Assessment of Vernacular Design Principles for Improving Indoor Air Quality in Historic Coastal Towns

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Abstract- ***Indoor air quality (IAQ) is a critical aspect of human health and comfort, especially in tropical coastal regions where heat and humidity pose persistent challenges. This study investigates the effectiveness of vernacular architectural principles in enhancing IAQ through a qualitative case study approach. Focusing on four historic coastal towns-Lamu (Kenya), Stone Town (Zanzibar), Elmina (Ghana), and Galle (Sri Lanka)-the research examines how indigenous building strategies contribute to thermal comfort, humidity control, and natural ventilation. Data collection involved architectural analysis, literature review, and secondary environmental sources. The findings reveal recurring design features such as courtyards, verandahs, breathable natural materials, and strategic building orientation. These elements function as passive systems that regulate airflow and moisture, maintaining stable indoor conditions with minimal reliance on mechanical ventilation. The study highlights how vernacular forms not only reflect cultural identity but also offer environmentally responsive solutions that remain relevant for contemporary sustainable architecture. It concludes that integrating these strategies into modern practice can improve IAQ, reduce energy use, and support healthier living environments in humid tropical climates. The paper recommends the reintegration of vernacular design into building codes, hybrid architectural models, and further empirical research to quantify performance outcomes.***

Indexed Terms- ***Vernacular Architecture, Indoor Air Quality (IAQ), Passive Design, Coastal Towns, Humid Tropical Climate, Sustainable Architecture, Natural Ventilation, Traditional Building Strategies***

I. INTRODUCTION

Human well-being depends heavily on indoor air quality (IAQ), particularly in tropical coastal regions where ventilation, temperature, and humidity are more problematic (Kumar et al., 2023). Indigenous populations created architectural adaptations based on centuries of environmental adaptation in numerous historic coastal cities (Daoudi et al., 2019). These solutions, which are now acknowledged as vernacular design principles, guaranteed fresh air circulation and thermal comfort without relying on mechanical equipment. Many of these climate-responsive techniques are disappearing as contemporary building methods progressively supplant ancient approaches, which leads to decreased occupant health, higher energy consumption, and poor indoor air quality (Saifudeen & Mani, 2024). Particularly in areas susceptible to environmental stressors and climate change, the renewed interest in sustainable design offers a chance to reconsider the value of vernacular architecture (Nguyen et al., 2019).

In contrast to standardized, imported designs and materials that are insufficiently responsive to local climate conditions, modern architectural methods in coastal cities frequently disregard conventional environmental logic (Ulusoy & Uzunahmet, 2022). This change has resulted in buildings that are thermally uncomfortable and inadequately ventilated, particularly in humid tropical regions. Although mechanical devices are commonly implemented to address these deficiencies, they are frequently expensive, energy-intensive, and unsustainable (Guitart, 2023). The recognition and reintegration of the climate wisdom inherent in vernacular architecture, particularly its contributions to improving indoor air quality, is still lacking in architectural research and practice.

This study aims to assess vernacular design principles used in historic coastal towns and their contributions to improving indoor air quality. The specific objectives are to: Identify common vernacular architectural features in selected coastal towns, examine how these features influence air movement, temperature regulation, and humidity control, and evaluate their relevance and effectiveness in today's sustainable design context.

The coastal cities in humid tropical regions of Africa and parts of Asia are the subject of this study. Only residential and communal structures that still have significant vernacular elements are included in the analysis. It does not address indoor air quality (IAQ) in highly urbanized or industrial buildings, nor does it include modern structures that have only partially integrated traditional components.

In conclusion, this study bridges the gap between traditional knowledge and modern practice, adding to the expanding conversation on sustainable design. It sheds light on how tried-and-true vernacular techniques may help create healthier interior spaces, lessen dependency on energy-intensive systems, and promote development that is rooted in culture. The results might persuade legislators, architects, and urban planners to reevaluate indigenous approaches as workable answers to environmental design problems.

II. CONCEPTUAL FRAMEWORK

2.1 Indoor Air Quality in the Context of Humid Climates

The quality of the air inside buildings and other structures is referred to as indoor air quality (IAQ), especially when it comes to the comfort and well-being of building occupants (Semang & Razali, 2022). Achieving adequate indoor air quality (IAQ) is especially difficult in humid tropical locations because of the high moisture content, which promotes the formation of mold, mildew, and other biological pollutants (Brambilla et al., 2022). In these types of climates, ventilation becomes essential for preventing the accumulation of interior pollutants and humidity. Coastal tropical areas require architectural solutions that prioritize cooling, airflow, and moisture control, in contrast to temperate climates where heating is frequently a top goal (Penner, 2024).

2.2 Vernacular Design Elements Affecting IAQ

By using passive design techniques, vernacular architecture provides environmentally friendly solutions for indoor comfort and air quality. Among these are the utilization of indigenous, organic materials that control temperature and humidity, such as clay, hemp, and sheep's wool (Călătan & Dico, 2022). Microclimates are produced and natural ventilation is facilitated by building orientation, courtyards, and shaded areas (Philokyprou, 2023). Elevated platforms minimize the intrusion of ground moisture, while thick walls offer thermal insulation (Du, 2019). These elements have a strong foundation in environmental adaptability; they are not arbitrary. Large overhangs and deeply positioned windows, for instance, let breezes flow while protecting interior rooms from direct solar heat absorption. Thick earth walls control internal temperatures and moisture variations, while courtyards serve as thermal regulators by promoting vertical air movement (stack effect).

2.3 Relationship between Building Design and Human Health

The physical health of building occupants is known to be correlated with architectural design. Allergies, exhaustion, respiratory issues, and other medical disorders might result from low IAQ (Kumar et al., 2023). On the other hand, it has been demonstrated that areas with natural ventilation and suitable material selections enhance overall productivity, mental clarity, and the quality of sleep. By using passive systems, vernacular buildings lessen exposure to indoor contaminants that are frequently released by HVAC systems or synthetic building materials (Cojocaru & Isopescu, 2021). Additionally, traditional materials' tactile attributes—like the earthy scent of clay or the thermal softness of thatch—have psychological advantages linked to biophilic design and cultural familiarity.

III. LITERATURE REVIEW

3.1 Overview of Vernacular Architecture in Coastal Towns

Buildings created with regional materials and construction methods that represent particular social and cultural settings and locations are referred to as vernacular architecture (Deprez, 2025). Environmental factors including temperature, salinity, wind patterns, and humidity influence this architectural history in coastal cities (Bera, 2021). Examples of how indigenous societies used orientation, shape, and materials to construct climate-resilient constructions can be seen in locations such as Galle, Sri Lanka; Stone Town, Zanzibar; and Lamu, Kenya. These plans frequently included strong stone walls that served as thermal buffers, open courtyards for ventilation, and narrow alleyways for shade. Despite challenging exterior conditions, these characteristics allowed structures to retain comparatively consistent indoor conditions (Maligi et al., 2024).

Coastal architecture typically uses mudbrick, laterite stone, coral blocks, timber, palm fronds, and thatch, though the exact materials used vary by location. Because of their breathability, these materials reduce condensation and the growth of mold by letting moisture through roofs and walls (Bera, 2021). For example, because of their ability to regulate humidity and provide thermal bulk, mudbrick and rammed earth construction were preferred in West African communities like Elmina and Brass. Coral stone and lime plaster were used in East Africa to reflect heat and keep interiors dry. In order to improve circulation and avoid heat trapping, the construction methods frequently used natural ventilation pathways, such as high ceilings, transoms, and perforated walls (Muqoffa et al., 2025).

3.3 Traditional Passive Cooling and Ventilation Strategies

Vernacular design incorporated a number of passive techniques to control indoor air quality. While stack ventilation was made possible by large vents and double roofs, cross-ventilation was accomplished by positioning openings on opposing walls (Izadpanahi et al., 2021). The courtyard typology functioned as a thermal chimney in coastal architecture of Sri Lanka and India, pulling hot air upward and replenishing it with cooler air at ground level (Nishinthan & Rajapaksha, 2023). In hot and muggy conditions, shading devices are essential for lowering solar heat gain and enhancing thermal comfort. In comparison to other shade forms, wind-catcher shading devices have been demonstrated to dramatically minimize hours of temperature discomfort while permitting modest airflow (Hlaing & Kojima, 2022). In humid regions, elevated floors on stilts helped reduce moisture penetration and allowed underfloor ventilation (Pramesti et al., 2021). These systems functioned as part of an integrated environmental response, requiring no mechanical intervention.

3.4 Gaps in Current Architectural Practice and Sustainability Trends

Despite the proven advantages of vernacular principles, current architectural practice frequently ignores them in favor of imported building systems and modern aesthetics (Yılmaz & Yılmaz, 2021). Glass, concrete, and sealed spaces have grown commonplace in many coastal towns, leading to structures that rely significantly on artificial lighting and air conditioning. This change has resulted in poorer indoor air quality, higher energy consumption, and higher operating expenses, especially in areas without or with inadequately maintained HVAC systems (Simpeh et al., 2021). In addition, localized traditional knowledge is rarely taken into consideration by current green building certifications, which instead emphasize standardized benchmarks. An opportunity to combine environmental performance with cultural identity is lost because of this divergence.

IV. RESEARCH METHODOLOGY AND CASE STUDY APPROACH

The effectiveness of vernacular architecture techniques in enhancing indoor air quality in ancient coastal communities is evaluated in this study using a qualitative case study methodology. Because of its ability to capture context-specific, environmental, and cultural factors in real-world contexts, the case study technique was selected. The selection of four towns—Lamu, Kenya; Stone Town, Zanzibar; Elmina, Ghana; and Galle, Sri Lanka—was based on their historical employment of passive design

approaches appropriate for coastal conditions, their geographic placement in humid tropical zones, and their preservation of traditional architecture.

Architectural study, literature reviews, visual documentation, and the synthesis of secondary environmental data were all used in the data collection process. The utilization of building form, materiality, ventilation pattern, and spatial organization in relation to air quality performance was analyzed for each case. All case studies' results were subjected to a thematic analysis, with an emphasis on recurrent design components that support thermal comfort, moisture management, and ventilation. In order to comprehend how indigenous architectural knowledge might influence sustainable indoor air quality solutions in modern practice, this method offers a comparison perspective.

V. CASE STUDY PRESENTATION AND ANALYSIS

The vernacular architectural methods of four historic coastal towns, all of which are situated in humid tropical regions, are presented and examined in this section. The objective is to evaluate how each context's unique design features enhance indoor air quality by promoting thermal comfort, moisture management, and natural ventilation. Performance results, passive IAQ techniques, and architectural elements make up the analysis's standard format.

5.1 Case Study 1: Lamu, Kenya

Architectural Features

Situated on the Kenyan coast, Lamu is a UNESCO World Heritage site that is distinguished by its Swahili architecture. Usually made of mangrove timber and coral stone, the structures have internal courtyards, flat roofs, and elaborately carved wooden doors. In order to maximize mutual shadowing and reduce solar exposure, houses are positioned along narrow roadways.

IAQ Strategies

By allowing vertical air flow, the interior courtyards serve as thermal chimneys, drawing in cooler air from the shaded environs and expelling warm, stale air. Thermal mass from thick coral walls helps insulate interior areas from outside heat. The building's air circulation is improved via rooftop access points and wooden latticework windows.

Plate 1.0: Building in Lamu, Kenya
Source: https://www.archnet.org/sites/6076 (Retrieved 2025)

5.2 Case Study 2: Stone Town, Zanzibar

Architectural Features

Coral stone homes with Swahili, Arab, and Indian influences can be found in Stone Town, a neighborhood in Zanzibar City. Narrow alleys, wooden balconies, lattice screens, and thick, lime-washed walls characterize the densely populated dwellings. Overhanging upper floors and shaded loggias are common features of multi-level buildings.

IAQ Strategies

High ceilings, well-placed windows, and vertical voids all help to control airflow. Small light wells and courtyards bring in cooler breezes while allowing hot air to escape above. In addition to reducing solar gain, shaded streets and carved wooden shutters promote filtered airflow into interior rooms.

Plate 2.0: The Old Fort (Ngome Kongwe), Stone Town, Zanzibar.
Source: (Codingest, 2023)
(Retrieved 2025)

5.3 Case Study 3: Elmina, Ghana
Architectural Features
Local people constructed the mudbrick and laterite buildings in Ghana's historic seaside town of Elmina both during and after the colonial era. Wide verandahs, overhanging roofs, and elevated plinths are common features of vernacular architecture that provide protection from flooding and ground moisture.

IAQ Strategies
Passive moisture regulation is made possible by mudbrick's permeable nature. In addition to offering shade, verandahs act as temporary temperature barriers between indoor and outdoor areas. By increasing air movement beneath the structure, the elevated floors of the structures help to reduce moisture.

Plate 3.0: St. George Castle, Elmina
Source: Wikipedia
(Retrieved 2025)

5.4 Case Study 4: Galle, Sri Lanka
Architectural Features
Situated on the southwest coast of Sri Lanka, Galle is renowned for its Dutch-colonial architecture combined with local courtyard house styles. The structures include lengthy verandahs, central courtyards, steeply pitched clay tile roofs, and strong clay brick walls.

IAQ Strategies
While clay tiles permit little heat transfer into interior rooms, courtyards are essential components for stack ventilation. By providing shaded circulation areas and allowing external air to flow before entering the rooms, verandahs, which are supported by timber columns, help to decrease heat transmission.

Plate 4.0: Building in Galle, Sri Lanka
Source: (Rajapaksha., 2013)
(Retrieved 2025)

5.5 Cross-Case Summary and Analysis
Across all four case studies, certain strategies appear consistently:

i. Courtyards and verandahs as key ventilation and thermal buffer zones.
ii. Thick, natural walls (mudbrick, coral stone, or clay brick) that absorb and release moisture slowly.
iii. Openings for cross and vertical ventilation, often shaded or screened for airflow without glare or heat.
iv. Shaded circulation paths and spatial hierarchy that guide airflow through interior spaces.

These characteristics successfully improved indoor air quality in each town, lowering reliance on artificial cooling while increasing human comfort.

The environmental logic was consistent despite the diversity of cultural expressions, proving that vernacular architecture provides globally applicable solutions for IAQ issues in coastal regions.

VI. DISCUSSION OF FINDINGS

The research's case studies show a recurring trend: old coastal towns' vernacular architecture uses eco-friendly techniques that improve interior air quality organically. There is a shared environmental logic among the structures in Lamu, Stone Town, Elmina, and Galle, despite differences in local culture and building methods. This reasoning is incorporated into passive ventilation systems, construction materials, and spatial layout, all of which are designed to lessen the negative effects of heat, humidity, and poor air circulation—problems that are common in tropical coastal regions.

The usage of courtyards and verandahs, which serve as ventilation channels and thermal buffers in addition to organizing social activities, is a recurring element throughout all sites. Both cross and stack ventilation are made possible by these open, shaded transitional areas, which encourage air movement. Their thoughtful placement improves airflow across interior areas, efficiently expelling humid or stale air and substituting it with fresher outdoor air. This natural airflow system is further reinforced by the orientation of structures, which often captures the predominant coastal breezes. This demonstrates intentional climatic awareness in traditional planning.
Another important factor is the use of materials. Superior thermal performance and breathability are exhibited by structures composed of clay brick, laterite, coral stone, or mudbrick. Slow moisture absorption and release made possible by these natural materials stabilizes indoor humidity and lowers the risk of mold growth and condensation. These traditional materials serve as a natural temperature and air quality regulator, unlike contemporary cement blocks or glass. This bolsters studies that show traditional wall assemblies are associated with healthier indoor spaces in tropical regions.

VII. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The purpose of this study was to evaluate the impact of vernacular design principles on indoor air quality (IAQ) in humid tropical conditions in historic coastal towns. It is clear from comparing case studies in Lamu, Stone Town, Elmina, and Galle that traditional architecture, despite being influenced by culture and climate, provides workable and efficient answers to the enduring problems of heat, humidity, and inadequate ventilation. A design language based on environmental responsiveness is revealed through the incorporation of courtyards, verandahs, high ceilings, breathable materials, and intentional orientation. Without depending on mechanical systems, these components enable hygienic, breathable interior environments in addition to providing thermal comfort.

The case studies highlight the timeless value of vernacular ideas, even if modern construction trends sometimes ignore traditional tactics in favor of imported, energy-intensive methods. They demonstrate that when design is informed by local climate information and cultural norms, better indoor air quality can be attained passively. These low-tech, context-driven solutions offer a sustainable alternative that is both economically and environmentally sound as climate change worsens and energy prices rise.

7.2 Recommendations

The following suggestions are offered to promote improved interior air quality in both new and existing buildings, particularly in tropical and coastal areas:

Reintegration of Vernacular Design Principles
Traditional material choices, passive ventilation strategies, and spatial configurations should serve as models for planners and architects. Locally informed, climate-responsive architecture should be emphasized in design studios and courses.

Adoption into Building Guidelines and Codes
Vernacular techniques, like the use of breathable walls, shaded outdoor buffers, and required natural ventilation ratios, should be incorporated into zoning

and construction laws by local planning authorities and housing agencies, particularly for public housing and educational facilities.

Promotion of Hybrid Design Models

Modern architecture should look for hybrid solutions that blend vernacular knowledge with modern necessities, aesthetics, and construction techniques rather than completely returning to traditional forms. Using contemporary materials in ways that replicate the functionality of more conventional ones is part of this.

Further Empirical Research and Testing

The justification for wider adoption should be strengthened by more quantitative research, such as in-situ temperature, humidity, and air movement data, even though the qualitative evidence of improved IAQ is compelling.

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