



DEVELOPING AN ARCHITECTURAL FRAMEWORK TO REDUCE AIRBORNE DISEASE TRANSMISSION IN NIGERIAN HEALTHCARE FACILITIES: A PROPOSED AIRBORNE DISEASE TREATMENT AND RESEARCH CENTRE, AWKA.

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Abstract

This study investigates the role of architectural spatial organization in reducing airborne disease transmission in Nigerian healthcare facilities through the proposal of an Airborne Disease Treatment and Research Centre in Awka, Anambra State. The research responds to persistent deficiencies in Nigerian healthcare infrastructure, including inadequate isolation facilities, poor ventilation systems, overcrowded circulation spaces, and weak infection prevention and control (IPC) measures that heighten infection risks during outbreaks such as COVID-19, tuberculosis, Ebola, and Lassa fever. The study aims to develop an architectural framework for optimizing spatial organization to reduce airborne disease transmission. The objectives were to identify functional spaces for containment, determine principles of zonal demarcation, evaluate hybrid ventilation strategies, and propose a design integrating clinical care with laboratory research. A qualitative research design employing Comparative Case Study (CCS) methodology and Systematic Literature Review (SLR) was adopted. Findings reveal that hierarchical zoning systems, unidirectional circulation, negative-pressure isolation rooms, and hybrid ventilation strategies significantly improve airborne pathogen containment. Passive bioclimatic strategies such as cross-ventilation, stack-effect ventilation, ecological courtyards, and North–South orientation achieved ventilation performance exceeding the recommended benchmark for isolation environments. The study proposes a climate-responsive biocontainment framework that contributes sustainable design guidelines for pandemic-resilient healthcare architecture in tropical developing regions.

Keywords: Architecture, Passive design strategies, Airborne disease transmission, Healthcare architecture, Infection Prevention and Control (IPC).

1. Introduction

The design of healthcare environments is increasingly recognized as a profound determinant of patient recovery, infection prevention, and public safety. Historically, architecture and medicine shared a symbiotic trajectory in which the physical configuration of medical spaces served as a primary defense against pathogens long before the emergence of modern pharmacology (Emmanuel et al., 2020). Earlier hospital models such as the “Pavilion Plan” and the “Nightingale Ward” emphasized natural ventilation, sunlight, patient separation, high ceilings, and cross-ventilation as critical strategies for reducing disease transmission (Emmanuel et al., 2020). Florence Nightingale’s work demonstrated that improved air quality and hygienic spatial layouts could reduce hospital mortality rates from 42% to less than 3% (Emmanuel et al., 2020). However, the late 20th century witnessed a shift toward “Monobloc” or “deep-plan” hospital designs that prioritized operational efficiency, compactness, and clinical proximity over environmental health factors such as natural airflow and solar irradiation (Emmanuel et al., 2020). The emergence of the SARS-CoV-2 pandemic, alongside persistent endemic diseases such as tuberculosis (TB) and Lassa fever, exposed the critical

vulnerabilities of these sealed indoor environments (Barau, Hussaini and Wakawa, 2021; Udomiaye et al., 2022). Consequently, there is now a renewed emphasis on healthcare architecture that optimizes spatial organization and environmental controls to reduce airborne disease transmission in healthcare facilities.

Airborne disease transmission occurs through pathogen-carrying aerosol droplets generated during coughing, sneezing, speaking, or breathing (Emmanuel et al., 2020). While larger droplets settle quickly due to gravity, fine aerosol particles can remain suspended in the air for extended periods, particularly in poorly ventilated indoor environments (Barau et al., 2021). In spaces characterized by inadequate ventilation and poor spatial organization, these droplet nuclei accumulate to dangerous concentrations, leading to increased healthcare-associated infections (HAIs) among patients, staff, and visitors (Emmanuel et al., 2020). Research indicates that the risk of airborne virus transmission in enclosed environments can be up to 18.7 times higher than in open-air settings (Barau et al., 2021). The spatial behavior of these aerosols is largely influenced by convective airflow patterns. In many contemporary hospitals, especially in developing regions, turbulent airflow occurs when ventilation systems lack clear exhaust routes, allowing pathogens to spread from infected individuals to healthy occupants (Emmanuel et al., 2020). To interrupt this transmission pathway, healthcare environments must incorporate pressure-controlled airflow systems, directional ventilation, and spatial zoning strategies that ensure air moves from clean zones toward contaminated zones, a principle commonly referred to as a pressure cascade (Barau et al., 2021). Sustainable healthcare architecture further emphasizes the integration of natural ventilation, hybrid ventilation systems, daylighting, and ecological courtyards as environmental infection prevention and control (IPC) measures (Emmanuel et al., 2020).

In Nigeria, the challenge of airborne disease containment is exacerbated by weak healthcare infrastructure, inadequate spatial organization, and systemic deficiencies within healthcare delivery systems. Current data suggests that only approximately 20% of primary healthcare facilities are fully functional, while the national doctor-patient ratio of roughly 1:2500 remains significantly below international standards (Uzochukwu, Maduka and Bankole Isaac, 2025). During outbreaks of COVID-19, Ebola, and Lassa fever, many tertiary healthcare facilities were forced to convert general wards into temporary isolation centres despite lacking specialized infrastructure such as negative-pressure rooms, interlocked anterooms, and dedicated air-handling systems (Barau et al., 2021). Many Nigerian hospitals are characterized by overcrowded lobbies, narrow corridors, and shared circulation routes where suspected infectious patients intermingle with healthcare workers, visitors, and administrative staff, thereby increasing nosocomial transmission risks (Emmanuel et al., 2020). These deficiencies create “hot zones” at facility entrances and waiting areas where infections may spread even before formal admission procedures occur (Barau et al., 2021). Furthermore, the dependence on mechanical HVAC systems in regions with erratic power supply introduces critical operational vulnerabilities, as ventilation systems can become ineffective or even function as airborne traps for pathogens when adequate air changes per hour (ACH) are not maintained (Emmanuel et al., 2020).

Awka, the capital of Anambra State, presents a particularly critical context for this study due to its rapid urbanization, growing population, and warm-humid tropical climate conditions that complicate ventilation and indoor air-quality management (Anaebonam, Barnaby and Okafor, 2024; Uzochukwu et al., 2025). The population of Awka and its surrounding regions has continued to increase significantly, placing mounting pressure on existing healthcare infrastructure (Anaebonam et al., 2024; Uzochukwu et al., 2025). The city experiences high relative humidity levels, moderate temperatures, urban dust domes, and heat island effects that can prolong pathogen persistence within the built environment and complicate natural ventilation strategies (Anaebonam et al., 2024). Existing healthcare institutions such as

Chukwuemeka Odumegwu University Teaching Hospital (COOUTH) serve extensive catchment populations but often lack the purposeful spatial organization and specialized infrastructure required for high-consequence infectious disease containment (Uzochukwu et al., 2025). These conditions underscore the urgent need for a purpose-built Airborne Treatment and Research Centre that integrates infection-control architecture with climate-responsive environmental strategies.

The fundamental problem addressed by this study is the absence of purposefully designed airborne disease containment infrastructure in Nigerian healthcare facilities, resulting in high rates of nosocomial infection transmission. Existing hospitals frequently exhibit poor zoning arrangements, turbulent airflow patterns, inadequate ventilation systems, and the absence of properly designed negative-pressure isolation units for respiratory illnesses (Barau et al., 2021). The COVID-19 pandemic further demonstrated the inadequacy of converting general hospital wards into isolation centres without supporting architectural and mechanical systems such as anterooms, pressure cascades, and segregated circulation networks (Barau et al., 2021). In Awka specifically, existing tertiary healthcare facilities continue to face increasing patient loads and spatial congestion, thereby intensifying the risks associated with airborne transmission (Uzochukwu et al., 2025).

The primary aim of this study is to develop an architectural framework for optimizing spatial organization to reduce airborne disease transmission in Nigerian healthcare facilities through the proposal of an Airborne Treatment and Research Centre in Awka. The specific objectives include identifying functional spaces necessary for effective disease containment, determining principles of zonal demarcation and circulation control, evaluating the effectiveness of hybrid ventilation systems, and proposing a healthcare design that integrates clinical care with advanced laboratory research. The significance of the study is multi-dimensional, as it provides a blueprint for safer healthcare environments, reduces nosocomial infection risks for patients and healthcare professionals, and contributes specialized design guidelines for medical biocontainment architecture within tropical developing regions.

2. Review of Related Literature and Theoretical Framework

The conceptual framework for this study establishes the architectural logic for controlling the movement of microscopic pathogens through physical space. It is predicated on the understanding that in the absence of a pharmacological cure or universal vaccination, the physical environment is the primary non-pharmacological intervention (NPI) available to public health (Emmanuel, Osondu and Kalu, 2020). The framework is rooted in the "Source-Pathway-Receptor" logic, originated by Holdgate (1980), where architecture manipulates the "Pathway" variable at scale. In unventilated Nigerian clinics, the pathway is short and direct; this research aims to optimize spatial organization to reduce airborne disease transmission in Nigerian healthcare facilities.

The framework identifies several interacting variables. Independent variables (architectural inputs) include spatial zoning, circulation logic, ventilation strategies, and physical metrics. Dependent variables (public health outcomes) include pathogen suspension rates, nosocomial infection rates, and occupant safety and well-being. Mediating variables encompass Awka's climatic realities, such as high relative humidity and temperature, and infrastructure reliability, such as erratic power supply (Anaebonam et al., 2024; Uzochukwu et al., 2025). The building is envisioned as a series of valves and filters, with triage units as peripheral filters and anterooms as pressure valves to minimize pathogen leakage (Barau et al., 2021; Garibaldi et al., 2015).

Table 1: Conceptual Mapping of Study Variables and Architectural Interventions.

Variable Category	Architectural Intervention	Functional Mechanism	Target Outcome
Independent Variable	Spatial Zoning	Green, Yellow, Red hierarchy	Biological containment
Independent Variable	Circulation Logic	One-Way Flow and External Portals	Pathogen isolation
Independent Variable	Ventilation Strategy	Stack Effect and HEPA Filtration	Pathogen dilution
Independent Variable	Physical Metrics	2600 mm Corridors; 2.5 m Bed Spacing	Social distancing
Mediating Variable	Bioclimatic Adaption	North-South orientation; High ceilings	Natural air exchange
Mediating Variable	Infrastructure Backup	Solar PV/T and Hybrid Power	System reliability

Source: Researcher, 2026.

The theoretical framework hinges on four primary architectural theories: Bioclimatic Design, Evidence-Based Design (EBD), Salutogenic Design, and Space Syntax. Bioclimatic Design Theory, introduced by the Olgyay brothers, prioritizes the local climate as the primary driver of building form (Olgyay, 1963; Manzano-Agugliaro, 2015). In warm-humid zones like Awka, it is the most effective strategy for managing high thermal loads and stagnant air (Malgwi and Sagada, 2014). The theory dictates East-West axis alignment, high ceilings for the stack effect, and solar shading to prevent overheating while allowing germicidal natural light (Emmanuel et al., 2020; Ghani and Aripin, 2018).

Evidence-Based Design (EBD) Theory involves basing built environment decisions on credible research to achieve best outcomes (Center for Health Design, 2009). EBD emphasizes single-patient occupancy for cross-infection reduction, spatial visibility from nursing stations, and standardized spatial metrics such as 2600 mm corridors and 2.5-meter bed spacing (Garibaldi et al., 2015; Emmanuel et al., 2020). Salutogenic Design Theory, introduced by Aaron Antonovsky, shifts focus from "pathogenesis" (origin of disease) to "salutogenesis" (origin of health). It supports an individual's Sense of Coherence through comprehensibility, manageability, and meaningfulness, achieved through clear wayfinding, micro-climate control, and biophilic design (Antonovsky, 1979; Brick, 2022). Space Syntax treats "space as the machine" (Hillier, 1996) and provides quantitative methodologies to analyze the relationship between spatial configuration and human behavior, including movement, visibility, and interaction (Akubue, 2022; Sadek and Shepley, 2016).

Theoretical studies explore the historical evolution of biocontainment architecture. Early European facilities were often located outside city walls; by the mid-1700s, hospitals like Hotel-Dieu were poorly ventilated pathogen traps. The 19th-century "Pavilion Plan" and Florence Nightingale's environmental model demonstrated that increasing air volume through architectural layout could dramatically reduce death rates (Emmanuel et al., 2020; Gormley, 2010). The shift toward "Monobloc" hospitals in the late 20th century relied on mechanical HVAC, creating airborne traps (Emmanuel et al., 2020). Contemporary biocontainment units transition toward High-level Isolation Units (HLIUs) with negative pressure and double-HEPA filtration. Spatial dynamics of aerosol transport are determined by convective processes, necessitating architectural layouts that provide "bilateral freeboards" for movement (Salonen et al., 2023; Emmanuel et al., 2020).

Zonal mapping divides facilities into Red (Danger, negative pressure), Yellow (Buffer), and Green (Safe) zones. Anterooms act as pressure valves, preventing the escape of droplet nuclei (Barau et al., 2021). Furthermore, theoretical studies advocate for integrated clinical-research models, as the emergence of pathogens like COVID-19 necessitates on-site molecular laboratories to overcome diagnostic delays (Barau et al., 2021; Olawepo et al., 2025).

Empirical studies synthesize findings relevant to the research objectives. Nurudeen Shehu Barau et al. (2021) identified four mandatory functional zones: Triage, Green, Yellow, and Red, and established that "Suspect Bays" must be single rooms to prevent cross-infection. Emmanuel et al. (2020) found that bilateral freeboards and 2600 mm corridor widths are necessary for social distancing. Ventilation performance standards establish 12 Air Changes per Hour (ACH) as the minimum for high-level isolation (Ninomura and Bartley, 2001). In tropical environments, high percentages of windows protect healthcare workers significantly better than sealed wards (Wang et al., 2003). Empirical models for hot-humid zones favor North-South windows and "Downward-Supply and Bottom-Exhaust" patterns for contaminant removal (MIT, 2018; Salonen et al., 2023).

Integrating diagnostics is an empirical necessity; data from Ebola and COVID-19 outbreaks in West Africa showed that centralized labs created delays (Barau et al., 2021). Successful models utilize unidirectional flow with physically segregated rooms for master mix preparation, extraction, and detection (Olawepo et al., 2025). The review establishes that while global insights exist, a critical research gap remains: the absence of an integrated architectural framework harmonizing BSL-3 laboratory requirements with decentralized "Pavilion" care wings optimized for Awka's microclimate and demographic stress.

3. Methodology

The study adopts a qualitative, exploratory research design centered on a Comparative Case Study (CCS) methodology as its primary vehicle of empirical inquiry, augmented by a Systematic Literature Review (SLR) to establish baseline standards. This dual-methodological framework is selected because architectural design research relies on the deep, contextual examination of physical building precedents to extract spatial logic and configurational relationships (Chukwu, 2025). By positioning the CCS as the core heuristic tool, the study systematically deconstructs and analyzes how diverse building typologies manage hazardous physical flows and zonal integrity (Bartlett and Vavrus, 2017). Through this comparative spatial dissection, abstract public health guidelines are translated via deductive logic into concrete architectural parameters for the proposed Awka facility (Emmanuel et al., 2020).

The Systematic Literature Review (SLR) followed a strict search strategy across primary academic databases: Scopus, PubMed, and Web of Science. The search query was designed to isolate architectural variables in infection control using the Boolean string: ("biocontainment" OR "isolation unit" OR "hospital design") AND ("airborne disease" OR "infection control" OR

"ventilation") AND ("tropics" OR "Nigeria" OR "developing countries"). Inclusion criteria were: peer-reviewed studies published between 2005 and 2025, focus on environmental/spatial NPIs, and architectural data from warm-humid contexts. Exclusion criteria ruled out studies purely focused on medical therapies or clinical drug trials. An initial pool of 245 records was retrieved. Following duplicate removal (85 records) and abstract screening, 110 articles underwent full-text assessment. Applying a standardized quality appraisal checklist assessing methodology, contextual relevance, and replication potential, a final sample of 60 key publications was synthesized.

The Comparative Case Study (CCS) horizontally evaluated three selected facilities representing local, regional, and international scales: Chukwuemeka Odumegwu University Teaching Hospital (COOUTH) in Awka (Local), a regional prototypal isolation center, and the Johns Hopkins Biocontainment Unit (International Benchmark). Precedents were appraised across five core spatial parameters: Zonal Segregation, Circulation Isolation, Air Exchange Rate, Pressure Cascades, and Diagnostic Integration, using a standardized scoring system (1 = poor, 5 = excellent).

The study area is Awka, Anambra State, located at latitude 6°12' N and longitude 7°04' E. Awka is in the warm-humid tropical zone, with high relative humidity peaking at 80% and temperatures between 22°C and 34°C (Nzoiwu, 2017; Royna, 2021). These factors require bioclimatic strategies like the stack effect and cross-ventilation (Alozie et al., 2016; Anaebonam et al., 2024). Rapid urbanization in Awka has stressed medical infrastructure like COOUTH, where overcrowded lobbies force infectious cases to intermingle with the general population (Uzochukwu et al., 2025; Emmanuel et al., 2020).

Table 2: Environmental Parameters of Awka and Architectural Implications.

Element	Parameter/Value	Architectural Implication
Climate	Tropical Wet and Dry	Requires differentiation between seasonal modes
Temperature	Max 32.1°C, Min 23.5°C	Requires passive cooling for well-being
Humidity	~80% at dawn	Requires air movement to prevent microbial growth
Geology	Imo Shale and Nanka Sands	Potential expansive soil issues for foundations
Rainfall	1805 mm - 1824 mm p.a.	High runoff risk on the Awka-Orlu upland
Urbanization	Built-up area expanded 125%	Urban Heat Island adds +2.2°C to ambient temperature

Source: Researcher, 2026.

Purposive sampling was used to select information-rich materials and cases. Instruments for data collection included a Documentary Evaluation Checklist for extraction of design standards (ACH, humidity, spatial metrics) and an Architectural Case Study Matrix to evaluate zonal integrity and circulation efficiency (Barau et al., 2021; Garibaldi et al., 2015; Smith et al., 2006). Instrument validity was established through expert appraisal at the Nnamdi Azikiwe University Department of Architecture and the use of the PRISMA framework. Reliability was ensured through methodological triangulation and standardized audit matrices. Data collection occurred in three phases: Systematic Literature Harvest (SLR), Precedent and Architectural Artifact Harvesting, and Contextual and Climatic Data Acquisition from NiMet. Analysis integrated thematic coding, graphical analysis of floor plans, and logical deduction.

4. Results and Discussion

4.1 Case Analysis and Spatial Requirements for Airborne Pathogen Containment

The comparative audit of the selected case studies yielded critical data on spatial deficits and high-containment logic. The Horizontal Case Study Matrix (Table 3) evaluates the performance of the three facilities across the designated evaluation criteria.

Table 3: Comparative Case Study (CCS) Matrix

Case Study Facility	Zonal Segregation	Circulation Isolation	Air Exchange Rate	Pressure Cascades	Diagnostic Integration	Mean Score
COOUTH (Local Case)	2	2	2	1	1	1.8
Prototypal Isolation Unit (Regional Case)	4	3	3	2	2	2.8
Johns Hopkins BCU (International Benchmark)	5	5	5	5	5	5.0

Source: Precedent and Architectural Artifact Analysis.

- Chukwuemeka Odumegwu University Teaching Hospital (COOUTH): The audit of the as-built layout revealed a critical triage deficit and shared circulation paths. Suspected respiratory cases must cross administrative and outpatient lobbies to access wards. Airflow is characterized by unmonitored cross-ventilation, with no pressure cascade or integrated rapid diagnostic laboratory. This spatial configuration acts as an airborne trap during outbreak conditions.
- Prototypal Isolation Facility (Regional Case): Shows basic zoning segregation but relies on standard split-unit mechanical AC, which lacks HEPA filtration and recirculates stagnant air. Anterooms are present but lacks door interlocking mechanisms, leading to pressure loss during door operation. Diagnostic specimen transport crosses clean personnel zones, creating containment leaks.

- Johns Hopkins Biocontainment Unit (JH-BCU): Incorporates a strict 100% fresh-air HVAC supply, maintaining a pressure cascade of at least -0.02 inches water gauge (approximately -5 Pa) between isolation rooms and adjacent anterooms. It features independent donning/doffing anterooms, UV-pass boxes, non-porous heat-welded finishes, and an integrated diagnostic molecular lab, preventing any cross-contamination.

Deductions from this comparison confirm that "Suspect Bays" must be designed as single-occupancy cells with independent ventilation loops, as multi-bed suspect areas in Nigeria are primary drivers of cross-infection before test results are released (Barau et al., 2021). Quantifiable spatial suppression benchmarks derived from the benchmark include a minimum corridor width of 2600 mm to support social distancing and bilateral freeboards, and a bed center spacing of at least 2.5 meters.

4.2 Functional Spaces and Spatial Requirements for Airborne Pathogen Containment

The synthesis of research identifies mandatory functional zones and spatial metrics required for effective containment. The Triage Annex serves as the facility's "Peripheral Filter," requiring a standalone unit at the site boundary to screen cases before they enter the building envelope. Isolation Wards (Red Zone) must provide single-occupancy High-Level Isolation Rooms (HIRs) with en-suite bathrooms, while Yellow Zone transition spaces facilitate access control for PPE donning and doffing (Garibaldi et al., 2015). A critical finding establishes that "Suspect Bays" must be single-patient rooms rather than multi-bed wards to prevent cross-infection during the diagnostic window (Barau et al., 2021). Quantifiable spatial suppression metrics include a minimum corridor width of 2600 mm for social distancing and bilateral freeboards, alongside a bed center spacing of at least 2.5 meters. Sinks must be accessible and placed near nonporous surfaces to encourage hand hygiene before and after patient care (NCDC, 2020).

4.3 Principles of Zonal Demarcation and Operational Ventilation Sequencing

The proposed framework establishes a strict tiered spatial system based on risk levels and pressure gradients: a Red Zone for patient care, a Yellow Zone for PPE donning/doffing and diagnostics, and a Green Zone for administrative support. To resolve the operational and environmental challenges in Nigeria, the facility's air-handling architecture is designed to operate under three distinct seasonal and risk-based operational sequences:

1. Normal Operation Mode (Low-to-Medium Risk): The facility operates in a hybrid, mixed-mode state. Public zones and administrative areas utilize passive cross-ventilation. Isolation rooms (Red Zone) utilize mechanical HEPA exhaust systems running on utility power to pull air through low exhaust grills while motorized supply louvers deliver fresh outdoor air.
2. Power Failure Mode (Emergency Transition): Upon utility grid failure, automatic transfer switches transition high-security mechanical exhaust systems to the hybrid solar PV/T battery backup within 5 seconds to maintain directional pressure. Simultaneously, motorized dampers selectively open high-level clerestory gravity vents, allowing the stack effect to maintain passive biological dilution in non-isolation zones without backdraft risks.
3. High-Risk / Aerosol-Generating Procedure Mode: When high-risk clinical procedures (e.g., intubation) occur, the isolation ward is sealed. Natural ventilation louvers are fully closed via motorized airtight gaskets. The room operates on 100% mechanical negative pressure, boosting airflow with double-HEPA filtration in series.

4.4 Effectiveness of Hybrid Ventilation Strategies in Awka's Climate

Reliance on purely mechanical systems is unsustainable in Awka due to power instability; therefore, a "Pavilion-within-a-Building" layout with 10-meter wide courtyard channels is used to facilitate natural air movement. High ceilings (min 3.5 m) and clerestory gravity vents leverage the stack effect, drawing cooler fresh air into the breathing zone while hot air rises and is exhausted. Buildings are oriented along the East-West axis to minimize solar gain while maximizing North-South cross-ventilation. To meet the standard for infectious isolation, hybrid calculations for a standard 4.2m * 3.6m * 3m isolation room establish a required airflow rate (Q) of 160 L/s per patient. Increasing window-to-wall area to 1.5 m² per bed boosts the natural exchange rate, providing a safety factor against WHO minimums. This is augmented by rooftop HEPA-filtered mechanical exhaust in Red Zones to ensure a "Downward-Supply and Bottom-Exhaust" laminar flow (MIT, 2018; Emmanuel et al., 2020).

4.5 Integration of Clinical Care with Advanced Laboratory Research

A critical requirement is the on-site BSL-3 molecular laboratory to eliminate centralized testing delays. The laboratory is designed as a self-contained unit with interlocking doors, kept negative to the anteroom to trap pathogens within the analytical suite. The architectural layout follows a strict "Chain of Experimental Design" comprising three physically segregated suites: a Reagent Preparation Room (positive pressure), a Specimen Extraction Room, and an Amplification and Detection Room. Specimen transfer is managed via UV-pass boxes and double-door pass-through autoclaves. To address the isolation burden, the design integrates high-visibility glass partitions that allow nursing stations in the Yellow Zone to monitor patients visually, reducing the frequency of physical entry into the Red Zone while enhancing patient psychological well-being (Barau et al., 2021; Garibaldi et al., 2015).

4.6 Discussion of Findings

The discussion of findings demonstrates that architectural spatial configuration serves as a dominant, safety-driven determinant of infection prevention and control (IPC) in healthcare environments. Aligning with the study's core findings, the four-tier zonal segregation (Triage → Green → Yellow → Red) and unidirectional circulation protocols function as physical barriers that sever pathogen transmission pathways, ensuring that high-consequence contaminated areas are structurally isolated from safe administrative spaces (Barau et al., 2021). Furthermore, the integration of decentralized molecular laboratories directly resolves the "Diagnostic Gap" that typically drives nosocomial outbreaks in traditional facilities (Olawepo et al., 2025). This spatial-laboratory dependency ensures that suspected cases can be held in single, negative-pressure rooms during the critical diagnostic window rather than in multi-bed wards, preventing cross-infection (Barau et al., 2021). Quantifiable physical metrics, specifically the 2600 mm corridor widths and 2.5 m bed spacing, are shown to be essential parameters that facilitate safe social distancing and prevent the accumulation of stagnant air pockets (Emmanuel et al., 2020). In Awka's warm-humid climate, where mechanical systems are prone to power-related failures, the application of passive bioclimatic strategies, such as North-South building orientation, high ceilings of at least 3.5 m, and maximized cross-ventilation, achieved a natural air exchange rate (MIT, 2018). Ultimately, the synthesis of a safety-driven spatial hierarchy and climate-responsive architecture provides a highly effective, resilient strategy for managing airborne pandemics in tropical healthcare settings (Uzochukwu et al., 2025).

5. Conclusion and Recommendations

The research concludes that the current lack of purposefully designed viral containment infrastructure in Nigeria is a significant threat to national public health and economic stability (Barau et al., 2021). The architectural envelope of the hospital is not a passive container but an active participant in either the suppression or the propagation of infectious diseases (Emmanuel et al., 2020). By optimizing spatial organization through strict hierarchical zoning, one-way circulation protocols, and high-volume natural dilution, architecture can effectively elongate the pathway between infected sources and susceptible receptors.

In the specific context of Awka, the proposed Airborne Treatment and Research Centre demonstrates that biocontainment can be achieved through a safety-driven, sustainable approach. This architectural framework harmonizes high-fidelity BSL-3 laboratory requirements with decentralized "Pavilion" care wings specifically adapted for the warm-humid tropical climate. Ultimately, the built environment remains the first and most resilient line of defense against emerging and re-emerging respiratory pandemics in Nigeria, serving as a critical infrastructure intervention for long-term health security.

Based on the research findings, the following itemized recommendations are proposed to enhance the safety and resilience of Nigerian healthcare facilities:

1. **Mandatory Standalone Triage Annexes:** All tertiary health facilities should implement stand alone, peripheral triage units located at site boundaries. These annexes must screen respiratory cases before they enter the primary building envelope and provide physical barriers to guide patient movement safely.
2. **Prioritization of Hybrid Ventilation:** Healthcare designs in warm-humid regions like Awka should adopt "Mixed-Mode" ventilation strategies. This includes utilizing high ceilings (minimum 3.5 m) to leverage the stack effect and North-South window placement to maintain a natural air exchange rate, ensuring safety even during power outages.
3. **Standardized Spatial Benchmarks in Building Codes:** The Nigerian National Building Code should mandate a minimum corridor width of 2600 mm to support social distancing and bilateral freeboards for movement. Additionally, a minimum of 2.5 meters between bed centers in clinical infectious zones must be strictly enforced to reduce aerosol concentrations.
4. **Integrated High-Security Laboratory Suites:** Every tertiary-level isolation center must include an integrated BSL-3 molecular laboratory suite. This suite should follow a strict "Chain of Experimental Design" with physically segregated rooms for reagent preparation, specimen extraction, and detection to eliminate diagnostic delays and prevent laboratory-acquired infections.
5. **Automation and Surface Safety:** Architects must specify touchless systems, such as motion-sensor faucets and doors, to minimize contact networks. Furthermore, all walls and surfaces in Red Zones should be coated with non-porous epoxy paint to facilitate efficient and frequent chemical decontamination.

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