**ABSTRACT**

According to the world health organization, Indoor air quality is a major global problem in the world and Nigeria is no exception. Poor indoor air quality is a leading factor to the rise in multiple respiratory diseases like lung cancer, asthma and heart diseases. People’s wellness and productivity have a direct relationship with how good the indoor air quality of their workplace and homes has been designed and maintained. So therefore it is important to assess the indoor air quality in tertiary institutions like AE-FUNAI and how it affects the students and staffs efficiency and productivity.

The aim of the research work is to assess the IAQ in AE-FUNAI with the ASHRAE, WHO and EPA index scoring system to identify the indoor pollutants which failed to reach the optimum indoor standards, the pollutants negative effects on the students’, staffs’ and the building itself and to help the institution properly manage them.

My research study is justified because I considered the three most populated buildings in AE-FUNAI which are considered a poor IAQ “hotspot” in the university which are the Hostel, lecture theaters and an administrative building. Also I considered the 4 major IAQ pollutants which are Particulate matter, CO2, Temperature and relative humidity.

They have been a limited research on indoor air quality in tertiary institution in Nigeria and around the world. Shararin et al (2013)and morakinyo et al both studied the IAQ in lectures theatres and office complex in universities respectively. Shararin et al results for CO2 in lecture theaters discovered a high level of CO2 while Morakinyo et al discovered also a high level temperature, CO2 and relative humidity. My research study is justified because I considered the three most populated buildings in any university which are the Hostel, lecture theaters and an administrative building and also 4 major IAQ pollutants which are Particulate matter, CO2, Temperature and relative humidity.

The data were collected in the morning, afternoon and evening session of the day for 10 days and analyzed qualitatively to find the trends and variants of the data set per session and per pollutant parameters respectively.

The results from the data collected and analyzed with the IAQ index scoring system within 2 weeks shows that in classrooms the PM2.5 is high, the CO2 is considerably high, the Temperature is high and the relative humidity was high too. The results from the data collected from the admin office shows that the PM2.5 is low, the temperature is average, the relative humidity was moderate and the CO2 level in the office is low. The classroom temperature is high, its PM2.5 level is extremely high, the relative humidity in the hostel is high and the CO2 level is extremely high.

The research only focused on the PM2.5, Temperature, CO2 and relative humidity more research is recommended in other parameters like CO, SO2, NO2 and also in secondary schools where children are more likely to be affected.

**CHAPTER ONE**

**INTRODUCTION**

Indoor air quality can be defined as the measure of the air within a building. According to the World health Organization (2002),Indoor air quality has become one of the world’s biggest environmental problem, especially in the developing countries of the world who lack access to clean fuel for cooking. Adekunle et al (2018) opined that Indoor air quality can be made unsafe as a result of human use of anthropogenic activities resulting in the emission of pollutants such as carbon monoxide, volatile organic compounds, particulate matter and microbial contaminants such as molds, bacteria and viruses into the environment. Dust is a major cause of airborne contamination and it emanates from human activities such as sweeping, movement and bed making.

According to Adekunle et al (2018) Patients admitted into hospitals are at a high risk of acquiring infections as a result of poor indoor air quality and this infection can easily be spread throughout the whole hospital either through direct contact, contaminated food, water, medication or medical devices (fomities) or by airborne transmission. Many bacteria are spread through the air, which includes Mycobacterium tuberculosis, Bacillus anthracis, Bordetella pertussis, which cause pulmonary tuberculosis, pulmonary anthrax and whooping cough respectively. These diseases may be deadly if not treated on time. Diseases like Bronchitis, Asthma and lung-related ailments are found to be in high occurrences at the university.

There is a need to assess indoor air quality, especially in tertiary institutions like Alex Ekwueme- Federal university Ndufu-Alike (AE-FUNAI) that have an ever increasing population of students and staffs. It has been reported in that contaminated air can cause both mild and severe irritating health conditions. It has also been reported that airborne bacteria in the university environment have been a major sign of concern for the university administration because of the rising case of breathing and respiratory issues among students in the institution.

Common Indoor air pollutants are: Carbon monoxide, temperature, volatile organic compounds (TVOC), Particulate matter, humidity, Ozone (O3) formaldehyde (HCHO) and aldehydes resulting from indoor emission sources like combustion appliances, paints, home furnitures, seasonal variations, meteorological factors, low ventilation and many other environmental factors according to Lee et al. (2018) and Walgraeve et al. (2011).

According to the U.S consumer product safety commission (2012) indoor air pollution is a serious health threat. Studies have shown that the concentrations of indoor air pollutants are sometimes 2-5 times higher in than outdoor air while in a few cases, indoor air pollutants could be over 100 times higher than outdoor pollutants. Therefore they should be a need for the assessment, monitoring, and reduction of indoor pollutants.

A handful of studies on indoor air quality has been published for example: Meˇciarová et al. (2017), Petry et al. (2014),  Lee et al. (2018), Shi et al. (2016), Wang et al. (2008); many of their interests were on PM, TVOC, formaldehyde, O3, CO, CO2, and other aldehydes.

Not many studies have been done on indoor air quality in Nigeria, few studies were obtained from (Ezezue and Diogu, 2017), Warri (Akpofure, 2015), Ile – Ife (Afolabi et al., 2016), Ido Ekiti (Ayodele et al., 2016), No study has been found for IAQ in AE-FUNAI

 However, information about indoor air quality of tertiary buildings in AE-FUNAI are limited. Availability of IAQ data is important as students and staffs are vulnerable to health hazards and spend a long time in lecture halls, offices and hostels. This project was carried out in the dry season from November 2020- April 2021.

**1.0 BACKGROUND OF STUDY**

AE-FUNAI is a federal university located in Ebonyi State. Ebonyi state is located in the South-Eastern part of Nigeria. Nigeria is a tropical country in West Africa with two distinct weather conditions (rainy and dry seasons) but the period varies according to location and time within the year. The institution studied is Alex Ekwueme Federal University Ndufu-Alike (AE-FUNAI), Ebonyi State. The rainy season period is from March to October while that for dry season is from November to February. Rainy season is associated with wetness due to rainfall. Dry season is a period associated with heat due to dryness and enormous amount of sunlight.

AE- FUNAI is a new federal university located in Ikwo local government area of Ebonyi state established in 2011. The university currently is divided into two sites Zone A and Zone B.

The Importance of the study of the air quality in AE-FUNAI cannot be over-emphasized, they are a handful publication about air quality in tertiary institutions in Nigeria like the Indoor Air Quality and Percieved Health Effects experienced by occupants of an office building in a t*ertiary Institution in Nigeria* ( Morakinyo et al, 2015) and the). Indoor Air Quality Level of Total Volatile Organic Compounds (Tvocs) in a University Offices.(Adebayo et al,2018) None of this area of research has been done in AE-FUNAI.

They is an increasing rate of health crisis at the AE-FUNAI Clinic such as Asthma which is easily triggered by poor IAQ. It is therefore important to carry out air quality studies which will aid the university in various ways such as to protect the lives of its students and staffs from any IAQ health crisis.

Also for the universities to combat its overgrowing population requires more lecture rooms, offices and hostels. The results from the study will help the university in the construction of a more sustainable building with IAQ consideration. This will help to reduce overcrowding in the building while improving IAQ.

 **1.1 STATEMENT OF PROBLEM**

The university currently accommodates about 10,000 students and staffs. All these students occupy and share less than 90 lecture rooms of which the room dimensions are not greater than 30m by10m. Also the buildings occupants at the hostel occupies hostel room less than 100 rooms of which the maximum room dimensions is not greater than 20m by 10m.

 According to reports coming from the university clinic, they ia an increasing number of students currently suffering from respiratory diseases like Asthma and allergies causing a big issue in the university.

Also, they have been a massive population growth among students and staffs. This has created a lot of academic tension between students and staffs. Poor IAQ has been noted tremendously in the university.

Finally they have been a poor deterioration and management of the university’s buildings and plants, so the importance to consider Indoor air quality as a management process cannot be over-emphasis.

**1.2 THE RESEARCH AIM**

 The aim of the research work is to assess the Indoor air quality in AE-FUNAI with the ASHRAE, WHO and EPA index scoring system to identify the indoor pollutants which failed to reach the optimum indoor standards, the pollutants negative effects on the students’, staffs’ and the building itself and to help the institution properly manage them.

**1.3 THE RESEARCH OBJECTIVE**

1. Review current literature on Indoor-air quality in Nigeria’s higher education institution
2. Identify the potential harmful pollutants affecting the quality of air in the case study area.
3. Collect relevant data on different levels of pollutants.
4. Analyze the collected data and make comparisons with the indoor air quality Index scoring system.
5. Statistically analyze the collected data using appropriate software.
6. Make appropriate recommendations from the research results

**1.4 SCOPE OF RESEARCH**

 This research has 2 purposes, firstly to assess the indoor air quality in AE-FUNAI to determine if it exceeds the critical points and requires immediate attention. The threshold for this research is measured against the WHO, ASHRAE and the HVAC indoor air standards.

Secondly to statistically analyze the data collected in each locatons. This is required to identify the IAQ origin, the factors responsible for the poor IAQ and make appropriate recommendations to improve the IAQ.

The scope of the research will be analyzed with the population of AE-FUNAI which is about 10000 students and staffs. The study will be carried out for 5 months from November 2020 to April 2021.

The research will be carried out with a multi-purpose sensor which can read humidity, temperature, CO2 and particulate matter which are the parameters to be tested.

The research samplings will be carried out in different building and in different locations in AE-FUNAI. The following buildings below are some of the buildings which this research will take place in the university.

1. An office building in the Administration block
2. A room in the male hostel.
3. A Student lecture hall (classroom)

**1.5 SIGNIFICANCE OF STUDY**

The Data collected from the study will be of great benefit to the following:

**UNIVERSITY ADMINISTRATION:** The result from the IAQ study from AE-FUNAI will provide the university administration with information on how the population increase correlates to poor IAQ which in return is responsible for the poor health conditions among students and staffs.

The data will also provide information to the administration on how to improve academic performance because poor IAQ creates mental tension between students and staffs alike.

**UNIVERSITY STRUCTURAL ENGINEERS & CONTRACTORS**: The result from IAQ study will be relevant to the contractors and engineers who will be constructing future buildings in the university. If they are a critical need for an improved IAQ then the engineer has to design buildings with a larger and higher number of windows and doors for easy ventilation. The engineer with the aid of the building code should be designing for adequate ventilation and larger room size to accommodate present and future population.

**STUDENTS AND STAFFS:** The result analyzed from the IAQ can be made known to the staffs and students to make them aware of the IAQ conditions of the university.

**1.6 JUSTIFICATION OF STUDY**

They have been scanty journals and publications done on IAQ in tertiary institution in Nigeria. They is also a lack of information on any study that co-analyzed IAQ pollutants from lecture rooms, admin office and student accommodation. These 3 locations are very important because the student accommodation and the hostel respectively, are where students spend over 90% of their day in a university.

Morakinyo et al (2019) in his journal the “Indoor air quality and Perceived Health Effects experienced by occupants of an office complex in a typical tertiary institution in Nigeria” also did a good research on the IAQ of classroom but did not tackle any student accommodation and a classroom. Abulude te al (2018) studied the IAQ in an office building in Akure but did not consider a classroom nor a student’s accommodation.

Sulieman et al(2013) in his study of indoor air quality in academic buildings in university only considered the CO2 level in lecture rooms while shittu et al considered PM level, temperature and relative humidity in selected office and lecture building in UNILAG with no consideration of any student’s accommodation.

It is now justifiable for me to present a research which tackles IAQ from a student point of view where most of their lives are spent in the lecture room, accommodation and where most staffs spend their time at which is at the administrative office.

**1.7 STUDY LIMITATIONS/ DELIMITATIONS**

During my study, research and sampling for this project I encountered some limitations such as

* The time to carry out the sampling and data collection was short. This is as a result of some events like exams and lectures ongoing during the project period.
* The IAQ monitor calibration limited the time expected for the project to start and its end.
* The IAQ monitor to be used was not easily available.

**CHAPTER TWO**

**LITERATURE REVIEW**

**2.0 Overview of Indoor Quality**

Indoor air quality (IAQ) is the measure of the quality of air within a building. Research has shown that the Indoor air quality affect the comfort, health and well-being of its occupants. Poor indoor air quality is responsible for poor learning outcomes in schools, reduced productivity and consciousness and also creates a sick building syndrome that is according Joshi (2008)

Indoor air quality can be affected by gases such as carbon monoxide particulate matter, radon, volatile organic compounds or any mass or energy stressor that can generate a negative health conditions among its occupants.

Ventilation, filtration and air quality source control are the primary methods used to improve IAQ in buildings. More methods to improve IAQ include cleaning, sweeping and dusting of the building.

Indoor air quality can be determined by the collection of air samples, the monitoring of human exposure, the assessment of the air using the WHO, ASHRAE, EPA standards and also the use of statistical analysis to determine the inflow of air inside a building.

Indoor air quality consists of the indoor environmental quality (IEQ) which also includes the IAQ in combination with other physical and psychological aspects which can affect human lives in a building such as Thermal Comfort, visual quality, acoustics and lighting

According to Rieck and Lundin (2019) Indoor air pollution in developing nations is a major health hazard The major source of indoor air pollution in developing countries is the burning of biomass (e.g. charcoal, wood ,crop residue and/or dung) for heating and cooking. The resulting exposure to high levels of particulate matter was responsible for the death 1.5 million and 2 million people in 2000.

**2.1 Building ecology**

People always assume that buildings and structures are simply inanimate physical entities, relatively stable over time. This implies that there is little interaction between the components of the building, what is in it (occupants and contents), and what is around it (the larger environment). We most times see the vast majority of the mass of material in a building as relatively unaltered physical material over time.

In reality, the innate nature of a building can be seen as the result of a complex set of interactions among the chemical, physical and biological dimensions. Buildings can be explained and understood as a dynamic entity with complex systems. Ecological studies and researches can help with the understanding of how the eco-system works and the relationship among the three dimensions.

Buildings and structures regularly evolve as a result of the changes in the environment around them as well as the activities, occupants and material within them. The different molecular components of a building and its surface inside a building are constantly interacting, and this interaction results in changes in the building’s ecosystem. For example, we may see a window or door as changing slightly over time as it becomes dirty, then it is cleaned, it compiles dirt again, it is cleaned again, and so on throughout its life. The dirt in this example comes as a result of the interaction between the chemical, physical, biological and even the moisture content found there.

Buildings are designed or intended to respond actively to some of these changes in and around them with the heating, cooling, ventilating, air cleaning or illuminating the building’s system. We clean, sanitize, and maintain buildings surfaces to enhance its appearance, performance and longevity. In other cases, such changes can slightly or even drastically alter buildings in ways that may be important to their own integrity or their impact on building occupants through the evolution of the physical, chemical, and biological processes that define them at any time.

**2.2 Concept of Indoor Environmental Quality in Alex Ekwueme Federal University Ndufu-Alike (AE-FUNAI), Ebonyi State**

The indoor environment can be described as to environment within a building and how it affects the wellbeing of occupants (Sakellaris et al. 2016; Al-Awadi 2018). The indoor environment is multifactorial as several factors acts individually and collectively to affect it.

This includes the chemical factors such as formaldehyde and radon, physical factors like humidity and temperature physical factors such as temperature and lighting; biological factors such as bacteria and fungi (Cartieaux et al. 2011). Table 1 and figure 1 extracted from Toyinbo (2012) illustrates the different IEQ factors and components respectively.

Table 1. The various physical, chemical, biological and particulate factors that affect IEQ (toyinbo 2012).



Figure 1. Different components affecting IEQ (Toyinbo 2012).



According to the environmental protection agence (EPA) research has shown that children are more vulnerable to IEQ issues (EPA. 2018). Several studies have shown the impact of the school/classroom environment on students (Turunen et al. 2014; Haverinen-Shaughnessy et al. 2015; Haverinen-Shaughnessy & Shaughnessy . 2015; Toyinbo et al. 2016 a & b). The above, along with the amount of time children spend in school studying makes the research on school IAQ an important topic.

Although there are several standards and recommendations by reputable international organizations such as WHO (World Health Organization) and ASHRAE (American Society of Heating, Refrigerating and Air-Condition Engineers) and different countries building codes, this recommendations are sometimes not met.

For example, only 44 out of 108 classrooms (41%) met the Finnish building code ventilation rate per student of 6 *l/s per* studentin a Finnish study (Toyinbo et al. 2016b). Ferreira and Cardoso(2014) also studied the CO2 level in Portuguese classrooms which exceeded the optimum recommendation to be 984ppm

**2.3** **Building and Environmental quality studies in Nigerian Tertiary Institution.**

A literature carried out on the above project topic on Google Scholar using different search iteration such as 1) indoor air in Nigeria schools; 2) indoor environmental quality in Nigeria schools; 3) environmental quality in Nigeria schools; 4) ventilation in Nigeria universities; 5) temperature in Nigeria schools; 6) thermal comfort in Nigeria schools; and 7) building in Nigeria schools. 8) Assessment of the Indoor Air Quality 9) Indoor air quality in a Nigerian Tertiary Institution.

 Few published articles that relate to the Indoor air quality in A Nigerian Tertiary Institution were retrieved through the search. This include a 2008 study by Ekpo et al. (2008) on hygiene conditions and helminthes infection of primary school students in Ogun state Nigeria; a study by Mustapha et al. (2011) on the effect of risk factors such as traffic air pollution on respiratory illness in school children in the Niger-Delta area of Nigeria; a study by Ana et al. (2015) on indoor Air Quality and risk factors associated with respiratory conditions In Nigeria; a study by Morakinyo et al. (2015) on the Indoor air quality and perceived health effect experienced by occupants of an office complex in a typical tertiary institution in Nigeria; a study by Abulede et al. (2019) that assessed the impact of humidity on indoor thermal comfort of buildings in warm humid climate of Abia state, Nigeria and other literature materials.

With the above, it can be said that there are very limited scientific studies on indoor air quality in Nigeria tertiary institutions. The lack of adequate research and publication may be related to the lack of interest in the project topic by researchers. It may also be due to inadequate funding for research as well as the lack of environmental health researchers in this field.

**2.4** **Ventilation and thermal comfort**

Ventilation is the process of replacing stale air in any space with cleaner air (Patton et al. 2016). This exchange of air mostly occur between the indoor and the outdoor environment. This can be done naturally through the opening of windows, doors and sometimes through cracks and other building openings, or mechanically through the installation of mechanical equipment (Aflaki et al. 2015). A notable difference between both is that mechanical ventilation is expensive to run because of its use of energy while natural ventilation usually has low operational costs (Tong et al. 2017).

Ventilation rate in naturally ventilated building depends on the airflow rate of outdoor air. This may result to inadequate ventilation when wind speed is low or overventilation when wind speed is high (Chu et al. 2015). The indoor air from natural ventilation is not filtered or conditioned; this may encourage the introduction of outdoor pollutants into the indoor environment especially in highly polluted areas such as those near to high volume traffic or unchecked incinerators (Amram et al. 2011). But in an environment with limited pollution, natural ventilation can be utilized properly to remove pollutants.

Mechanical ventilation uses a force (energy) approach in providing air exchange. Energy dependent mechanical plant(s) are used to drive air with air flow rate being dependent on the strength/force rate of the plant (WHO 2009). Mechanical ventilation system can either be a mechanical supply and exhaust ventilation system in which fresh air is mechanically introduced indoor and stale air is mechanically removed, or a mechanical exhaust ventilation system in which only stale air is mechanically removed from the indoor environment (Niachou et al. 2005). The speed/airflow rate are sometimes adjustable to give a specific or desired ventilation rate.

 In commercial buildings such as schools, air is sometimes re-circulated and/or outdoor air intakes blocked to reduce energy cost and also to quickly achieve desired thermal condition (Martin 2014). Air recirculation may encourage the build-up of pollutants indoor. Air recirculation can also make indoor CO2 to increase when oxygen used for metabolic activities become depleted and not replaced (Jurado et al. 2014).

Adequate ventilation of a building is expected to help replenish indoor oxygen while simultaneously reducing indoor CO2 and other bioeffluents especially to metabolic activities (Rosbach et al. 2013; Gaihre et al. 2014). It is also expected to reduce the concentration of indoor pollutants such as bacterial, mold and odor and regulate indoor temperature to comfort level (Smedje et al. 2017).

According to Mendell et al and Fisk et al. buildings with inadequate ventilation may increase the transmission of infectious respiratory diseases caused by viruses.

Studies have also shown ventilation to affect indoor temperature with rooms adequately ventilated having thermal comfort and vice versa (e.g. Sekhar 2016). Thermal comfort refers to the feeling of people in their thermal environment (ASHRAE Standard 55 2004; Lu et al. 2015). Thermal comfort is affected by some environmental and personal factors such as radiant temperature, air speed, humidity, air temperature, clothing material/insulation and metabolic rate (Daghigh 2015).

For example, the material and the number of clothes worn together can affect the body heat stress. So can also the radiant heat from the indoor environment such as those from the sun and electrical equipment (e.g. printers and laptops).

**2.5 INDOOR AIR QUALITY STANDARDS AND PARAMETERS**

The IAQ of a building has various standards and guidelines such as the WHO (World health organization) guideline, ASHRAE (American association for heating, refrigeneration and air -conditioning engineers, EPA ( Environmental protection agency) and OSHA ( Occupational safety and health administration) guidelines.

Tiele et al (2018) has provided an indepth IEQ Index scoring system taken from the above standards and guidelines with each indoor air parameter calibrated under good, average, poor or bad in table 4

Table 2: IEQ Index scoring system. Tiele et al (2018)



**2.6** **Indoor air quality with regards to students’ health.**

Permaul et al (2012) opined that the various indoor environmental factors and components in school can affect students’ health by either causing or exacerbating a negative health outcome since higher concentration of indoor pollutants are sometimes more obvious in schools than in homes. The Students’ wellbeing in term of comfort as well as their learning performance can also be affected (Bakó-Biró et al. 2012; Turunen et al. 2014). Examples of health outcomes related to the school environment includes asthmatic symptoms among pupils (Zhao et al. 2008), influenza virus (Koep et al. 2013), wheezing (Ferreira & Cardoso 2014)

A low humidity in classroom was related to an increase influenza virus transmission during the winter months as shown by Koep et al. (2013). Humidification of the indoor environment

is therefore important in this regard to curtail viral spread (Myatt et al. 2010; Koep et al. 2013; Metz & Finn 2015).

A school study of 2000 pupils in China found 30% of the students to have daytime breathlessness while 8 and 2% had wheezing and asthma respectively (Zhao et al. 2008). Breathlessness as well as wheezing by students were found to be related to Sulfur dioxide (SO2), NO2 or formaldehyde in schools.

Students comfort can also be impaired by uncomfortable indoor environmental quality. For example, thermal discomfort in school may result to loss of concentration of students due to tiredness and sleepiness (Bidassey-Manilal et al. 2016). Absenteeism may increase due to inadequate ventilation (Mendell et al. 2013; Gaihre et al. 2014), exposure to PM (Macnaughton 2017) and thermal discomfort (Mendell & Heath 2005).

**CHAPTER THREE**

**RESEARCH METHODOLOGY**

The indoor air quality is a quantitative research and the purpose of this research is to identify the harmful pollutant affecting the quality of air in AE-FUNAI and help the institution tackle it, thereby creating a conducive academic environment for staffs and students.

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Three locations in Alex Ekwueme Federal University Ndufu-Alike (AE-FUNAI), Ebonyi State were critically selected for on-site investigation and assessment. Some of the reasons this locations were considered was because

1. It was an enclosed building which will allow for the collection of air pollutants in the room.
2. The type of building occupants and the consequences of poor indoor air quality to themselves and the institution alike.
3. The proximity of the various location to potential sources of pollutant such as traffic, sewage disposal methods and waste assessment.

**3.0 THE RESEARCH LOCATION**

The location and buildings chosen for the IAQ assessment in AE-FUNAI were:

1. Hall 2 of the medical lecture hall located in the Zone A area of the university.
2. Room 13, A block of the male hostel located in THE Zone B area of the university.
3. An office in the university’s administrative block.(The SPAT office, personnel unit) located at the second floor of the admin block.

The parameters to be measured are Indoor temperature (T), relative humidity (RH) carbon dioxide (CO2), Barometric pressure, particulate matter (PM 2.5) and the Health Index were measured with the Lutron PM-1064SD Air quality monitor/recorder. The IAQ was assessed from a single location one at at time 3 times per day for one week. The assessment was carried out in the morning around 9 AM, in the afternoon around 12 PM and around 4 PM in the evening this will enables me to maximize the room average traffic and be able to monitor the air quality all around during the daytime.

Some other pre-assessment precautions ensured were but not limiting to measuring classroom dimension, visually inspecting the mode of ventilation and condition of the surfaces and materials in the building, interviewing maintenance personnels and occupants, and assessing cleaning procedures.

The assessment would be carried out within 3 weeks one location per week. Logging started at least 20 minutes after arrival at the location to allow the monitor capture as much data as possible before allowing for data logging.

**3.1 THE RESEARCH PROCESS**

The IAQ monitoring was conducted from the 1st of march 2021 – 12th of march 2021. The initial research process was to identify the IAQ pollutants to be measured which are the temperature, rRelative humidity (RH), carbon dioxide CO2 and Particulate matter 2.5 (PM2.5) followed by the identification and calibration of measuring device used was the Lutron PM-1064SD which is a multi-purpose Air quality monitor.

The assessment was carried out in each location in the morning around 9 AM, at noon around 12 PM and in the evening around 4 PM. The assessment time was designed in order to maximize the period in the locations with the highest population density.

The next step in the IAQ monitoring was to arrive at the location at most 5 minutes before the monitoring time. The IAQ was monitored for 15 minutes at each location to ensure that the monitor captures the maximum and minimum reading. The maximum and readings of each pollutant per session is then logged in a data handbook to be used to determine the mean value of the pollutants at the location. At the location, the Air quality monitor was placed 1.0m above ground level on top of a wooden desk available at the locations. The air quality monitoring practical was conducted for 10 days from Monday to Friday for 2 weeks.

After each daily session at the various locations the daily records where manually logged . The logged data were manually assessed with the IAQ Index scoring system and then analyzed statistically to determine the trends and variation among the pollutant at the various locations.

**CHAPTER 4**

**RESULTS AND DISCUSSION**

**4.0 A MULTIPLE BAR GRAPH SHOWING THE PM CHARTS FOR 3 PLACES FOR DIFFERENT SESSIONS IN 10 DAYS**

**FIG 2. SHOWING PM CHART FOR DAY 1**

FIG 3. SHOWING PM CHART FOR DAY 2

FIG 4 SHOWING PM CHART FOR DAY 3

FIG 5 SHOWING PM CHART FOR DAY 4

FIG 6 SHOWING PM CHART FOR DAY 5

FIG 7. SHOWING PM CHART FOR DAY 6

FIG 8. SHOWING PM CHART FOR DAY 7

FIG 9. SHOWING PM CHART FOR DAY 8

FIG 10. SHOWING PM CHART FOR DAY 9

FIG 11 SHOWING PM CHART FOR DAY 10

**4.1 A MULTIPLE BAR GRAPH SHOWING THE TEMPERATURE CHARTS FOR 3 PLACES FOR DIFFERENT SESSIONS IN 10 DAYS**

**FIG 12 SHOWING TEMP CHART FOR DAY 1**

**FIG 13 SHOWING TEMP CHART FOR DAY 2**

**FIG 14 SHOWING TEMP CHART FOR DAY 3**

**FIG 15 SHOWING TEMP CHART FOR DAY 4**

**FIG 16 SHOWING TEMP CHART FOR DAY 5**

**FIG 17 SHOWING TEMP CHART FOR DAY 6**

**FIG 18 SHOWING TEMP CHART FOR DAY 7**

**FIG 19 SHOWING TEMP CHART FOR DAY 8**

**FIG 20 SHOWING TEMP CHART FOR DAY 9**

**FIG 21 SHOWING TEMP CHART FOR DAY 10**

**4.2 A MULTIPLE BAR GRAPH SHOWING THE RH CHARTS FOR 3 PLACES FOR DIFFERENT SESSIONS IN 10 DAYS**

**FIG 22. SHOWING RH CHART FOR DAY 1**

FIG 2. SHOWING RH CHART FOR DAY 2

FIG 24. SHOWING RH CHART FOR DAY 3

FIG 25 SHOWING RH CHART FOR DAY 4

FIG 26. SHOWING RH CHART FOR DAY 5

FIG 27. SHOWING RH CHART FOR DAY 6

FIG 28. SHOWING RH CHART FOR DAY 7

FIG 29. SHOWS RH CHART FOR DAY 8

FIG 30 SHOWS RH CHART FOR DAY 9

FIG 31 SHOWS RH CHART FOR DAY 10

**4.3 A MULTIPLE BAR GRAPH SHOWING THE CO2 CHARTS FOR 3 PLACES FOR DIFFERENT SESSIONS IN 10 DAYS**

**FIG 32. SHOWING CO2 CHART FOR DAY 1**

FIG 33 SHOWING CO2 CHART FOR DAY 2

FIG 34. SHOWING CO2 CHART FOR DAY 3

FIG 35. SHOWING CO2 CHART FOR DAY 4

FIG 36 SHOWING CO2 CHART FOR DAY 5

FIG 37. SHOWING CO2 CHART FOR DAY 6

FIG 38. SHOWING CO2 CHART FOR DAY 7

FIG 39. SHOWING CO2 CHART FOR DAY 8

FIG 40. SHOWING CO2 CHART FOR DAY 9

FIG 41. SHOWING CO2 CHART FOR DAY 10

**4.4 TRENDS OF THE INDOOR AIR QUALITY VARIABLE (PM, TEMPERATURE, RH, CO2) FOR THE HOSTEL, ADMIN OFFICE AND CLASSROOMS FOR 10 DAYS**

**PM TREND FOR THE THREE SESSIONS OF THE DAY**

**FIG 42 SHOWING PM TRENDS FOR MORNING**

**FIG 43. SHOWING PM TREND FOR AFTERNOON**

**FIG 44. SHOWING PM TRENDS FOR EVENING**

**4.5 TEMPERATURE TREND FOR THE THREE SESSIONS OF THE DAY**

**FIG 45. SHOWING TEMP TREND FOR MORNING**

**FIG 46 SHOWING TEMP TREND FOR AFTERNOON**

**FIG 47. SHOWING TEMP TREND FOR EVENING**

**F**

**4.6 RH TREND FOR THE THREE SESSIONS OF THE DAY**

**FIG 48. SHOWING RH TRENDS FOR MORNING**

**FIG 49. SHOWING RH TREND FOR AFTERNOON**

**FIG 50 SHOWING RH TREND FOR EVENING**

**4.7. CO2 TREND FOR THE THREE SESSIONS OF THE DAY**

**FIG 51. SHOWING CO2 TRENDS FOR MORNING**

**FIG 52 SHOWING CO2 TRENDS FOR AFTERNOON**

**FIG 53. SHOWING CO2 TRENDS FOR EVENING**

**4.8 ANALYSIS OF VARIANCE (ANOVA) TEST**

**TABLE 3: ANALYSIS OF VARIANCE (ANOVA) IN PM FOR THE 3 PLACES OF THE 3 SESSIONS OF THE DAY (PARTICULATE MATTER)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SESSIONS | THE ROOMS | N | Mean ± Std. Deviation | F-ratio | P-value |
| MORNING PM | Classroom | 10 | 18.8500 ± 2.39270 | 15.856 | .000 |
|  | Admin office | 10 | 15.2500 ± 1.51383 |
|  | Hostel | 10 | 22.5500 ± 4.14628 |
|  | Total | 30 | 18.8833 ± 4.12453 |
| NOON PM | Classroom | 10 | 19.3000 ± 3.70585 | 9.060 | .001 |
|  | Admin office | 10 | 13.7000 ± 1.11056 |
|  | Hostel | 10 | 19.6500 ± 4.68479 |
|  | Total | 30 | 17.5500 ± 4.37538 |
| EVENING PM | Classroom | 10 | 17.6000 ± 3.71782 | 19.973 | .000 |
|  | Admin office | 10 | 13.3500 ± 0.81820 |
|  | Hostel | 10 | 22.5000 ± 4.12311 |

**TABLE 4: ANALYSIS OF VARIANCE (ANOVA) IN TEMPERATURE FOR THE 3 PLACES OF THE 3 SESSIONS OF THE DAY (TEMPERATURE)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SESSIONS | THE ROOMS | N | Mean ± Std. Deviation | F-ratio | P-value |
| MORNING TEMPERATURE | Classroom | 10 | 32.2000 ± .90707 | 19.019 | .000 |
|  | Admin office | 10 | 29.7750± 1.43299 |
|  | Hostel | 10 | 32.5950 ± .89519 |
|  | Total | 30 | 31.5233 ± 1.65809 |
| NOON TEMPERATURE | Classroom | 10 | 33.7650 ± 0.91319 | 35.092 | .000 |
|  | Admin office | 10 | 29.7200 ± 1.80373 |
|  | Hostel | 10 | 33.7150 ± 0.71997 |
|  | Total | 30 | 32.4000 ± 2.26822 |
| EVENING TEMPERATURE | Classroom | 10 | 34.7500 ± 1.21198 | 47.681 | .000 |
|  | Admin office | 10 | 29.6400 ± 1.08469 |
|  | Hostel | 10 | 34.3650 ± 1.56508 |
|  | Total  | 30 | 32.9183 ± 2.67690 |

**TABLE 5: ANALYSIS OF VARIANCE (ANOVA) IN CO2 FOR THE 3 PLACES OF THE 3 SESSIONS OF THE DAY (CO2)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SESSIONS | THE ROOMS | N | Mean ± Std. Deviation | F-ratio | P-value |
| MORNING CO2 | Classroom | 10 | 968.9500 ± 286.46606 | 17.451 | .000 |
|  | Admin office | 10 | 571.9550 ± 111.26254 |
|  | Hostel | 10 | 1051.9600 ± 136.75783 |
|  | Total | 30 | 864.2883 ± 283.73365 |
| NOON CO2 | Classroom | 10 | 978.4550 ± 209.99203 | 28.240 | .000 |
|  | Admin office | 10 | 493.6250 ± 32.57880 |
|  | Hostel | 10 | 819.1050 ± 140.40259 |
|  | Total | 30 | 763.7283 ± 249.49173 |
| EVENING CO2 | Classroom | 10 | 705.4450 ± 145.41885 | 83.023 | .000 |
|  | Admin office | 10 | 504.2000 ± 51.77312 |
|  | Hostel | 10 | 1147.1500 ± 123.52171 |
|  | Total | 30 | 785.5983 ± 294.49280 |

**TABLE 6: ANALYSIS OF VARIANCE (ANOVA) IN RH FOR THE 3 PLACES OF THE 3 SESSIONS OF THE DAY (RELATIVE HUMIDITY)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SESSIONS | THE ROOMS | N | Mean ± Std. Deviation | F-ratio | P-value |
| MORNING RH | Classroom | 10 | 71.2000 ±3.74870 | 11.610 | .000 |
|  | Admin office | 10 | 60.2800 ±6.70088 |
|  | Hostel | 10 | 70.4450 ±6.09483 |
|  | Total | 30 | 67.3083 ± 7.44804 |
| NOON RH | Classroom | 10 | 45.4050 ± 2.79309 | 5.578 | .010 |
|  | Admin office | 10 | 41.1050 ± 3.17713 |
|  | Hostel | 10 | 46.5000 ± 5.08312 |
|  | Total | 30 | 44.2621 ± 4.33249 |
| EVENING RH | Classroom | 10 | 57.9850 ± 7.73606 | 2.413 | .109 |
|  | Admin office | 10 | 51.7750 ± 8.10539 |
|  | Hostel | 10 | 58.7350 ± 7.47659 |
|  | Total | 30 | 56.1650 ± 8.14711 |

STATISTICAL ANALYSIS

Analysis was done using SPSS Version 25 and excel 2017. Trends show the patterns of each pollutant through time (days). P-value less than 0.05 indicates a statisticalsignificant difference in the means of each pollutant.

**DISCUSSION**

The results depicted from the time series graph shown in figure 42 shows the Particulate matter in the morning session across the 3 different location (Classroom, admin office and hostel) The time series graph shows that on average the PM value is highest in the Hostel in the morning with an average of over 22.5ug/m3 which is marked poor according to our IAQ Index scoring system and lowest in the admin block with an average of 15.5ug/m3 which is also considered poor in the IAQ index scoring system. The PM in the classroom is also considered high with an average of over 19.5.

The impending reason the Morning session’s PM2.5 was high especially in the hostel was because of the dry weather conditions at the time which promotes particulate matter in the air. Also because of the overpopulated, unhygienic and poorly ventilated hostels with alot of physical activities that encourages PM in the hostel especially in the morning. Also the cleaning works like sweeping by the cleaners in these locations everyday in the morning encourage the movement of dust in the air.

The morning’s session of the admin office time series graph shows lesser PM value than the other location even though its values were high. This may be attributed to a lesser building’s occupant, lesser physical activities and better ventilation.

The result depicted from the time series graph shown in figure 43 shows that the PM in the afternoon session across the hostel and classroom were extremely inconsistent. The day 2 hostel session showed the highest value while the admin office showed the lowest value with an average of 13.5ug/m3 which is considered “average” in our IAQ Index scoring system.

The average of the classroom and hostel afternoon’s PM session where 18.5ug/m3 and 22.5ug/m3 respectively which are both considered “poor” in our IAQ Index scoring system but the results faired better than the morning session result because of a reduction in physical chaos in the university environment. Day 9 and Day 10 saw a drop in the PM values which occurred as a result of the first rain which fell on the 11th of March, 2021. This goes to show that PM value is reduced at any introduction of moisture.

The results from the time series graph of the evening session seen in fig 44 of the PM data show inconsistent trends seen in the hostel and classroom location. On average, the evening PM value in the classroom dropped to 17.6ug/m3 as a result of decline in physical activities (End of lectures) although this value is considered “poor” in our IAQ Index scoring system it was much better than the afternoon session. The evening’s PM value in the hostel rose to a 22.5ug/m3 as a result of increase in physical activities of students returning from their classroom. The value of the evening’s PM value averaged 12.5 which was considered “average” but was still conducive for its occupants. The results from the 9th and 10th were still low as a result of the rainfall on the 11th of march, 2021.

Overall, this implies they is an urgent need for the institution to tackle the high rate of PM2.5 in its environment. According to the global burden of disease project(2015) PM2.5 is associated with the a lot of disturbing adverse health effects such as asthma attacks, acute and chronic bronchitis, premature mortality, increased hospital admissions for heart or lung causes, respiratory symptoms and emergency room visits.

The temperature readings of the IAQ at the various locations were characterized by a high reading as a result of poor ventilation and the hot dry climate of Nigeria. The results from the temperature reading in the morning session as seen on figure 45 indicates that hostel and classroom ranked the highest with a temperature reading that averaged 32.2 and 30.8 degree Celsius respectively which are considered “poor” in our IAQ Index scoring system. This came as a result of the poorly ventilated buildings which are the classrooms and the hostel plus the hot dry climate as at the time when the data were collected. The result collected from the admin office averaged 28.4 degree Celsius which also is considered “poor” according to our IAQ Index scoring system. The drop in value of the temperature readings of the morning session came as a result of a lesser populated admin office and the use of natural and mechanical ventilation.

The temperature value of the afternoon session as seen on figure 46 has shown the direct increase in the temperature across the various locations at noon. The classroom averaged the highest temperature increase at noon with 34.3C as a result of increase outdoor temperature, overpopulated lecture hall and poor ventilation in the classroom. The difference between the temperatures of the various locations were minimal, the average hostel temperature were 33.9 C while the average admin office noon temperature was 29.6C. All these values were considered “poor” according to the IAQ Index scoring system and they resulted from poor ventilation and overpopulation by building’s occupants.

The evening’s temperature reading of the various locations as seen on the figure 47 also shows an increase in the overall temperature of the various locations. This arose as a result of increase in outdoor temperature and poor ventilation in these locations. These results were also considered “poor” according to the IAQ Index scoring system. The hostel readings averaged the highest result which is 34.3C degree Celsius, followed by the classroom which value is 32.1C and then the admin office which value is 26.5C. The admin office considerably results to lower temperature than the rest because of the less population present at the admin office and the use of natural and artificial ventilation.

Abdul-Wahab(2011) suggested that high indoor temperature above 25C can cause headache and fatigue while low temperature below 18C is likely to cause Chills and Influenza like symptoms. This justified an assumption about the increase rate of fatigue seen in student during lectures

The relative humidity data of our various locations is usually highest around morning when the overnight low temperature is frequently close to dew point. The RH drops during the day as the temperature rises and usually reaches its lowest value in the late afternoon when the days maximum temperature is recorded.

The result of the value of the Relative Humidity in the morning session across the various locations on the time series graph as seen on figure 48 shows an inconsistent time series data across the 3 locations in a zigzag pattern. The classroom recorded the highest value with a mean value of 71.1% which according to our IAQ Index scoring system is considered “poor” The hostel value record was poor with value of 68.4 and the admin office value recorded “average” with an average of 56.2%

The results of the value of the RH in the afternoon session across the location shown in figure 49 noted a slight drop in the mean of the session’s data. The values of the RH at the admin office recorded a mean value of 40.8% which is noted as being at the best possible conditions for RH. The values of the RH in the classroom and hostel also passed the IAQ Index scoring system with the best score with a mean value of 43.7% and 46.6% respectively.

The results from the RH of the evening session shown in figure 50 shows that the classroom value was good with a mean value of 46.6% which according to our IAQ index scoring system is a good value. The Hostel value was recorded 58.6% which is an average value in our IAQ index scoring system while the value in the admin office shows a mean value of 51.3% which is an average score in our scoring system. The slight increase in this value was because of the slight drop in temperature.

Alozie et al (2016) result revealed that the thermal comfort of building occupants in the warm humid climate might not be affected by variations in relative humidity thus; higher relative humidity in air-conditioned spaces might be acceptable.

**A relative humidity level above 70% is conducive to mold, bacteria, virus, and dust mite growth. The increased water vapor in the air facilitates off-gassing of some volatile organic compounds (VOCs) like formaldehyde. Our body’s inability to sweat at high humidity levels can also raise the body’s internal temperature, increasing the risk of cardiovascular disease and heat stress. The result and the assumption from the assessment show a good and average level of Relative Humidity. Thus this effect were not paramount among building occupants.**

The value of carbon dioxide (CO2) is mostly affected by the building’s occupants present in the location exhaling CO2 while depleting oxygen. The result shown in figure 51 shows the CO2 value in the morning section is high at the hostel and classroom where student spends most of their time. The classroom and hostel value for CO2 in the morning session are 968.7ppm and 1051ppm respectively which are considered poor in the IAQ index scoring system. The admin office mean value is 571ppm which is considered to be an average score in our index scoring system.

In figure 52, the CO2 level in the afternoon session drastically reduced in the hostel as a result of reduction in students in the hostel who have left to attend lectures in the morning. The Classroom and hostel mean value for the afternoon session are 1008.4ppm and 818.8ppm which indicate an average and poor score on the IAQ index scoring system respectively. The admin office mean value in the afternoon session is 493ppm which was rated “good” in the IAQ index scoring system.

The evening CO2 reading in the time series graph as indicated in figure 53 shows a decline in CO2 level in classrooms and in the admin office as a result of less students and staff (End of lectures and work day). Also the graph shows the increase in the level of CO2 in the hostel as (student are through with the day and then retired in their hostel). The value of the CO2 in the evening session in the hostel, classroom and admin office are poor, average and good in the index scoring system.

The analysis of variance(ANOVA) been analyzed is a one way analysis that compares the means of the 3 different locations which are the classroom, admin office and the hostel. We wish to test if they is a significant difference between the means of the various location.

We have to establish 2 different hypothesis in the analysis of variance which are the null hypothesis and the alternative hypothesis. The null hypothesis states that there is no significant difference between the means of the various locations while the alternative hypothesis states that they is a significant difference between the means and that the means are not equal.

In the morning, afternoon and evening session across the mean in the classroom, hostel and admin office they is a significant difference among the particulate matter

 In table 3,4 and 5 the means of the pollutants which are Particulate matter, temperature and CO2 showed that they is a significant difference at the different location throughout the daily session. The means of the relative humidity in the morning and afternoon showed a significant difference at the various location except for the evening session where the difference Is not significant.

The result from this study compared to other research work can be seen in Shararin et al and Morakinyo et al both studied the IAQ in lectures theatres and office complex in universities respectively. Shararin et al results for CO2 in lecture theaters discovered a high level of CO2 while Morakinyo et al discovered also a high level of temperature, CO2 and relative humidity. Papadopoulos et al (2020) also indicates a high temperature, a perfect relative humidity value and a high CO2 level in a classroom. Shittu et al (2019) recorded a PM 2.5 value of 16ug/m3 and 12ug/m3 in the Engineering dean’s office and in their lecture theater respectively which are perfectly fine according to our index scoring system

**CHAPTER 5**

**CONCLUSION**

The comparative assessment of indoor air in AE-FUNAI was carried out within 10 days across the hostel, classroom and admin office building of the university. The result from the study shows that Particulate matter 2.5 level was considerable poor in the institution but showed more disturbing value is the hostel and classroom. According to the World Health Organization (2018) PM2.5 can penetrate the lungs and enter the blood system. Chronic exposure to particle contributes to the risk of developing cardiovascular and respiratory diseases. Airnow.gov (N.D) opined that indoor PM2.5 levels can be reduced by wet mopping and proper hygiene. The university administration is advised to reduce the PM2.5 level in the university by improving its hygiene culture by encouraging the university cleaners to always wet mop and clean the various locations properly.

Temperature levels performed poorly across the various locations. The results from the bar chat and the time series graph indicates that the temperature at the admin office performed better than the hostel and classroom because the admin office was less populated and better ventilated than the other 2 locations. Nguyen et al (2014) shows that they is linear correlation between indoor temperature and outdoor temperature in warmer temperature range which goes to show you the effect of the harsh dry climate of march, 2021. The indoor air temperature was also affected by over-crowding. It is therefore advised that the university administration provides air conditioner (AC) at the various locations.

Relative humidity value in the admin office was good because of better natural and mechanical ventilation. The Relative humidity recorded in the hostel and classroom reported an average result. High RH according to Urgent Care (2014) can create certain health risk such as fainting, muscle cramp , fatigue which can reduce students’ academic performance and dehydration. The university administration is thereby advised to provide and encourage proper ventilation in the university’s buildings.

CO2 reading performed poorly in the IAQ Index scoring system at the hostel and classroom because of population and the collective exhalations produced by the building’s occupants. The Co2 result for the admin office faired better because of a reduced number of the buildings occupants.

Mendell et al (2005) and Fisk et al (2013) advised that building with inadequate ventilation may increase the transmission oof infectious respiratory diseases caused by the virus. To improve CO2 level in the hostel and classroom, the university administration should depopulate the classrooms and hostel by provision of more buildings and also improve the building’s ventilation by provision of a more efficient and sustainable ventilation system.

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