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SYSTEMATIC REVIEW OF SOCIO-SPATIAL DESIGN STRATEGIES FOR ENVIRONMENTAL HEALTH EQUITY IN WARM HUMID ENVIRONMENTS

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Abstract

Warm-humid built environments are increasingly exposed to environmental health risks associated with heat stress, poor ventilation, dampness, indoor air pollution, inadequate housing, and unequal access to green infrastructure. These risks are often more severe among low-income households, children, older adults, and residents of poorly serviced settlements. Although existing studies have examined passive design, thermal comfort, indoor environmental quality, green infrastructure, and urban health, the evidence remains fragmented and does not sufficiently explain how socio-spatial design strategies can promote environmental health equity. This study systematically reviewed socio-spatial design strategies for environmental health equity in warm-humid built environments. It examined the strategies that improve environmental health equity, their influence on vulnerable populations, and how evidence-based approaches compare with conventional design practices. The review followed the PRISMA 2020 framework for study identification and selection, while the Joanna Briggs Institute (JBI) evidence-synthesis approach guided quality appraisal, data extraction, and narrative thematic synthesis. 120 records were initially identified, while 63 studies were retained. The findings show that passive ventilation, climate-responsive orientation, shading, improved window typology, moisture-sensitive housing design, green-blue infrastructure, shaded public spaces, and informal settlement upgrading can reduce heat exposure, improve indoor environmental quality, support thermal comfort, and enhance wellbeing. The study contributes a socio-spatial environmental health equity framework linking design strategies, exposure reduction, vulnerability, access, and health outcomes. It concludes that warm-humid built environments require integrated design and planning approaches that are climate-responsive, health-supportive, and socially inclusive.

Keywords: Environmental health equity; environmental equity; green infrastructure; indoor environmental quality; socio-spatial design; thermal comfort; warm-humid built environments;

1. INTRODUCTION

Environmental health inequality is recognized as a significant global challenge for sustainable architecture, urban planning, and public health, as the built environment influences who gets shielded from the negative impact of the environment and who is subjected to poor living conditions. According to the World Health Organization (WHO, 2024), the combined impacts of home and indoor air pollution are responsible for millions of premature deaths each year, with the majority of the world's population living in areas where air quality exceeds recommended health standards. Heat exposure is also increasing among vulnerable groups, and research posits a high increase in the number of heat-related mortalities in older individuals beyond prior baselines (Romanello et al., 2024). The hazards are amplified by the worldwide housing crisis, with billions of people insufficiently housed and many residing in informal settlements, congested neighbourhoods or poorly maintained residential environments (UN-Habitat, 2025). The implication is that environmental health is not just a physical or climatic concern but also a built environment problem influenced by housing quality, ventilation, orientation, neighbourhood density, drainage, public space, green infrastructure, and unequal access to environmental amenities. The issue is exacerbated in warm-humid environments with deteriorating indoor environmental quality, respiratory risks, thermal discomfort and mold growth due to high humidity, reduced air movement, overcrowding, buildup of moisture and minimal passive cooling opportunities (Amaripadath et al., 2023; Hernández-Martín et al., 2025). In furtherance, studies on thermal comfort in school environments, architecture studios and residential buildings in warm-humid Africa and Nigeria imply that in addition to building performance, socioeconomic conditions, environmental quality, adaptive opportunities and exposure history all influence users' comfort and wellbeing (Munonye et al., 2023a, 2023b; Obi-George et al., 2024; Obi-George et al., 2025). Though it is generally held that building performance is improved by sustainability, energy efficiency, improved ventilation, and indoor comfort, the issue of the uneven distribution of environmental benefits and risks still exists. Heat, reduced access to green infrastructure, poor ventilation, and poor air quality do indeed commonly exist among low-income and vulnerable people. The challenge therefore exceeds designing improved buildings; rather, it is to ensure fair access across the built environment.

Some studies have recommended varied resolutions to environmental health risks, which focus on technical, physical, or performance-based propositions. Various studies on passive design in hot, humid and tropical climates also underscore building orientation, solar shading, planting vegetation, improved ventilation, building envelope/form, and use of reflective surfaces for reduced heat exposure and enhanced comfort (Al Niyadi & Elnabawi Mahgoub, 2025; Aderinsola et al., 2025; Hu et al., 2023; Pratiwi et al., 2025). Research pinpointed that occupants' health and comfort have been jeopardized by poor indoor air and ventilation, reduced building material quality, increased humidity and temperature, suggesting the need for marked improvement in these factors affecting only the building itself (Booker et al., 2025; Loureiro et al., 2025; Lozinsky et al., 2025). Nonetheless, the suggested solutions do not adequately consider the building occupants who use these spaces daily, nor do they take into account the social and spatial settings that influence whether these occupants ultimately benefit from the interventions. Further studies show that green spaces, public areas that are shaded, parks and integrating nature into our environment can lower heat exposure and improve wellbeing (Das, 2025; Nazish et al., 2024; Pasgaard et al., 2025; Zarei & Shahab, 2025). However, the interventions are not evenly distributed; rather, some populations remain disadvantaged while some benefit more. Many studies have equally identified that urban infrastructure, public spaces, housing quality, and neighbourhood design impinge on health outcomes (Andalib et al., 2024; Rollings et al., 2024; Seyedrezaei et al., 2023). These studies are yet limited to portraying connections between health and the built environment, excluding the clarification of how socio-spatial design strategies might lower environmental risks and improve health outcomes equitably. This gap is noticeable in African warm-humid environments, with existing evidence mostly embedded in indoor thermal comfort and air quality, housing, urban heat and planning studies.

This study addresses the identified gap by systematically reviewing socio-spatial design strategies for environmental health equity in warm-humid built environments. The rationale is based on recent research indicating that physical building performance, environmental exposure, capacity for adaptation, social vulnerability, patterns of spatial access and environmental inequity all impact environmental health outcomes too (Ahrens et al., 2026; Aznarez et al., 2024; Cousins, 2024; Nóblega-Carriquiry et al., 2026). This review leverages existing studies to connect various findings and understand how design and planning decisions can mitigate environmental inequity, particularly in warm-humid contexts. In comparison with conventional building and planning approaches, this study will particularly examine socio-spatial design strategies that are efficient for improved environmental health equity and its influence on expected outcomes such as heat exposure, air quality, respiratory risk, thermal comfort, and access to green space among vulnerable populations. The study will then develop a socio-spatial framework which can be applied by architects, urban planners, environmental health professionals, housing authorities, and policymakers in creating warm-humid built environments that are not only environmentally efficient and climate-responsive but also healthier, more inclusive, and socially equitable.

2. METHODOLOGY

2.1 Research Design

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) was used to synthesize data obtained from existing studies on improving environmental health equity in warm-humid built environments via socio-spatial strategies. The method was considered appropriate due to the widespread nature of existing literature across environmental health, architecture, urban planning, housing, and sustainability. The PRISMA 2020 framework was adopted for determining and accessing because it allows for a robust and replicable procedure (Page et al., 2021). Again, noting the diversity in study design and heterogeneous evidence where studies investigated different variables, methodologies and peculiar environmental health outcomes, the narrative thematic synthesis approach was also used since the evidence could not be statically merged. The findings were grouped into similar themes and subsequently evaluated to discover the socio-spatial design methods that improve environmental health equity in warm-humid built environments.

2.2 Research Strategy

The literature was widely searched in Scopus, ScienceDirect, Sage Journals, SpringerLink, Web of Science, Taylor & Francis, and Google Scholar. These databases were selected because they provided a full representation of the diverse fields of research in urban planning, climate adaptation, environmental health, architecture, sustainability, and housing. The literature search covered studies published from January 2020 to June 2026. To ensure currency of the evidence, the synthesis placed greater emphasis on studies published between January 2023 and June 2026. Studies published between 2020 and 2022 were nevertheless retained where they provided directly relevant empirical evidence, foundational explanations or important contextual findings.

The search technique was designed based on four fundamental concepts: environmental health equality, socio-spatial design, warm-humid built environments, and environmental health outcomes. Keywords related to these concepts included warm-humid climate, environmental health equity, environmental justice, indoor environmental quality, socio-spatial design, urban design, neighbourhood planning, built environment, tropical climate, thermal comfort, ventilation, urban heat, green infrastructure, and public health. Boolean operators (AND, OR) were employed to merge search terms and enhance precision in retrieval. The comprehensiveness of the search was improved by both backward and forward citation searches on pivotal studies identified during the review process (Page et al., 2021; Rethlefsen et al., 2021).

2.3 Criteria for Eligibility

The eligibility criteria were established before screening to ensure that the included studies addressed the review objectives. Studies were included if they: (1) examined environmental health outcomes associated with the built environment; (2) addressed environmental health equity, vulnerability or environmental justice; (3) focused on warm-humid, tropical, hot-humid or comparable climatic environments; and (4) were published as peer-reviewed journal articles, conference papers or reputable institutional reports between January 2020 and June 2026. Although the synthesis emphasized recent evidence published from January 2023 onwards, studies published between 2020 and 2022 were retained where they made substantial empirical, conceptual or contextual contributions to the review questions. Duplicate records, editorials, commentaries, book reviews, studies without clear methodologies and publications without direct built-environment, health, wellbeing, vulnerability or equity implications were excluded.

2.4 Screening Process and Study Selection

All identified records were imported into Zotero for reference management and duplicate removal. The remaining records were screened in two stages. Titles and abstracts were assessed against the predefined eligibility criteria. Second, the full texts of potentially relevant reports were examined to determine their final eligibility. Reasons for excluding reports at the full-text stage were recorded. The identification, screening, eligibility and inclusion process was documented using a PRISMA 2020 flow diagram, presented in Figure 1.

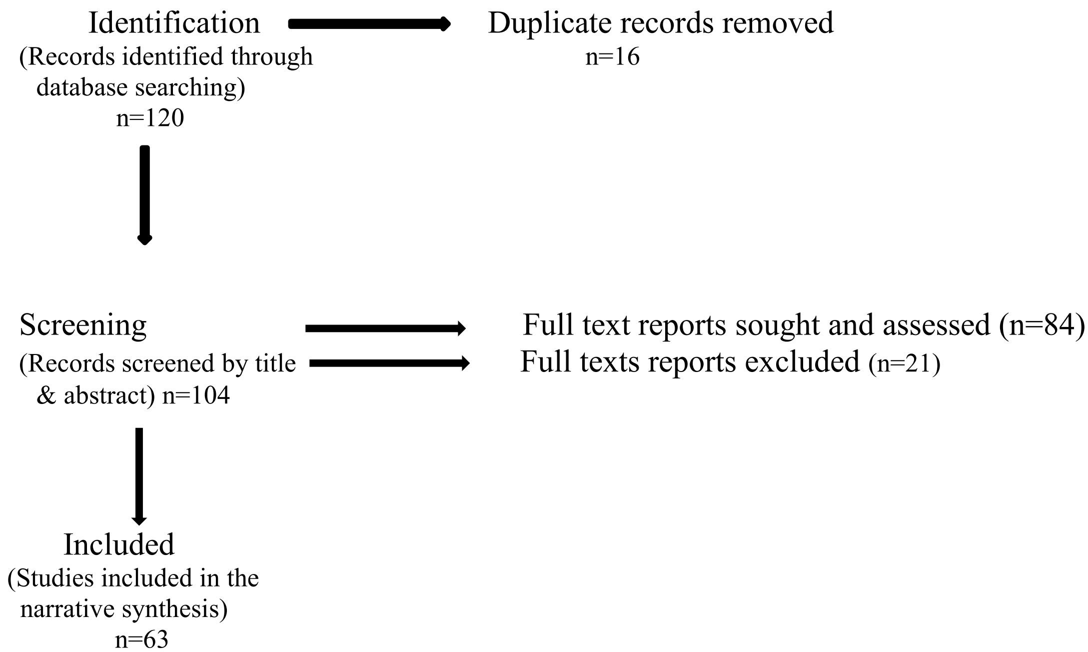

Fig. 1: PRISMA 2020 flow diagram for study identification, screening and inclusion

Adapted from Page et al. (2021) using present review results

2.5 Quality Appraisal

The methodological quality of the included studies was assessed using the relevant Joanna Briggs Institute critical-appraisal criteria. Appraisal focused on the clarity of the study objectives, appropriateness of the research design, transparency of the sampling and data-collection procedures, suitability of the analytical methods and relevance of the evidence to environmental health equity in warm-humid built environments. The appraisal informed the interpretation of the findings rather than functioning solely as an exclusion criterion.

2.6 Data Extraction

A structured matrix was used to extract the author, publication year, study location, climatic context, research objective, methodology, socio-spatial strategy, population group, environmental health outcome and key findings from each included study. The extracted information facilitated comparison across studies and supported the identification of recurring themes, evidence gaps and emerging patterns.

3. RESULTS

3.1 Study Selection and Evidence

Of the 120 records initially identified, 63 studies met the eligibility criteria and were included in the narrative thematic synthesis, as presented in Figure 1. The evidence base covered publications from January 2020 to June 2026, with the synthesis placing particular emphasis on studies published from 2023 onwards to reflect current developments in the field. The evidence comprised global and multi-country reviews as well as studies from Nigeria, Ghana, Mozambique, South Africa and other Sub-Saharan African settings. Major areas of investigation included thermal comfort, passive design, indoor air quality, occupant wellbeing, green infrastructure and settlement upgrading. The geographical and thematic distribution of the studies supported the review's focus on environmental health equity in African warm-humid environments (Ifebi et al., 2020; Munonye et al., 2023a, 2023b; Obi-George et al., 2024; Obi-George et al., 2025; Sani et al., 2025; Uzuegbunam et al., 2025).

3.2 Socio-Spatial Design Strategies for Environmental Health Equity

The first research question examined socio-spatial design strategies that are effective for improving environmental health equity in warm-humid built environments. The synthesis shows that the most frequently reported strategies were passive ventilation, climate-responsive orientation, shading, improved window typology, moisture-sensitive housing design, green-blue infrastructure, informal settlement upgrading, and inclusive neighbourhood planning.

Passive ventilation and climate-responsive building design emerged as central strategies across the reviewed studies. Studies on hot, humid, and tropical environments showed that orientation, shading, vegetation, building form, reflective materials, natural ventilation, and hybrid ventilation can reduce heat exposure and improve thermal comfort (Al Niyadi & Elnabawi Mahgoub, 2025; Aderinsola et al., 2025; Hu et al., 2023; Pratiwi et al., 2025). In humid climates, the role of humidity was particularly important because thermal discomfort is influenced not only by air temperature but also by moisture, air movement, and ventilation effectiveness (Amaripadath et al., 2023). Nigerian and African evidence further supports this finding. Studies in Enugu, Onitsha, and Ebonyi showed that window typology, floor level, building orientation, headroom, and natural ventilation influence indoor air quality and thermal comfort in offices, educational buildings, and hospital wards (Basil et al., 2024; Basil et al., 2026; Mba et al., 2025; Uzuegbunam et al., 2025).

The review also found that indoor environmental quality and housing design are important socio-spatial pathways for health equity. Studies on residential indoor air quality, social housing, retrofits, and vulnerable occupants showed that ventilation, dampness, mould, material quality, household smoke exposure, and occupant behaviour influence respiratory health and wellbeing (Booker et al., 2025; Hashemi & Dungrani, 2025; Kurmanbekova et al., 2025; Lozinsky et al., 2025). African evidence reinforces this concern, as household smoke exposure and indoor/outdoor particle pollution remain important environmental health risks in African cities and Nigerian households (Safo-Adu et al., 2023; Sani et al., 2025). This indicates that housing quality and indoor environmental conditions are not only technical building issues but also equity concerns, especially where low-income households have limited control over ventilation, materials, energy sources, and maintenance.

Green-blue infrastructure was another major design strategy identified in the review. Studies showed that parks, urban greening, shaded public spaces, and nature-based solutions can reduce heat exposure, support wellbeing, and contribute to climate adaptation (Aznarez et al., 2024; Das, 2025; Nazish et al., 2024; Zarei & Shahab, 2025). However, the evidence also shows that these benefits depend on location, access, quality, and governance. Environmental benefits may become socially uneven especially in locations where green spaces are concentrated in wealthier areas. Studies from South Africa and wider Sub-Saharan Africa suggest that urban green infrastructure must integrate social access, ecological performance, and inclusive planning if it is to contribute meaningfully to environmental justice (Antiri et al., 2025; Pasgaard et al., 2025).

3.3 Environmental Health Outcomes of Socio-Spatial Design Strategies

The second research question examined how socio-spatial design strategies influence health-equity outcomes among vulnerable populations. The synthesis shows that the major outcomes were reduced heat exposure, improved thermal comfort, better indoor air quality, lower respiratory risk, improved access to green space, and enhanced wellbeing. Heat exposure was one of the strongest environmental health concerns across the included studies. Built form, surface materials, shade availability, ventilation corridors, roof exposure, and settlement density were repeatedly linked to heat stress and thermal discomfort (Li et al., 2026; Nazish et al., 2024; Zheng et al., 2026). In informal settlements, heat risk was intensified by poor housing quality, limited infrastructure, overcrowding, and weak access to cooling resources (Correia & Delgado Henriques, 2025; Olufadewa et al., 2025; Shand et al., 2026). These findings show that heat exposure is not distributed evenly. It is shaped by both physical design and social vulnerability.

Indoor air quality and respiratory health also emerged as key outcomes. Studies showed that poor ventilation, dampness, indoor pollutants, household smoke, and inadequate building retrofits can increase health risks, especially among children, older adults, low-income households, and other vulnerable occupants (Booker et al., 2025; Hernández-Martín et al., 2025; Li et al., 2025; Loureiro et al., 2025). Evidence from Nigerian and African settings further demonstrates that indoor air conditions are shaped by season, building form, window design, energy use, and household characteristics (Abai et al., 2025; Basil et al., 2024; Sani et al., 2025; Safo-Adu et al., 2023). This suggests that improving environmental health equity requires attention to everyday indoor spaces, not only outdoor urban conditions.

The review also found that thermal comfort and wellbeing are influenced by the interaction between physical building conditions and user experience. Nigerian studies show that indoor air temperature influences thermal sensation in architecture studios, while thermal comfort affects student perception and performance in studio learning environments (Ifebi et al., 2020; Obi-George et al., 2025). Residential evidence also shows that building material efficiency is linked to occupants' wellbeing, while school-based comfort-temperature studies suggest that children and adults may experience comfort differently in warm-humid settings (Munonye et al., 2023b; Obi-George et al., 2024). These findings are important because they show that environmental health equity is not only about reducing physical exposure. It also involves understanding how different users experience, tolerate, and adapt to their built environments.

3.4 Evidence-Based Strategies Compared with Conventional Design Practice

The third research question compared evidence-based socio-spatial strategies with conventional or standard design practices. The synthesis indicates that conventional approaches often treat environmental performance as a technical matter, while evidence-based socio-spatial strategies connect design decisions with exposure reduction, adaptive capacity, and fairer access to environmental benefits. In conventional building practice, openings may be small, poorly positioned, fixed, or inadequately protected from rain and security concerns. This can restrict airflow, increase humidity, and trap pollutants indoors. Evidence from warm-humid and tropical studies suggests that cross-ventilated layouts, effective window typology, operable openings, high-level windows, and hybrid ventilation provide better health-supportive outcomes (Al Niyadi & Elnabawi Mahgoub, 2025; Basil et al., 2026; Mba et al., 2025; Uzuegbunam et al., 2025). Similarly, buildings with unshaded façades, exposed roofs, and hard-paved surroundings are more likely to experience heat gain and outdoor heat stress. Evidence-based alternatives include shading, orientation, vegetation, roof treatment, reflective materials, and climate-responsive building envelopes (Aderinsola et al., 2025; Hu et al., 2023; Pratiwi et al., 2025; Xi et al., 2025).

The review also shows that energy retrofits, when implemented without indoor air quality safeguards, may create unintended health risks by trapping pollutants or moisture indoors. Health-sensitive retrofits are therefore more appropriate because they combine energy performance with ventilation, moisture control, and occupant wellbeing (Hashemi & Dungrani, 2025; Lozinsky et al., 2025). In urban planning, conventional green-space provision may improve environmental performance but still fail equity if green infrastructure is unevenly distributed or poorly accessible. Evidence-based approaches require public access criteria, community participation, and deliberate targeting of underserved neighbourhoods (Aznarez et al., 2024; Das, 2025; Pasgaard et al., 2025; Zarei & Shahab, 2025).

For informal settlements, conventional responses often focus on clearance, neglect, or isolated infrastructure provision. The evidence suggests that more equitable approaches include incremental upgrading, shaded public routes, ventilation corridors, improved drainage, water access, material improvements, and participatory heat adaptation (Castro, 2026; Correia & Delgado Henriques, 2025; Olufadewa et al., 2025; Shand et al., 2026). These findings indicate that socio-spatial strategies are more effective when they address both environmental exposure and the social conditions that shape vulnerability.

4. DISCUSSION

The findings indicate that technically effective design does not automatically produce equitable environmental-health outcomes. Although building form, ventilation, window typology, materials and indoor temperature can improve comfort, indoor air quality and wellbeing in warm-humid African buildings, their benefits may remain unequal where vulnerable groups have limited access to appropriate housing, infrastructure and adaptive resources (Ifebi et al., 2020; Munonye et al., 2023a, 2023b; Obi-George et al., 2024; Obi-George et al., 2025; Basil et al., 2026; Uzuegbunam et al., 2025). Similarly, green infrastructure, public spaces and settlement upgrading contribute to environmental health equity only when they are accessible and deliberately directed towards underserved populations (Antiri et al., 2025; Olufadewa et al., 2025; Pasgaard et al., 2025; Shand et al., 2026). The broader implication is that socio-spatial interventions should be assessed not only by their environmental performance but also by how fairly they reduce exposure, strengthen adaptive capacity and distribute health benefits. However, differences in the methods, locations and outcome measures of the reviewed studies limited direct comparison of the evidence.

4.1 Proposed Socio-Spatial Environmental Health Equity Framework

Table 1 presents the proposed framework linking socio-spatial design strategies with environmental risks, equity pathways and expected health outcomes.

Table 1: Framework for socio-spatial environmental health equity

Socio-Spatial Strategy	Main Problem Addressed	Pathway of Equity	Expected Health Equity Outcomes
Window design, cross and passive ventilation	Heat, humidity, trapped pollutants	Improves indoor air movement for households and users with limited mechanical cooling	Better thermal comfort and indoor air quality
Orientation, shading, roof treatment, and climate-responsive envelope	Heat gain and solar exposure	Reduces dependence on expensive cooling systems	Lower heat stress and improved comfort
Moisture-sensitive housing design and material improvement	Dampness, mould, and poor indoor conditions	Protects vulnerable occupants in low-quality housing	Reduced respiratory and comfort related risks
Green-blue infrastructure and shaded places	Outdoor heat and limited environmental amenities	Improves access to cooling and restorative public	Better wellbeing and reduced spatial

		spaces	inequality
Informal settlement upgrading and inclusive neighbourhood planning	Overcrowding, poor drainage, weak infrastructure, and heat exposure	Targets areas with higher environmental vulnerability	Improved resilience and healthier settlements

Source: Author's framework developed from study findings

The framework in Table 1 integrates exposure reduction, adaptive capacity and equitable access across building, settlement and neighbourhood scales. This moves the discussion beyond isolated building solutions and provides a broader design-planning approach for warm-humid environments.

5. CONCLUSION

This systematic review examined socio-spatial design strategies for environmental health equity in warm-humid built environments. The findings show that heat exposure, poor ventilation, dampness, indoor air pollution, inadequate housing, and limited green-space access are not only environmental problems. They are also equity problems because vulnerable groups often experience them more severely. The review found that passive ventilation, climate-responsive orientation, shading, improved window typology, moisture-sensitive housing, green-blue infrastructure, shaded public spaces, and informal settlement upgrading can improve environmental health outcomes. These strategies can reduce heat stress, improve indoor air quality, support thermal comfort, and enhance wellbeing. The main contribution of the study is the proposed socio-spatial environmental health equity framework. The framework shows how design and planning strategies can reduce exposure, improve adaptive capacity, and expand access to environmental benefits. The study concludes that warm-humid built environments require design approaches that are not only climate-responsive but also socially fair, health-supportive, and inclusive.

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