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# Improving Indoor Air Quality in Condominiums Through Green Architecture

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**ABSTRACT:** *Clean air is an essential human need. It is therefore not surprising that the WHO global health observatory estimated that in 2012, seven million deaths were caused by air pollution; with ambient air pollution contributing to 3.7 million deaths while household air pollution was responsible for 4.3 million deaths, and 7.7% of the global mortality. Africa is not left out in this epidemy. A review of literature on indoor air pollution and its contributory factors reveals that majority of the indoor pollutants come from construction material residues, indoor furnishings and finishing as well as lifestyle of the occupants of the buildings. The study carried out case studies on selected condominiums in Lagos to identify specific contributory factors to indoor air pollution and its effect on the building occupants. The research concludes by recommending that indoor air quality could be improved by introducing 'green' practices such as building with renewable construction materials, passive design, natural ventilation as well as healthy indoor plants to purify indoor air.*

**KEYWORDS**: air quality, green architecture, indoor air pollution.

## INTRODUCTION

Air is one of the most vital constituents of man's environment. Man, on the average, requires about 12kg of air each day, which is nearly 12 to 15 times more than the amount of food consumed (Ladan, 2013). Clean and pure air is therefore necessary for human health and survival. With rapid technological advancement, man keeps spending less time outdoor and with nature. People spend up to 90% of their time indoors, where the level of contamination inside is often higher than it is outside (Anchin, 2006). Hence, the need to look into the impact of indoor air on man.

Indoor air quality (IAQ) is a term that refers to air quality within and around buildings and structures especially as it relates to the health and comfort of the building occupants. Indoor air pollution (IAP) is caused by a number of factors that can be classified to four different groups:

chemical contaminants (e.g. carbon monoxide, formaldehyde), physical factors (e.g. temperature, air velocity), biological agents (e.g. bacteria, virus, and mold) and radiation (e.g. radon.) (Indoor Air Quality Management Quality Group 2003). In another light, Chaol, Chiang, Wang and Chou (2008) said poor ventilation is the main cause for the poor IAQ since the concentrations of the examined indoor pollutants (carbon monoxide, carbon dioxide and humidity) in their study are higher indoors than outdoors.

This means that Volatile Organic Compounds (VOCs) will increase at higher ambient temperatures. They are found in common household and office building materials, furnishings, finishes and a variety of commercial products (Muhamad-Darus, Zain-Ahmed and Latif, 2011). Well-sealed indoor air environments can concentrate chemical emissions. Other specific sources of VOCs include dry-cleaned clothes, cleaners, paints, paint strippers, solvents, adhesives, furniture coatings, fragrances, carpets, pesticide sprays, and stored fuels. Under damp conditions, fungi amplify indoors, produce VOCs, and are detected by a commonly recognized moldy, musty odor. Control of moisture to inhibit biological growth is the only effective means to eliminate biologically generated VOCs indoors (Das and Behera, 2008).

Muhamad-Darus et al (2011) also added that any available water from: leaks in roofs, walls, windows, plumbing; basement seepage; humidity and condensation, encourages biological growth. The US Environmental Protection Agency () discovered that climate change will increase heat and humidity in some areas of the United States, likely resulting in an increase in mechanical air conditioning and may increase the generation of biological material indoors. Appropriately sized and adequately maintained ventilation units should help control biological growth by supporting acceptable levels of humidity, limiting condensation on cooler surfaces and addressing pooling water (for example accumulated water in drip catch trays in air conditioners).

On the contrary, Ladan (2013) observed that a lot of studies conducted by experts on the environment has shown over the years that exhaust from vehicular activities has contributed to poor air quality in cities such as Lagos, Ibadan, Kano, Kaduna, and the Federal Capital Territory. This indicates that outdoor air has a direct influence on IAQ. Other factors which may have contributed to indoor air quality of terrace houses in the tropics according to Muhamad-Darus, Zain-Ahmed and Latif (2011) are location of the house, ventilation system, number of occupants and their activity and also the quality of ambient air (outdoor air).

Omole, Azubuike, Ogbiye, Ede and Ajayi (2016) observed that many Nigerians are exposed to air pollution arising from generator fumes, residing in nonresidential buildings, sleeping with actively burning candle/kerosene lamps in a locked room, and cooking in poorly ventilated kitchens.However, the key methods to keep good indoor air quality are contaminant control, humidity management, ventilation and filtration (A guide to understand ASHRAE Standard 62-2001 2002). Also, Šenitková (2017) suggested addressing IAP either by source control or dilution. In these two approaches, the concept of green architecture can be employed.

Green architecture as an approach to building can minimize harmful effects on human health and the environment. "The "Green architecture" definition is long behind the bounds of landscape projecting only…the "green architecture" projecting is a new stage of modern architecture development based on principles of connecting natural components with architectural forming." (Katola and Goy, 2015). This method of design and construction attempts to safeguard air, water and earth by choosing eco-friendly building materials and construction practices. Due to advancement in research on the characterization of various chemicals and field measurements on the concentration of those chemicals in indoor spaces, building owners and clients have paid more attention to the use of building materials emitting various chemical substances harmful to human bodies.

In turn, architects deem it fit to avoid using those harmful materials for interior design, as in the past, no compulsory requirements have been imposed on the architectural design of buildings in terms of indoor air quality, while different mandates were laid on energy conservation, such as increase in insulation and air tightness as they can be explicitly expressed in architectural drawings (Kimura, 2002).

**Statement of the Problem**

IAQ is more important than thermal, acoustical and visual comfort issues as it is related to health risk in building design as well as careful maintenance by occupants (Kimura, 2002). Outdoor air quality is being degraded gradually in the world irrespective of advanced or developing countries because of increasing human activities. This makes the difference in carbon dioxide concentration between indoor and outdoor smaller and consequently a greater amount of outside air is required to maintain the same level of $CO_2$ concentration indoors as there is a close sync between indoor environmental quality, energy efficiency, environmental sustainability and human health (Schenck, Ahmed, Bracker and DeBernardo, 2010). There have been projections that within 30 years, the majority (up to three-quarters) of our built environment is going to be replaced with new and renovated construction (Architect 2030, 2010) which impacts the environment and its air quality. Acting directly to address incorporating mitigation measures through green architecture in new building design may have the benefit of reducing the likelihood.

## RESEARCH AIM AND OBJECTIVES

The aim of this research is to identify causes of indoor air pollution in residential buildings with the view to achieving safe and adequate indoor air quality for the condominium dwellers.
The specific objectives of this paper are to:

i. identify the ventilation systems and use of materials in interior and exterior spaces of condominiums in Nigeria,
ii. Assess the impact of the ventilation systems and materials used on the IAQ,
iii. identify factors that lead to and/or contribute to poor IAQ and
iv. determine possible sustainable solutions to improve IAQ;

**Study Area**
The study area is the Lagos Island. This location was chosen due to the concentration of condominiums in the area and its micro-climatic and environmental conditions.

**Research Design**
Case study approach is adopted whereby cases are examined, analyzed, categorized and tabulated. Past studies mention the fact that case study research permits the exploration and understanding of complex issues (Zaidah, 2007) and that it can be well thought out to be a straight forward research method particularly when it requires an all-inclusive and in-depth investigation. For the purpose of this research the evaluative case study is appropriate. Here, purposive sampling is used which may be typical or representative of diversity and best and worst cases. This type of case study is chosen so as to assess the effectiveness of ventilation systems, material finishes and green building indexes in order to determine strategies that have been achieved so as to suggest relevant modifications and alternatives.

**Sample and Sampling Techniques**
This research involved the use of both qualitative and quantitative research, purposive sampling method is adopted, and this required purposive selection of cases that fall within the warm-humid climate region of Nigeria.

**Instrument of Data Collection**
The tools or instrument of data collection used are visual survey with the help of checklist.

***Visual survey***
This involved looking out for elements that have to do with the requirements for achieving optimum indoor environment.

**RESULTS AND DISCUSSION**

The following apartment condominiums were studied;
i. Titanium Towers, Ikoyi, Lagos
ii. 1004 estate, V.I., Lagos
iii. Eko Courts, Ikoyi, Lagos,

**CASE STUDY ONE:** Titanium Towers, Ikoyi, Lagos
**Floors:** 16 floors
**Area:** 8900sqm
**Project Year**: 2013

**OVERVIEW**
Titanium towers is two-block residential development. It is a simple tower design with little curves, yet it still maintains a degree of elegance. It has an impressive ground floor entrance into

the blocks and provides three typologies of apartment; two-bedroom, three-bedroom and penthouse. It offers superior accommodation to match superior taste and built to artistic standards. Alucobond panel and glass are used to finish most part of the exterior surface while ceramic tiles of varying grades and quality as well as paint and wood are used for the interiors. The entrance to the building is designed so that it promotes views, relieve obstruction and also invite the public with outdoor recreational facilities and greenery.

Facilities provided include modern lift, fire alarm and burglar alarm systems, secure underground parking, visitor parking, air-conditioners, sewage treatment plant, gym, outdoor recreational facilities, etc.

*Plate 1 & 2: exterior view of the building*

*Source: Authors' archive 2018*

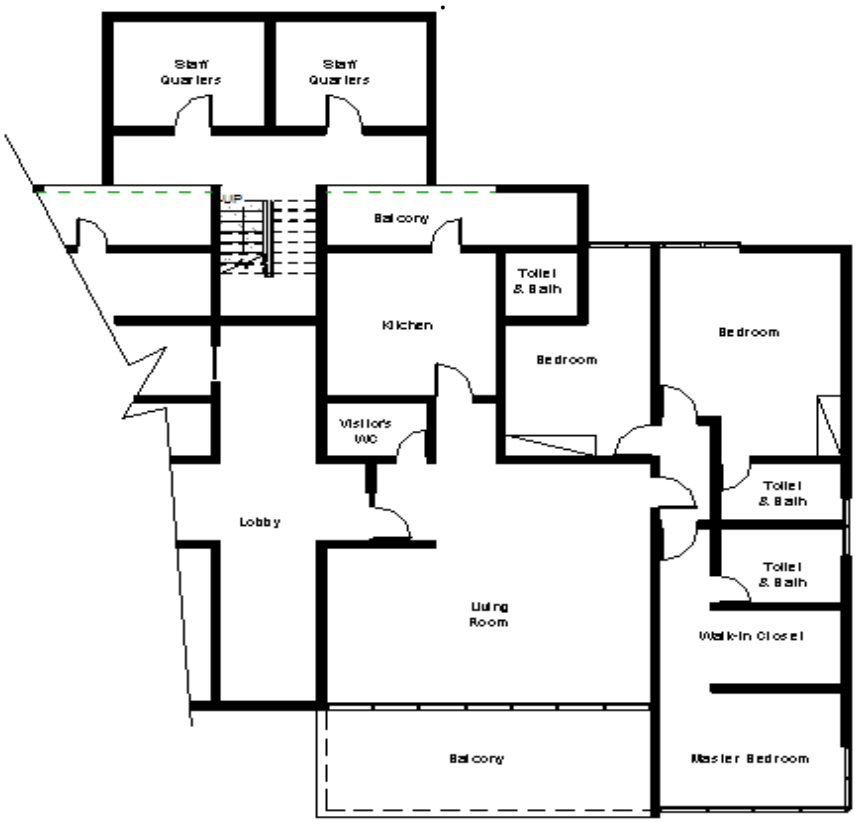



*Figure1: Floor Plan of an apartment*

*Source: Authors' archive 2018.*

*Plate 3 & 4: interior view of the building*

*Source: Authors' archive 2018.*

*Plate 5: HVAC system*

*Source: Authors' archive, (2018).*

*Plate 6: showing vent*

*Source: (Authors' archive, 2018).*

*Plate 7: leakages in the basement*

*Source: Authors' archive, (2018).*

**Appraisal**

1. Structurally sound building achieved through the use of durable materials and framed construction system.
2. Good interior finishes and internal arragement
3. Aesthetic outlook of façade.
4. Presence of landscape elements that could be used to harness the microclimate.
5. High dependency on mechanical cooling systems (air-conditioners)
6. Cross ventilation was not achieved in any of the spaces.
7. Trees, shrubs and grasses are sparsely planted around the building

**Inference**

Little attention was paid to air flow as was seen from the design of the rooms. The position of windows in some of the rooms are not serving the purpose of ventilation. Due to this reason, the

concentration of contaminants can easily increase hereby leading to IAP. Most of the building interior finishes (paint) emit VOCs into the interior and as such contribute to IAP. There are leakages in the basement. This increases the relative humidity of the spaces and high humidity encourages the growth of molds on walls and furniture. Release of the spores into the air can endanger the health of the occupants.

**Visual Survey of the Case Study**

*Table 1: Checklist Result for Case Study One*

| S/N | GREEN BUILDING INDEX | FEATURES | COMMENTS |
|---|---|---|---|
| 1 | Green index | None | |
| 2 | Daily energy-saving index | Use of large openings, large swimming pools | serving as passive cooling systems |
| 3 | Water resources | Water treatment plant | |
| 4 | Biodiversity | none | |
| 5 | Carbon dioxide reduction | Fair usage of wood material for furniture though in refined forms | |
| 6 | Waste reduction | | |
| 7 | Base water | | |
| 8 | Sewage and trash improvement index | Sewage treatment plant | |
| 9 | Interior index | Vents | |

*Source: Authors' Archive,2018*

**CASE STUDY TWO:** 1004 Estate, V.I., Lagos
**Project Year**: 1979

**OVERVIEW**

The 1004 estate is a community on its own. A cluster of buildings with apartments totaling 1004. Each apartment rests on 2 floors. 1004 estate was built in the late 1900s. Prototypes are maisonettes and studio apartments. The estate was previously maintained by the federal government but now managed by 1004 estates limited. The façade was recently improved upon to blend with modernism. The building depends heavily on artificial lighting and mechanical cooling.

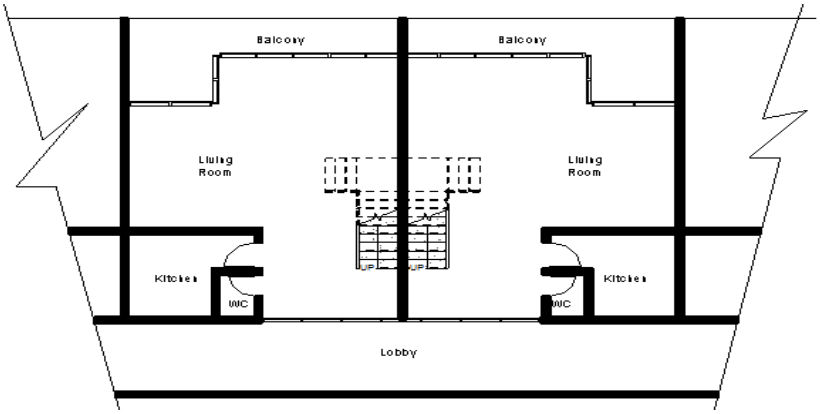
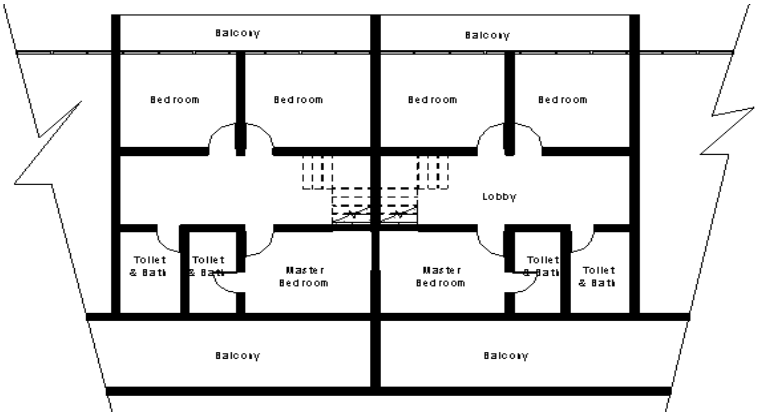



*Figure 2: Ground Floor Plan of an apartment*

*Source: Authors' archive 2018.*




*Source: Authors' archive 2018.*

*Plate 7 & 8: exterior view of the estate*

*Source: Authors' archive 2018.*

*Plate 9 & 10: interior view of an apartment*

*Source: Authors' archive 2018.*

***Appraisal***

1. Good orientation of buildings on site.
2. Good site planning.
3. Good ingress and egress points.
4. Free flowing living spaces.
5. Balconies to enhance view and enjoy nature.
6. Rooms are not cross ventilated.
7. Mold on some furniture (sign of poor indoor quality)

***Inference***

High humidity in the air led to mold formation on furniture. The building interior is painted with emulsion paint which emits harmful chemicals into the building interior. However, due to the large windows, there is in flow of air into the building hereby leading to the reduction in the contaminant by dilution. Also, there are potted plants in the apartment and on the lobbies which aid reduction of carbon dioxide in the building through the process of photosynthesis.

Air conditioning systems can incubate legionnaires' disease and mold as such be a source of biological pollutants. Poor ventilation as can be seen in the rooms can cause airborne pollutants to accumulate more than they would otherwise occur in nature.Windows, though large, are sliding. This implies that they provide only 50% opening. This reduces the amount of air flow into the spaces.

***Visual Survey of the Case Study***

*Table 2: Checklist Result For Case Study Two*

| S/N | GREEN BUILDING INDEX | FEATURES | COMMENTS |
|---|---|---|---|
| 1 | Green index | none | |
| 2 | Daily energy-saving index | Use of large openings, large swimming pools | serving as passive cooling systems |
| 3 | Water resources | Water treatment plant and | |
| 4 | Biodiversity | none | |
| 5 | Carbon dioxide reduction | Fair usage of wood material for furniture and stairs though in refined forms | Contributes to decrease in air quality due to emission of VOCs as was observed from the smell of the apartments |
| 6 | Waste reduction | none | |
| 7 | Base water | None | |
| 8 | Sewage and trash improvement index | None | |
| 9 | Interior index | | |

*Source: Authors' Archive, 2018*

**CASE STUDY THREE:** Eko Courts, V.I., Lagos
**Project Year**: 1980
**OVERVIEW**

The Eko Courts was commissioned by Late Alhaji Lateef Jakande on 28th July 1980. It comprises of three blocks. Each of the towers contains 21 floors with two apartments on each floor. The apartments are two bedroom and three bedroom.

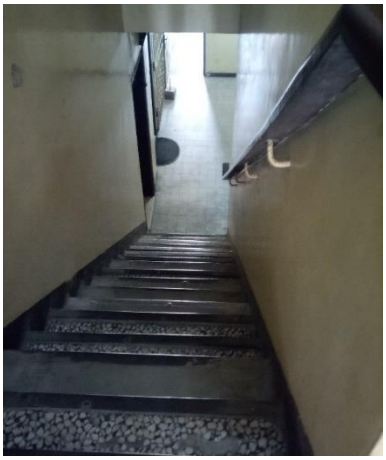



*Plate 11, 12 & 13: views of the blocks*

*Source: Authors' archive 2018*

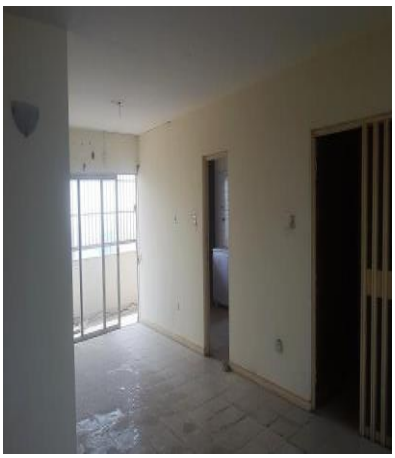



*Plate 14 & 15: interior view of an apartment*

*Source: Authors' archive 2018.*

***Appraisal***

1. Presence of soft lanscape elements
2. Free flowing living spaces
3. Balconies to enhance view and enjoy nature
4. Rooms are not cross ventilated
5. Mold on some furniture and biological growth on walls (sign of poor indoor quality)

***Inference***

Though it is visually imposing, its aesthetic value is very low. The building depends mostly on mechanical ventilation. Passive cooling techniques help improve air quality. Biological growth can be seen on the walls due to poor maintenance of the facility. This can encourage the growth of mold hereby leading to the spread of spores in the air.

The building is located in a central area. IAP can also be caused due to high concentration of carbon monoxide in the outside air. This is because of heavy vehicular movement around the area as exhaust form vehicles contain carbon monoxide

***Visual Survey of the Case Study***

*Table 3: Checklist Result For Case Study Three*

| S/N | GREEN BUILDING INDEX | FEATURES | COMMENTS |
|---|---|---|---|
| 1 | Green index | none | |
| 2 | Daily energy-saving index | Use of large openings, large swimming pools | serving as passive cooling systems |
| 3 | Water resources | none | |
| 4 | Biodiversity | none | |
| 5 | Carbon dioxide reduction | none | |
| 6 | Waste reduction | none | |
| 7 | Base water | None | |
| 8 | Sewage and trash improvement index | None | |
| 9 | Interior index | Vents, | Serving as extraction for polluted air |

*Source: Authors' Archive,2018*

## RECOMMENDATION AND CONCLUSION

It was observed from the case studies that the buildings can adversely impact the health of its occupants due to poor ventilation, lack of routine maintenance, poor choice of finishings, inadequate vegetation in and around the buildings, etc. Due to this, the following recommendations have been made;

There is always dispute as to whether natural ventilation is preferred or not. Therefore, as long as outdoor air is clear and less noisy, natural ventilation is recommended especially in rainy season when there is no need for heating or cooling.

Lush vegetations in and around buildings should be encouraged as plants reduce carbon dioxide in the air and release oxygen. Passive cooling techniques such as artificial water bodies could be introduced.

Also, attention should be paid to sustainable materials for interior finishes and furniture with particular emphasis on materials that do not contribute to indoor air pollution.

It is also recommended that town planning officials should enforce strict compliance with building codes and the uses to which such building are put. Residential areas should be kept free of air pollution that may arise from construction and post-construction activities (maintenance). All buildings that fail to meet standards regarding sizes, proper ventilation and safe building materials should not be approved for construction.

Moreover, routine inspections should be carried out on such buildings to ensure continual compliance. Furthermore, advocacy programs should be carried by non-governmental organizations, schools, religious organizations and govern agencies to educate the general population on the dangers of IAP so that building owners are likewise aware of the impact of their daily activities on their environment and health.

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