indoor environment is conducive. Detailed minimum and maximum of particulate matter 2.5 values and energy consumption of the houses can be found in Appendix B.

Table 4.1: Correlation relationship between the average IAQ and the average energy consumption

		IAQ	Energy consumption
IAQ	Pearson correlation	1	-0.126”
	Sig (2 tailed)		000
	N	22	21
Energy consumption	Pearson correlation	-0.126”	1
	Sig (2 tailed)	000	
	N	21	22

The result of the correlation relationship between the average operative IAQ and the average energy consumption is perfectly negative where the Pearson’s correlation coefficient, r, is equal to -0.126 (p-value < 0.01) which indicates moderate and significant correlation. However, when considering the relationship by ventilation rate and energy consumption, there is a strong negative and significant correlation.

CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATIONS

5.2 Conclusion

According to the findings, the majority of the building spaces at the housing unit estates had average Particulate matter2.5 concentration levels that are within the permitted range according to international and local standards such as the ASHRAE, IDPH and OSHA.

Although the study is not conclusive, it does show that the levels of hazardous air pollutants are capable of causing discomfort to the occupants of the studied buildings. It could be speculated that the primary cause of the higher contaminate concentration levels at some of the residential houses was the equipment, rug carpet, cooking with kerosene, generator, insecticide, and furniture present (Zhou *et al.*, 2011). Also, the lack of open windows may be a cause of higher particulate matter2.5 and carbon dioxide concentration levels in some buildings; however, such a causal relationship is not conclusive because the findings were limited to measuring particulatematter2.5 and carbon dioxide concentration levels in building spaces rather than measuring emissions from these potential causes. Similarly, all of the performed building spaces' temperature and relative humidity levels were found to be within acceptable ranges according to international and local IAQ regulations. Furthermore, adequate ventilation in residential structures is thought to help to reduce concentrationsof indoor air quality indicators such as particulate matter2.5 and carbon dioxide.

5.3 Recommendations

The air quality is determined by the number of individuals who share the same air zone. The amazing ambiance of nature's air is determined by how people manage it. Everyone has an impact on air quality. The absence of building management and maintenance quality contributes to poor air quality. Toxic materials and bad practices contribute to hazardous air in the workplace. As a result, not only people's health is affected, but also their work performance and productivity. These findings suggest that with adequate electrical supply and consumption, indoor air pollution exposure will be considerably reduced; nonetheless, more research on indoor air pollutants and electrical energy in Nigeria is required. The IAQ will get a set of recommendations as a result of this research, which include:

i. IAQ is important and easy to achieve during building construction, but also during the entire lifespan of the building if people pay attention to the source of the VOC.
ii. An HVAC and building design can prevent mold and fungi.
iii. Interior humidity conditions should be managed based on needs by the HVAC regardless of the wide range of outdoor conditions.
iv. The HVAC must be able to dehumidify at 1%. Humidity Ratio should be able to be managed in extreme or below average conditions.
v. It is important for every building to consider how to prevent moisture infiltration.
vi. Fan force Ventilation does not actually reduce the dry bulb temperature but it creates a psychological sense of cooling by increasing the rate of sweat evaporation. For formal sedentary activity the maximum comfortable velocity is usually about 160 fpm (0.82 m/sec) which is just barely noticeable, but indoor settings where people can move about the maximum might be 300 fpm (1.60 m/sec) where a gentle breeze will be felt against the

face and papers might rustle. These air speeds will produce a feeling of comfort that seems like a temperature reduction of 4.6F

vii. Dehumidification only can improve comfort with up to 1136 hours annually. However, this is usually done alongside air conditioning. Air conditioning is a major source of energy use in buildings and taking advantage of other comfort variables will help drive down the need for air conditioning and consequently result in reduced energy use.

Although, physiological comfort is not the only aspect of building occupant comfort but it is the most energy demanding. However, there is a need for proper design of all active/artificial comfort parameters. For example, in designing for visual comfort and energy efficiency, natural lighting should as much as possible but in supplementing it, the efficiency or luminous efficacy of the lighting products should be considered. More efficient light sources and fixtures not only reduce lighting loads, but also reduce cooling loads for the same visible brightness.

Finally, to properly harness all these design strategies in such way to bring about optimal use of energy then automatic controls must be put in place to monitor regulate all the areas.

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APPENDIX A

House No.1	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	8	649	26.8	86
	8.05	838	29.5	65
Mean/Average	8.025	743.5	28.15	75.5

Particulate matter PM

House No.2	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	12.55	721	27.4	80
	14.2	834	31	60
Mean/Average	13.375	777.5	29.2	70

House No. 3	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	7.61	811	26.6	84
	10.3	699	30	70
Mean/Average	8.955	755	28.3	77

House No. 4	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	8.1	463	26.9	83
	9.15	541	31	61
Mean/Average	8.625	502	28.95	72

House No.5	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	11.83	589	26.1	81
	12.4	673	33	60
Mean/Average	12.115	631	29.55	70.5

House No.6	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	11.35	447	28	84
	14.14	573	30.6	55
Mean/Average	12.745	510	29.3	69.5

House No.7	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	7.6	841	29.5	74
	8.9	662	32	57
Mean/Average	8.25	751.5	30.75	65.5

House No.8	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	6.4	732	24.6	63
	8.9	691	28.5	68.4
Mean/Average	7.65	711.5	26.55	65.7

House No.9	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	7.48	402	22.6	62.8
	10.3	615	27.9	64.1
Mean/Average	8.89	508.5	25.25	63.45

House No.10	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	9.1	405	25.6	62.9
	12.6	497	30	58.6
Mean/Average	10.85	451	27.8	60.75

House No. 11	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	14.04	348	27	85
	16.5	475	32	62.7
Mean/Average	15.27	411.5	29.5	73.85

House No. 12	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	8.03	417	24.5	63
	12.1	557	29.2	57.1
Mean/Average	10.065	487	26.85	60.05

House No. 13	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	11	400	27.3	72
	14.8	560	32	53
Mean/Average	12.9	480	29.65	62.5

House No. 14	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	10.2	397	24.6	66
	13.5	503	29.9	50.1
Mean/Average	11.85	450	27.25	58.05

House No. 15	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	9	469	26.9	84
	12.4	520	31	61.2
Mean/Average	10.7	494.5	28.95	72.6

House No. 16	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	7.3	404	27.3	53
	9.6	549	33	60
Mean/Average	8.45	476.5	30.15	56.5

House No. 17	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	8	601	26.7	65
	12	719	29	50
Mean/Average	10	660	27.85	57.5

House No. 18	Particulate matter PM2.5 (µg/m^3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	7	677	24.6	81
	15.6	831	32	58
Mean/Average	11.3	754	28.3	69.5

House No. 19	Particulate matter PM2.5 (µg/m³)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	8.3	451	27.7	86
	17.2	690	31	59.6
Mean/Average	12.75	570.5	29.35	72.8

House No.20	Particulate matter PM2.5 (µg/m³)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	9.9	482	25.3	73
	14.8	743	29.2	54
Mean/Average	12.35	612.5	27.25	63.5

House No. 21	Particulate matter PM2.5 (µg/m³)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	13.5	646	26	77
	18	809	31	62
Mean/Average	15.75	727.5	28.5	69.5

House No. 22	Particulate matter PM2.5 (µg/m³)	Carbon dioxide (ppm)	Temperature (ºC)	Relative Humidity (%)
200 housing unit estate in Lokoja, Kogi State	12.12	461	27.4	89
	16.31	590	33	58
Mean/Average	14.215	525.5	30.2	73.5

APPENDIX B

House 1	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (°C)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	8	649	26.8	86	0.449
	8.05	838	29.5	65	7.89
Mean/Average	8.025	743.5	28.15	75.5	4.1695
	855.175				
House 2	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	12.55	721	27.4	80	1.089
	14.2	834	31	60	9.31
Mean/Average	13.375	777.5	29.2	70	5.1995
	890.075				
House 3	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	7.61	811	26.6	84	0.745
	10.3	699	30	70	8.981
Mean/Average	8.955	755	28.3	77	4.863
	869.255				
House 4	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	8.1	463	26.9	83	1.86
	9.15	541	31	61	10.62
Mean/Average	8.625	502	28.95	72	6.24
	611.575				
House 5	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	11.83	589	26.1	81	0.839
	12.4	673	33	60	12.517
Mean/Average	12.115	631	29.55	70.5	6.678
	743.165				

House 6	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	11.35	447	28	84	2.413
	14.14	573	30.6	55	16.312
Mean/Average	12.745	510	29.3	69.5	9.3625
	621.545				
House 7	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	7.6	841	29.5	74	0.955
	8.9	662	32	57	10.151
Mean/Average	8.25	751.5	30.75	65.5	5.553
	856				
House 8	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	6.4	732	24.6	63	0.642
	8.9	691	28.5	68.4	8.627
Mean/Average	7.65	711.5	26.55	65.7	4.6345
	811.4				
House 9	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	7.48	402	22.6	62.8	0.853
	10.3	615	27.9	64.1	15.231
Mean/Average	8.89	508.5	25.25	63.45	8.042
	606.09				
House 10	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	9.1	405	25.6	62.9	0.745
	12.6	497	30	58.6	11.135
Mean/Average	10.85	451	27.8	60.75	5.94
	550.4				

House 11	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	14.04	348	27	85	0.778
 Mean/Average	16.5 15.27	475 411.5	32 29.5	62.7 73.85	9.217 4.9975
	530.12				
House 12	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	8.03	417	24.5	63	0.847
	12.1	557	29.2	57.1	7.462
Mean/Average	10.065	487	26.85	60.05	4.1545
	583.965				
House 13	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	11	400	27.3	72	0.741
	14.8	560	32	53	9.779
Mean/Average	12.9	480	29.65	62.5	5.26
	585.05				
House 14	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	10.2	397	24.6	66	0.818
	13.5	503	29.9	50.1	15.231
Mean/Average	11.85	450	27.25	58.05	8.0245
	547.15				
House 15	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	9	469	26.9	84	0.757
	12.4	520	31	61.2	13.552
Mean/Average	10.7	494.5	28.95	72.6	7.1545
	606.75				

House 16	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	7.3	404	27.3	53	0.789
	9.6	549	33	60	9.473
Mean/Average	8.45	476.5	30.15	56.5	5.131
	571.6				
House 17	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate	8	601	26.7	65	0.698
	12	719	29	50	11.417
Mean/Average	10	660	27.85	57.5	6.0575
	755.35				
House 18	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	7	677	24.6	81	1.563
	15.6	831	32	58	17.62
Mean/Average	11.3	754	28.3	69.5	9.5915
	863.1				
House 19	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	8.3	451	27.7	86	2.341
	17.2	690	31	59.6	15.412
Mean/Average	12.75	570.5	29.35	72.8	8.8765
	685.4				
House 20	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	9.9	482	25.3	73	1.097
	14.8	743	29.2	54	11.975
Mean/Average	12.35	612.5	27.25	63.5	6.536
	715.6				

House 21	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	13.5	646	26	77	0.867
	18	809	31	62	9.731
Mean/Average	15.75	727.5	28.5	69.5	5.299
	841.25				
House 22	Particulate matter PM (ug/m3)	Carbon dioxide (ppm)	Temperature (oC)	Relative Humidity (%)	Energy consumption (kWh)
200 housing unit estate in Lokoja, Kogi State	12.12	461	27.4	89	0.832
	16.31	590	33	58	7.599
Mean/Average	14.215	525.5	30.2	73.5	4.2155

APPENDIX C