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Indoor Environmental Quality as a Performance Indicator of Sustainable Buildings: Case Study of a LEED Standard Office in Nigeria

Presented By:

Arc. Sonter J. Chen, MNIA
sonter.chen@sonjonchennigeria.org

Ph.D Candidate, Department of Architecture, Federal University of
Technology Minna, Niger State, Nigeria

Managing Director: Sonjonchen Nigeria Limited

Introduction

- Most of the world's urbanized population spend as much as 90% of their time indoors.
- This makes buildings and indoor environments critical in influencing human beings physical, mental, and social health.
- Indoor Environmental Quality is a Key Performance Indicator of Sustainable Buildings and its Dimensions include:
- Thermal, Visual, Acoustic, Indoor Air Quality



Research Problem

- Green building Standards have emerged as tools to promote sustainable building practices.
- Despite the emphasis of LEED certification on Indoor Environmental Quality (IEQ) as a critical indicator of sustainability, there is insufficient evidence on how these standards perform in practice within the Nigerian context.

01

Premise

- Some studies in other climatic regions have investigated environmental conditions with findings that are not consistent in green and conventional buildings.

02

Empirical Discourse

- Whilst some studies have presented empirical evidence that indicate better IEQ in green buildings compared to non-green buildings, some have reported identical or even impaired IEQ performance of green buildings relative to non-certified buildings



Research Aim & Objectives

The aim of this study is to evaluate the impact of Indoor Environmental Quality as a performance indicator of sustainable construction, using a LEED standard office building in Abuja, Nigeria with particular focus on occupants wellbeing

01

Objectives

1. To assess the actual IEQ performance of the building, comparing measured values against benchmarks set by World Health Organization (WHO), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHREA) and Leadership in Energy and Environmental Design (LEED).

02

2. To examine the relationship between occupants' perceptions of their well-being and key IEQ parameters, highlighting the human centred performance outcomes of sustainable construction



Building Description

- Sustainable, energy-efficient design and construction was a project principle expressed in the pursuit of LEED standards for the office building, which is in Idu Industrial Area, Abuja, Nigeria.
- The following LEED credit categories were attempted; however, certification has not yet been awarded:

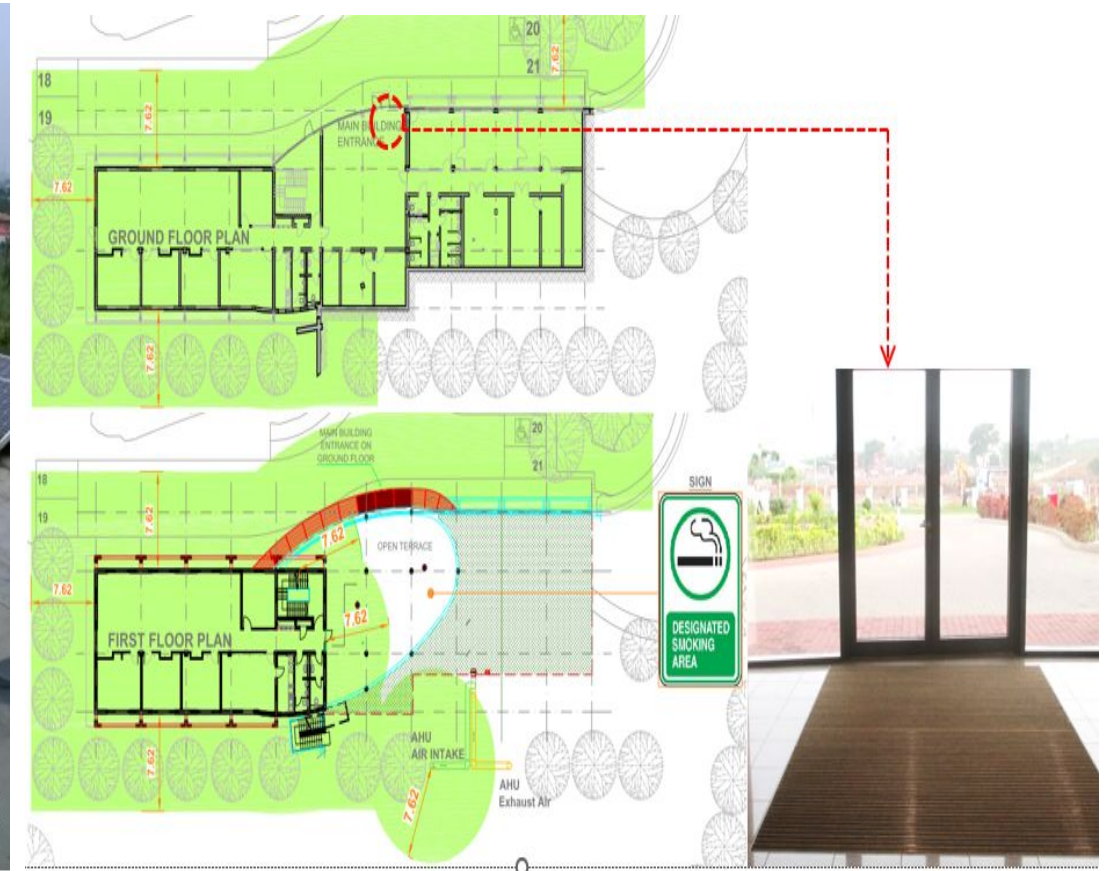
Sustainable Sites

- **Vegetated Area:** 75.9% of site (12,914 m²) landscaped – exceeds LEED's 50% requirement
- **Ecosystem Support:** Landscaping with **native & adaptive vegetation**
- **Storm water Management:** On-site percolation via **gravel and grass-lined ditches**
- **Parking Strategy:** Minimal spaces; priority for **disabled**
- **Sustainable Transport:** Provision of **bicycle stands**

Energy and

Atmosphere

- **Energy-Related Design:** Minimizes heat gain & optimizes usage
- **Insulation:** Foam glass on roof & walls
- **Glazing:** Double-glazed low-e windows/doors (U-value: 1.1 W/m²K)
- **Smart Lighting:** Motion sensor-controlled lighting
- **Building Management System (BMS):** Monitors/controls AHUs, chillers, fan coils, energy & water meters
- **Optimized Energy Model:** Simulated to maximize consumption reduction
- **Heat Recovery:** Integrated into air handling system
- **Renewable Energy:** On-site solar panels for electricity generation



Water

Efficiency

- **Potable Water Savings:** 60%+ reduction for sewage conveyance
- **Efficient Fixtures:** High-efficiency WCs & urinals
- **Two-Pipe System:** Separate supply for flush vs. flow fixtures
- **Wastewater Separation:** Greywater & Blackwater piped separately
- **Future-Ready:** Supports on-site wastewater treatment
- **Landscaping:** Native/adaptive plants to reduce water use

Indoor Air Quality

- **Non-Smoking Policy:** Designated areas to control tobacco smoke
- **Mat Wells:** At entrances to trap grit & debris
- **Cleaner Air:** Reduced pollutants, improved IEQ

Materials & Resources

Use of regional materials like masonry, concrete, floor tiles, interior painting, doors and furniture.

Methodology

- The research employed a mixed methods approach to comprehensively evaluate IEQ and its impact on occupant physical well-being.
- The study was conducted across three building zones (Ground, First, and Second Floor), with data collected over six weeks during both dry and rainy seasons, capturing the variations in environmental conditions and occupancy patterns.

01

Research Design

The research focused on key IEQ parameters such as ventilation, temperature, humidity, CO2, and particulate matter, using the Tuya IEQ monitor and air flow anemometers.

02

Data Collection

A cross sectional IEQ survey, physiological monitoring via wearable and subjective well-being assessments through a structured questionnaire adapted from CBT.

03

Ethical Considerations

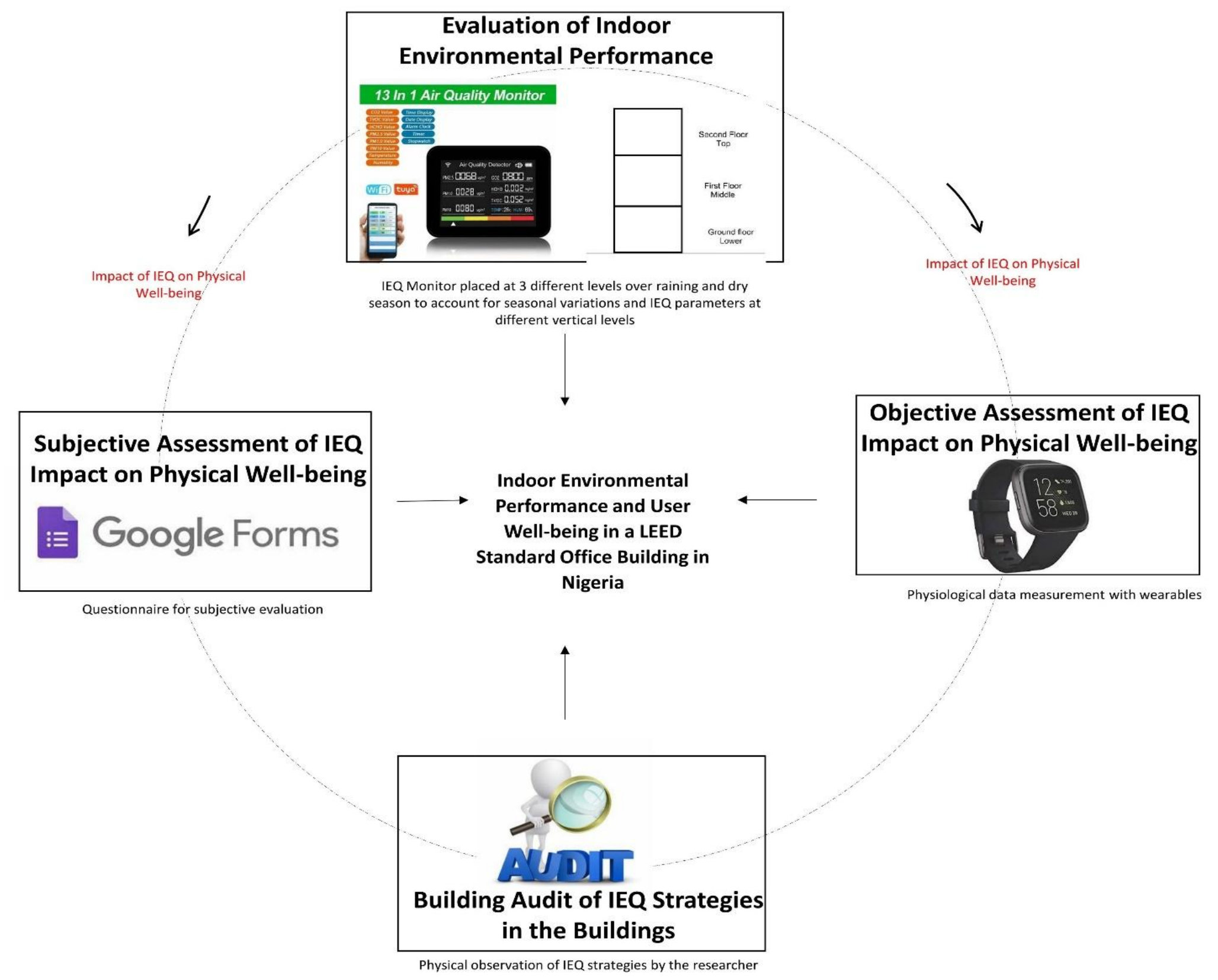
All participants gave informed consent before taking part in the study



Data Collection



On site data collection with the logger and Wi-Fi device



Data Analysis

01

IEQ Data

- Machines recorded **continuous data** for IEQ

The software automatically generated **graphs with mean values and variation** (e.g., standard deviation) for each parameter.

02

Questionnaire

- 68 questionnaires distributed
- 40 responses received (58.8% response rate)
- Data analyzed with SPSS
- Results presented using descriptive statistics (%)

03

Correlation & Benchmarking

Pearson Correlation Analysis to examine the statistical relationships between IEQ parameters (e.g., CO₂, VOCs, PM2.5, temperature, humidity) and occupant outcomes (well-being and productivity).

Results

01

IEQ Data over Raining and Dry seasons

Raining Season (Oct 2024)

PM2.5: **15 $\mu\text{g}/\text{m}^3$** , PM1.0: **9 $\mu\text{g}/\text{m}^3$** , PM10: **32 $\mu\text{g}/\text{m}^3$**

CO₂: **406 ppm**

CO: **0 ppm** (absent)

HCHO: **0.001 ppm**, VOCs: **0.010 ppm**

Temperature: **25.2°C**, Humidity: **60%**

Dry Season (Dec 2024)

PM2.5: **13.8 $\mu\text{g}/\text{m}^3$** , PM1.0: **8.5 $\mu\text{g}/\text{m}^3$** , PM10: **13 $\mu\text{g}/\text{m}^3$**

CO₂: **420 ppm**

CO: **0 ppm** (absent)

HCHO: **0.002 ppm**, VOCs: **0.011 ppm**

Temperature: **26°C**, Humidity: **62%**

Ventilation & Airflow

Ventilation rate: **20 cfm/person**

Air velocity: **0.25 m/s**

Overall Summary

Very good indoor air quality across both seasons

Moderate PM levels, very low harmful gases

CO₂ levels consistent with environmental background, **not a concern**

02

Questionnaire

- **Demographics** – Most respondents were built environment professionals with long work exposure, providing reliable insights into IEQ impacts on well-being and productivity.
- **IEQ Perceptions** – Overall satisfaction with air quality, thermal comfort, and lighting was high, though pollutants, occasional thermal discomfort, lighting issues, and office noise were noted as challenges.
- **Impact on Well-Being & Productivity** – Control over temperature and good lighting supported comfort and productivity, while pollutants and noise emerged as key stressors affecting health and performance.

03

Correlation Analysis

- **Well-being** showed strong negative correlations with CO₂ ($r = -0.55$) and VOCs ($r = -0.50$), confirming poor air quality significantly reduces occupant comfort.
- **Productivity** was moderately boosted by optimal temperature ($r = 0.45$) but reduced by higher CO₂ and VOC levels.
- Overall, **improving air quality** through CO₂, VOC, and PM_{2.5} control is essential for sustaining both well-being and productivity.

Results Cont'd

04

Benchmarking

The measured IEQ parameters of the Office were benchmarked against **WHO Air Quality Guidelines (AQG)**, **ASHRAE standards**, and **LEED v4.1/v5 requirements**.

- **Air Quality:** CO levels (0 ppm) were excellent, well below all benchmark thresholds. CO₂ levels (413 ppm) were comfortably within WHO (250–450 ppm) and ASHRAE (<500 ppm) standards, and significantly below the LEED threshold of 1000 ppm, indicating effective ventilation. Formaldehyde (HCHO) and VOCs were far lower than allowable limits, showing strong pollutant control. For particulates, PM_{2.5} (14.4 µg/m³) and PM₁₀ (22.5 µg/m³) met WHO and LEED thresholds, though PM_{2.5} was close to the upper ASHRAE limit, suggesting a need for ongoing monitoring.
- **Ventilation:** The recorded rate of 20 cfm/person aligned with ASHRAE 62.1 guidelines (15–60 cfm/person) and LEED credit requirements, reinforcing adequate fresh air delivery.
- **Thermal Environment:** Average temperature (25.3°C) was within the ASHRAE recommended range for summer (23–28°C), while relative humidity (61%) remained comfortably within the 30–65% range. Air movement (0.25 m/s) matched ASHRAE and LEED guidance, supporting acceptable comfort levels.
- **Overall**, the building demonstrated strong compliance with global benchmarks, validating its LEED performance claims. However, borderline PM_{2.5} levels highlight an area for improvement, particularly in Nigeria's dust-prone environment.

Conclusion

KEY FINDINGS

Air Quality – Low levels of PM (PM_{2.5}, PM_{1.0}, PM₁₀), CO, HCHO, VOCs, and acceptable CO₂ concentrations confirm good indoor air quality across seasons.

Thermal Comfort – Effective thermostat controls and temperature zoning allow occupants to regulate conditions, supporting comfort and productivity.

Lighting Quality – Adequate natural light and well-maintained fixtures provide favorable visual comfort, though artificial lighting controls could be enhanced for efficiency.

Noise & Acoustics – Noise disturbances from movement around and occupants discussions remain a challenge despite basic insulation, highlighting a gap in full occupant behavior.

Occupant Feedback – Satisfaction surveys revealed generally positive perceptions, but also pointed to improvement needs in noise management.

Overall Performance – The office demonstrates strong compliance with IEQ benchmarks, though refining acoustic and lighting systems would further strengthen its sustainability performance in practice.

Recommendations

- **Longitudinal Studies on IEQ and Occupant Productivity**

- Conduct long-term research to evaluate how sustained exposure to IEQ conditions in sustainable buildings affects health, well-being, and productivity.
- Extend analysis to seasonal variations, especially relevant in the Nigerian climate, to assess consistency of LEED performance in practice.

- **Regular IEQ Monitoring and Occupant Feedback**

- Establish continuous monitoring of key IEQ parameters (air quality, thermal comfort, lighting, acoustics) in LEED-certified offices.
- Use transparent reporting and regular occupant surveys to align building performance with user comfort, reinforcing IEQ as a sustainability indicator.

- **Integration of Green Building Standards and Certifications**

- Strengthen adaptation of certifications such as **LEED** in office developments across Nigeria to institutionalize high IEQ standards.
- Implement supportive policies and incentives for developers to prioritize sustainable design, operation, and occupant-centered performance.

Thank You for Listening
Questions?



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