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# A systematic review of the impact of therapeutic biophilic design on health and wellbeing of patients and care providers in healthcare services settings

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Hospitals often evoke negative feelings due to their antiseptic architecture and personal memories. Biophilic hospital design can reduce stress and enhance health and wellness for patients and caregivers, creating sustainable therapeutic environments. This research paper explores these environments and presents case studies demonstrating the positive outcomes of biophilic design on health and wellbeing. This paper systematically reviews and critically assesses literature using secondary data from peer-reviewed journals and reliable sources on sustainable design from 2010–2023. The results show that biophilic design in hospitals reduces hospitalization time, patient mortality, pain levels, and stress for healthcare providers. It alleviates anxiety, improves experiences for patients, families, and staff, reduces patient harm, and supports faster recovery. Overall, it positively influences the psychological and physiological responses of patients and staff. Future research should analyze the impact of individual biophilic design elements separately and explore implementation challenges. It should also quantify benefits such as reduced staff absenteeism and increased productivity. This study fills the gap of the limitation of holistic studies on biophilic design's impact on patient care and service delivery in hospital settings.

## KEYWORDS

biophilic design, healthcare service setting, sustainable therapeutic environment, patients, care providers sustainable design, architecture, interior design, health

## 1 Introduction

### 1.1 Healthcare services settings

Healthcare services are delivered in individual clients' homes or offices (Christensen and Fagan, 2018). Any location where medical services, such as physical, dental, or mental healthcare, are provided is referred to as a healthcare environment. It includes, but is not limited to any licensed healthcare facility such as hospitals, ambulatory surgical centers, birthing centers, special inpatient care facilities, long-term acute care facilities, inpatient rehabilitation facilities, inpatient hospice facilities, nursing facilities, assisted living facilities, and residential facilities, behavioral health residential facilities, home healthcare, hospice, pharmacies, in-home care, vehicles or temporary sites where healthcare is delivered or is related to the provision of healthcare (for example, mobile clinics, ambulances, non-

emergency medical transport vehicles (NEMT), secure transportation, and street based medicine), outpatient facilities, such as dialysis centers, healthcare provider offices, dental offices, behavioral healthcare offices, urgent care centers, counseling offices, school-based health centers, offices that provide complementary and alternative medicine such as acupuncture, homeopathy, naturopathy, chiropractic and osteopathic medicine, and other specialty centers (Law Insider, 2023). Therefore, healthcare services settings encompass a wide range of services and locations where medical care is delivered (Christensen and Fagan, 2018).

Architecture denotes the strategy, procedure, pattern, and final healthcare services setting. This is so that architecture may communicate the story of the architect who designed it as well as the person who commissioned it, in addition to revealing the character or style of a particular structure (Janetius, 2020). The National Council for Interior Design Qualification (NCIDQ) defines interior design as the art and science of comprehending human behavior in order to create practical spaces within a structure using innovative and technical solutions. These solutions are used inside a building to create a built-in environment that is useful, improves the tenants' quality of life and culture, and is also visually pleasing (El-Zeiny, 2012). In the following sections, the concept of designing sustainable therapeutic environments both internally and externally will be explored further.

## 1.2 Sustainable therapeutic environment in healthcare services settings

Environmental psychology (the psycho-social impacts of the environment), psychoneuroimmunology (the effects of the environment on the immune system), and neuroscience (how the brain perceives architecture) are fields that have played a role in shaping therapeutic environment theory. Patients in healthcare settings often feel anxious and concerned about their safety, health, and isolation from usual social interactions. The complex, expansive nature of typical hospitals only adds to this stress. Such stress can weaken a person's mental and spiritual strength and suppress their immune system, thereby hindering recovery and healing. Healthcare facilities are designed to not only support advanced medical technologies and patient safety but also to create a therapeutic environment that is psycho-socially supportive for patients, families, and caregivers. The physical environment in which patients receive care impacts their outcomes, satisfaction, safety, staff productivity, and overall organizational performance, both positively and negatively. No environment is neutral (Smith and Watkins, 2016). The implementation of therapeutic design (TD) in architecture, space, and landscape contributes to the United Nations Sustainable Development Goals (SDGs) and integrates digital technologies like Building Information Modeling (BIM) into the design process, potentially addressing the chronic housing shortage. The built environment and art therapy (AT) are linked to sustainable development and closely associated with health and wellbeing (Liu, Yang and Osmani, 2021). Even in healthcare facility design, for maximum efficiency, a sustainable therapeutic environment should incorporate features that enable patient control and effective staff

service delivery. The concept of a sustainable therapeutic environment emphasizes the importance of factors such as daylighting, indoor air quality, noise, and thermal comfort in designing a supportive service (Akpan-Idiok and Ackley, 2017).

The sum of the internal and external circumstances is conceptualized as a sustainable therapeutic environment and impacts that a person may experience while they are unwell. These represent the observable physical elements in the current state of the architecture, furniture, lighting, ventilation, interior design, and psychological on the patient, forces were applied. Compared to the former, less palpable "feeling tones" brought about by the traditions, conventions, interpersonal interactions, cultural values, and prevalent ideas for the proper behaviors and duties of the healthcare professional and patient. A therapeutic setting is comparable to some qualities of an environment's architecture helps the sufferer recuperate. An environment that supports clinical excellence in the care of the physical body, the psycho-social and spiritual needs of the patient, family, and staff, and produces measurable positive effects on patient clinical outcomes and staff effectiveness is referred to as a sustainable therapeutic environment. Research on people's experiences and emotional reactions to their healthcare has provided evidence in support of this. The phrase "therapeutic environment" refers to a supportive setting (Akpan-Idiok and Ackley, 2017). The need to associate with other kinds of life is known as biophilia, and it is one of the key words in the sustainable therapeutic environment.

## 1.3 Factors of sustainable therapeutic environment in healthcare services settings

Patients in healthcare seek therapeutic environments that provide optimal medical care and facilitate quick recovery. The interior design of these environments is crucial for creating a comfortable atmosphere that reduces patient isolation, distracts from illness, promotes positive emotions, and aids in speedy recovery. Elements such as a connection to nature, enhanced social supports, and stimulating interior design should be incorporated into therapeutic environments to achieve these benefits. These factors positively impact healthcare providers and contribute to the physical and psychological wellbeing and overall welfare of patients. Incorporating these elements into the indoor design of healthcare settings addresses patients' needs for comfort and relaxation, creating a warm and inviting atmosphere. Satisfying these therapeutic environmental factors at the physical, psychological, and social levels benefits both patients and healthcare workers, accelerating patient recovery and improving staff performance and productivity (Attia, 2021). Many factors contribute to attaining the best experience in a therapeutic environment. These factors include health, wellness, architecture, interior design, healthcare setting, and sustainable therapeutic environment. Health is comprised of three components physical, mental and social health. Architecture is the art and science of planning, creating, and constructing a place, a structure, and its surroundings with aesthetic elements to achieve a certain goal that excites the audience. Sustainable therapeutic environment is establishing a human-friendly, well-balanced atmosphere, it helps patients feel more secure, at peace, and less stressed while also

enhancing their capacity for self-healing. It should use natural lighting of the highest quality, soothing colors, therapeutic sounds like music, bird songs, and water sounds, good ventilation, reduce the level of noise, offer interactive arts, and provide views of indoor greenery and a natural landscape, depending on the needs of each patient to produce these effects (Attia, 2021). A healthy organism is capable of “allostasis” in the physical realm, which is the maintenance of physiological homeostasis under variable conditions.

## 1.4 Importance of sustainable therapeutic environment

A healthy organism can develop a defensive reaction in the face of physiological stress, lowering the risk of injury and restoring a (adapted) balance. The harm (or “allostatic load”) persists if this physiological coping mechanism fails, which might eventually lead to sickness. In terms of the mental realm, (Antonovsky, A., (1993) identifies the “sense of coherence” as a component that helps people successfully manage, recover from intense psychological stress, and fend off post-traumatic stress disorders. The subjective abilities that make a challenging situation more understandable, manageable, and meaningful are included in the feeling of coherence. Strengthened adaptability and self-management skills frequently lead to an improvement in subjective wellbeing and can lead to a beneficial interaction between the mind and body. People’s capacity to fulfill their potential and obligations, their ability to live independently despite a medical condition, and their capacity to engage in social activities like work are just a few of the dimensions of health that can be identified in the social domain. In this area, health may be viewed as a dynamic balance between possibilities and constraints that changes over time and is influenced by environmental and social factors. People who are able to cope with their condition can work, engage in social activities, and feel well despite their limits (Huber, et al., 2011). Having good feelings like contentment and satisfaction, as well as realizing one’s potential, having some degree of control over one’s life, understanding one’s purpose, and having satisfied interpersonal interactions, are all considered to be components of wellness. It is a viable setting that promotes the growth and prosperity of a person or a population. This idea is significant because it goes beyond the lack of mental health to encompass the ability of an individual to fulfill their full potential, cope with everyday challenges, work professionally and fruitfully, and give back to their community. It also entails the realization that everything is going well because wellbeing is linked to success on the professional, personal, and interpersonal levels (Ruggeri, Garcia-Garzon, Maguire, Matz and Huppert, 2020).

## 1.5 Biophilic design in healthcare services settings

To obtain the optimum health results, biophilic design is the process of basing decisions about the built environment on sound judgment or reliable research generated from either an appetite for nature or quantifiable biological reactions, respectively. A pattern in nature that causes a favorable biological reaction in people is

described as a “biophilic design pattern”. intended to give information, direction, and assistance throughout the design process for the built environment, which is made up of locations and areas that humans have created or altered, with a focus on structures, parks, streetscapes, and other areas that serve as the backdrop for human activities (Ryan and Browning, 2020). Biophilic impact guidelines, biophilic design tactics, design considerations, and a design culture that favors biophilia over biophobia are all part of the healing process via biophilic design (Ghazaly, Badokhon, Alyamani and Alnumani, 2022).

It is essential to clearly define the various terms mentioned starting with ‘biophilia’ which is the concept that humans have an innate connection to nature and living systems. It is based on the idea that people have a natural affinity for life and life-like processes, which can significantly impact their wellbeing. The term was popularized by biologist (Wilson, E. O., 1984), where he proposed that this connection to nature is deeply rooted in our biology and psychology. In practical terms, biophilia often manifests in design and architecture by incorporating natural elements into spaces, such as natural light, plants, and organic shapes, to enhance human health, reduce stress, and improve overall wellbeing. This concept is increasingly applied in various fields, including healthcare, where biophilic design aims to create environments that promote healing and comfort for patients and caregivers. Whereas the term ‘biophobia’ refer to the fear or aversion to natural elements and living systems. It is the opposite of biophilia and can manifest as discomfort or anxiety in the presence of nature, which might include aversions to animals, plants, or natural environments. It has been used to describe a range of responses, from mild discomfort to intense fear or avoidance behaviors. This concept can be important in various contexts, including design and therapy, where understanding an individual’s or group’s biophobic tendencies can help in creating environments that reduce stress and enhance comfort (Nisbet, E. K., Zelenski, J. M., and Murphy, S. A., 2009). Lastly, Biophilic design is an approach to architecture and interior design that integrates natural elements into built environments to enhance human wellbeing and connectivity with nature. This design philosophy is based on the concept of biophilia, which posits that humans have an inherent affinity for nature (Haverkamp, R., and Kusch, H., 2019).

Biophilic design integrates natural elements into built environments to promote human health and wellbeing. In healthcare settings, it aims to enhance the healing process and improve the overall environment for both patients and care providers. This comparative analysis reviews and contrasts key findings from various studies on the impact of biophilic design in hospitals. Amongst the key concepts are:

- 1) Biophilic Design Elements: Inclusion of natural light, plants, natural materials, views of nature, and water features.
- 2) Health Outcomes: Psychological and physiological effects on patients, such as reduced stress, faster recovery times, and improved mood.
- 3) Wellbeing of Care Providers: Reduced burnout, enhanced job satisfaction, and improved overall mental health of hospital staff.

Table 1, outlines the significant findings, highlights discrepancies, and practical challenges in implementing biophilic design in healthcare settings.

TABLE 1 Preliminary comparative analysis.

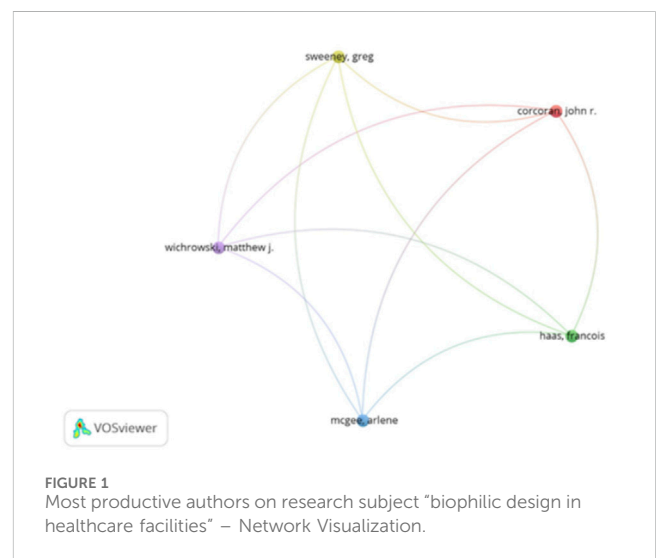
| Concept                             | Academic study                       | Finding  | Comparison   |
|-------------------------------------|--------------------------------------|--|--|
| Psychological Benefits for Patients | Study A (Ulrich, 1984)               | Found that patients with views of nature had shorter postoperative stays and required fewer pain medications                                 | Both studies highlight significant psychological benefits, with Ulrich focusing on postoperative recovery metrics and Salingeros on general stress and anxiety reduction                                       |
|                                     | Study B (Salingeros, 2015)           | Emphasized the reduction in stress and anxiety through exposure to natural elements within the hospital environment                          |  |
| Physiological Benefits for Patients | Study C (Park and Mattson, 2009)     | Demonstrated that patients in rooms with plants showed lower blood pressure and heart rates compared to those in rooms without plants        | Both studies underline the physiological improvements, with Park and Mattson emphasizing cardiovascular health and Van den Berg focusing on sleep quality  |
|                                     | Study D (Berg, Joye and Vries, 2019) | Found that the presence of natural light in patient rooms contributed to improved sleep patterns and circadian rhythm regulation             |  |
| Wellbeing of Care Providers         | Study E (McCoy and Evans, 2002)      | Indicated that care providers in biophilic environments experienced less job stress and higher job satisfaction                              | Both studies consistently show positive impacts on the wellbeing of care providers, highlighting reduced stress and burnout, with McCoy and Evans also noting increased job satisfaction                       |
|                                     | Study F (Ulrich, et al., 1991)       | Reported reduced instances of burnout and improved mental health among staff working in biophilic-designed hospitals                         |  |
| Design Implementation Challenges    | Study G (Joseph, 2006)               | Discussed the practical challenges of integrating biophilic design in existing hospital infrastructure, including cost and space constraints | Both studies acknowledge significant challenges in implementing biophilic design, with Joseph focusing on physical and financial barriers, while Hartig emphasizes administrative and institutional resistance |
|                                     | Study H (Hartig, et al., 2010)       | Explored the resistance from hospital administration and the necessity of evidence-based design to gain support                              |  |

There is a general agreement among studies that biophilic design positively impacts both patients and care providers by improving psychological and physiological health outcomes. While the variations in the extent of measured benefits and specific biophilic elements used. Certain studies emphasize direct contact with nature (plants and gardens), while others focus on indirect elements (views and light). Practical implementation remains a consistent issue, highlighting the need for strategic planning and evidence-based approaches to overcome barriers.

Even though there is a growing interest within the scientific community, there is still a clear gap in the literature that connects the effects of systematic therapeutic environment on health and wellbeing in healthcare settings. This paper will attempt to fill that gap by determining the impact of therapeutic environments on health and wellbeing of patients and caregivers in healthcare settings through a systematic literature review. Furthermore, this study provides an up-to-date compilation of benchmark information for successful implementations (case studies) across the globe to further confirm whether the sort of impact revealed through literature is legitimate. The main objectives of this paper are to conduct a Systematic Literature review that will 1) Explore what sustainable therapeutic environment parameters are in healthcare settings 2) Outline the sustainable therapeutic environment initiatives that have been implemented to enhance health and wellbeing 3) Identify the correlation between sustainable therapeutic environment on the health and wellbeing of caregivers and patients.

## 2 Methodology

Using the systematic database searching techniques the results of a comprehensive examination and critical assessment of the



relevant literature was summarized. English language articles in published, peer-reviewed journals and reliable industry sources were included for this systematic review. Given its high regard in the academic and research communities for its comprehensive coverage of peer-reviewed resources and advanced search capabilities, Scopus Database was used in addition to reliable industry publications referred to as grey paper to understand the evolution of this concept over the past 13 years (2010–2023) when the practical application has become more prominent. The analysis was conducted on 61 peer reviewed journal articles, books/book chapters, conference papers, reports/guidelines, websites/online industry articles, and systematic reviews.

TABLE 2 Search string in Scopus database.

| No. | Search string  | Justification  |
|-----|--|--|
| 01  | "biophilic" AND "design" AND "healing" AND "environments"        | Capture general studies on biophilic design in healing environments                |
| 02  | "biophilia" AND "design" AND "healing" AND "environments"        | Include variations of the term biophilic   |
| 03  | "biophilia" AND "design" AND "in" AND "healthcare"               | Narrow the focus to healthcare settings  |
| 04  | "biophilic" AND "design" AND "in" AND "healthcare" AND "setting" | Ensure comprehensive coverage similar to the previous string with slight variation |
| 05  | "biophilic" AND "design" AND "healthcare"                        | Focus directly on biophilic design in healthcare                                   |
| 06  | "biophilic" AND "design" AND "hospital"                          | Specifically target hospital environments  |
| 07  | "biophilic" AND "design" AND "healthcare" AND "hospital"         | Capture studies mentioning both healthcare and hospitals explicitly                |
| 08  | "biophilic" AND "design" AND "patient" AND "care"                | Focus on patient care aspects  |
| 09  | "biophilic" AND "design" AND "staff"                             | Include the impact on healthcare staff   |
| 10  | "biophilic" AND "design" AND "care" AND "providers"              | Cover all types of care providers  |
| 11  | "biophilic" AND "design" AND "workers"                           | Broaden the scope to all healthcare workers  |
| 12  | "biophilic" AND "design" AND "enhanced" AND "care"               | Capture studies focusing on enhanced care outcomes                                 |
| 13  | "biophilia" AND "design" AND "enhanced" AND "care"               | Include the term biophilia in similar studies                                      |
| 14  | "biophilia" AND "design" AND "healthcare"                        | Conduct a general search for biophilia in healthcare                               |
| 15  | "biophilia" AND "design" AND "hospital"                          | Target hospital environments specifically  |
| 16  | "biophilia" AND "design" AND "healthcare" AND "hospital"         | Capture comprehensive studies involving both terms                                 |
| 17  | "biophilia" AND "design" AND "patient" AND "care"                | Focus on patient outcomes  |
| 18  | "biophilia" AND "design" AND "staff"                             | Include staff outcomes   |
| 19  | "biophilia" AND "design" AND "care" AND "providers"              | Cover all care providers   |
| 20  | "biophilia" AND "design" AND "workers"                           | Broaden to all healthcare workers  |
| 21  | "biophilia" AND "design" AND "patient"                           | Focus on patient-related studies   |
| 22  | "biophilic" AND "design" AND "patient"                           | Maintain a similar focus on patient outcomes                                       |
| 23  | "biophilic" AND "design" AND "nurse"                             | Target nursing staff   |
| 24  | "biophilia" AND "design" AND "nurse"                             | Include the term biophilia   |
| 25  | "biophilic" AND "design" AND "doctor"                            | Target doctors   |
| 26  | "biophilic" AND "design" AND "physician"                         | Include another term for doctors to ensure a comprehensive search                  |
| 27  | "impact" AND "biophilic" AND "design"                            | Capture studies on the impact of biophilic design                                  |
| 28  | "therapeutic" AND "design"                                       | Include studies focusing on therapeutic design elements                            |
| 29  | "advantage" AND "biophilic" AND "design"                         | Find studies highlighting the advantages of biophilic design                       |
| 30  | "implication" AND "biophilic" AND "design"                       | Explore the implications of implementing biophilic design                          |

For the bibliographic analysis, the search strategy focused on selecting relevant keywords such as "biophilic designs in healthcare" and was restricted to publications from 2010 to 2023 to ensure the inclusion of recent and relevant research. The VOSviewer software was employed to create bibliometric networks, leveraging data from the Scopus database. This approach facilitated the generation of various bibliometric maps that visually represent the relationships and trends within the field. The advanced search results from Scopus were exported to VOSviewer to construct a network visualization, as shown in Figure 1. This visualization was used to analyze the connections among publications and authors, providing insights

into the development and linkage of research on biophilic designs in healthcare.

In the network visualization illustrated in Figure 1, there is limited publications that specifically address biophilic design in healthcare facilities let alone the positive impact of its application on caregivers and patients that are exposed to those biophilic designs. The figure represents the name of the main authors that addressed this concept, whereby from the size of the labels and circles the weight of each is equal. The links between those circles indicates that the relatedness of the journals in terms of co-citation links. A VOSViewer mapping was then done using "biophilic design



TABLE 3 Systematic review analysis summary by type.

| References type          | Count | Percentage (%) |
|--------------------------|-------|----------------|
| Journal Articles         | 37    | 60             |
| Books                    | 3     | 5              |
| Book Chapters            | 4     | 6              |
| Conference Papers        | 1     | 2              |
| Reports/Guidelines       | 3     | 5              |
| Websites/Online Articles | 12    | 19             |
| Systematic Reviews       | 1     | 3              |
| TOTAL                    | 61    | 100            |

in healthcare facilities” as the keyword to know the top authors in this field. This dictated that the expansion of the radius of keyword usage to ensure that the desired content to answer our research question is attained as demonstrated in Table 2 Search terms included the following search string combinations.

Moreover, a systematic review and critical assessment of literature on biophilic design in healthcare settings and its implications on patients and caregivers for a period of 13 years was also performed. The academic literature, published in the Scopus database, between 2010 and 2023, in English, as well as the grey literature which comprised of reliable news articles, industry magazines, web sites that are renowned and trusted in the healthcare design industry as demonstrated in Tables 3, 4. Moreover, we summarized and reported the results according to the steps advised by Transfield et al. (2003) and the “preferred reporting items for systematic reviews and meta-analyses” (PRISMA) guidelines. For the selection process, empirical studies, academic book sections, literature reviews and conference proceedings were included during the search process. Papers published in English, between 2010 and 2023, with clear research questions and objectives on biophilic design in healthcare and their impact on improving patient care and service delivery were selected. On the other hand, conceptual papers, editorials, publications in languages other than English, publications prior to 2020, as well as industrial sectors other than healthcare were excluded from the study. Given the topic is a key industry trend topic, the search was expanded to include reliable industry sources and official newspapers which capture the insights of subject matter experts and yielded supplementary sources from reliable sources and industry insights such as HCO news, Whole Building Design Guide, Healthcare facilities today, Centres for Disease Control and Prevention, HOK, ETKHO Hospital Engineering, Healthcare Radius, Law Insider and Hospital Health.

## 3 Results and discussion

### 3.1 Literature search outcomes

The literature search identifies that the use of Biophilic Design Parameters “Patterns”, as detailed in Table 5, is justified by their grounding in established research and their relevance to sustainable

therapeutic environments. Derived from the work of (Tekin, Corcoran and Gutiérrez, 2022), these parameters offer a consistent framework for evaluating and comparing various therapeutic environment efforts. This approach ensures that the case studies studied align with proven patterns that enhance patient wellbeing, providing an evidence-based method for analyzing the impact of biophilic design on health and wellness.

The outcome of the journal searches yielded 379 sources that were analyzed further as demonstrated in the next section. Information from all of the 61 references was compiled in soft copy folder and independently reviewed, followed by a selection of a final list of papers to be analyzed. Article topics and content were examined and included based on the criteria for inclusion and exclusion of material to eliminate papers whose research questions were not fully aligned with the scope of this review. As a result, 61 out of which 38 relevant journals published within 2010 and 2023 were selected for this study. In addition, a total of 12 relevant supplementary sources were included to the search and are shown in Figure 2.

Numerous studies conducted in a variety of contexts, including healthcare facilities, workplaces, children’s spaces, community spaces confirmed the beneficial impacts of biophilic design on human health and performance. When applied to healthcare buildings, the discussion of biophilic design concepts is particularly fascinating. This is attributable not just to the high incidence of critical and stressful situations for patients, their families, and medical personnel in hospitals, but also to the fact that the city and the hospital are two distinct but related systems that the same people frequent and utilize. Despite the humanization of spaces intended for a wider hospitality and the process of interpenetration with the city, the hospital remains a place that is not easily permeable to external culture. It is still a separate world in which the patient is unable to fully comprehend the organizational rules. In addition to the more important economic and social aspects, it is true that humanization interventions have restored the importance of beauty and the connection between people and environment in the hospital’s architecture. Beauty is best understood as an ethical means of enabling the person, as a transient patient at the hospital, to accept the set of space-time regulations governing it and to be in an emotional state that supports healing and care (Totaforti, 2018).

Table 6 provides a clear summary for our systematic review by analyzing 61 sources, in terms of key findings, methodology, sample size, potential biases, and validity. This is to ensure the robustness and reliability of the conclusions drawn from the systematic review.

### 3.2 Challenges and opportunities from a Patient’s perspective

The growth of a larger sense of trust and the activation of a positive feedback to the information and the stimulations coming from outside are both facilitated by a space that is viewed as dialogic, friendly, intelligible, visually pleasing, and calming. The inability to regulate the environment, particularly regarding the physical and organizational spaces and timings of the place of care, is a common source of stress for patients in therapeutic situations. Other stressors include a lack of privacy, the presence of strange, frequently

TABLE 4 Systematic review analysis by type.

| References                                     | Type            |
|--|-----------------|
| Akpan-Idiok and Ackley (2017)                  | Journal Article |
| Antonovsky, A. (1993)                          | Journal Article |
| Attia, D. I. (2021), (July)                    | Journal Article |
| Blakemore, A. (2017)                           | Journal Article |
| Brambilla, A., et al. (2023)                   | Journal Article |
| Brambilla, A., et al. (2023)                   | Journal Article |
| Brand, J. L., and Augustin, S. (2021)          | Journal Article |
| Din, S. K.-J., et al. (2023)                   | Journal Article |
| Ebaid, M. A. (2023), June 30                   | Journal Article |
| El Messeidy, R. (2019), September              | Journal Article |
| Fudickar, A., et al. (2022)                    | Journal Article |
| Ghazaly, M., et al. (2022)                     | Journal Article |
| Gray, T., and Birrell, C. (2014)               | Journal Article |
| Hartig, T., et al. (2010), October             | Journal Article |
| Haverkamp, R., and Kusch, H. (2019)            | Journal Article |
| Huber, M., et al. (2011), July 26              | Journal Article |
| ITO, H., et al. (2022), April                  | Journal Article |
| Lavdas, A. A. (2013)                           | Journal Article |
| Lei, Q., et al. (2022)                         | Journal Article |
| Liu, Z., et al. (2021)                         | Journal Article |
| March (1991)                                   | Journal Article |
| McCoy, J. M., and Evans, G. W. (2002)          | Journal Article |
| El Messeidy, R. (2019), September              | Journal Article |
| Muhamad, J., et al. (2022)                     | Journal Article |
| Nisbet, E. K., et al. (2009)                   | Journal Article |
| Norouziانpour, H. (2020)                       | Journal Article |
| Park, S. H., and Mattson, R. H. (2009)         | Journal Article |
| Ruggeri, K., et al. (2020)                     | Journal Article |
| Russo, A., and Andreucci, M. B. (2023)         | Journal Article |
| Shen, J., et al. (2020)                        | Journal Article |
| Tekin, B. H., and Gutiérrez, R. U. (2023)      | Journal Article |
| Tekin, B. H., et al. (2022), August 22         | Journal Article |
| Tekin, B. H., et al. (2023)                    | Journal Article |
| Tota-forti, S. (2018)                          | Journal Article |
| Ulrich, R. S. (1984), April 27                 | Journal Article |
| Ulrich, R. S., et al. (1991), September        | Journal Article |
| Zhao, Y., et al. (2022)                        | Journal Article |
| Berg, A. E., Joye, Y., and Vries, S. d. (2019) | Book Chapter    |

(Continued in next column)

TABLE 4 (Continued) Systematic review analysis by type.

| References  | Type                   |
|---|------------------------|
| Janetius, S. T. (2020), April                         | Book Chapter           |
| Ryan, C. O., and Browning, W. D. (2020), September 23 | Book Chapter           |
| Showkat, H., and Parveen, N. (2017)                   | Book Chapter           |
| Salingaros, N. A. (2015)                              | Book                   |
| Terrapin Bright Green LLC. (2014)                     | Book                   |
| Wilson, E. O. (1984)                                  | Book                   |
| El-Zeiny, R. M. (2012)                                | Conference Paper       |
| Christensen, B. E., and Fagan, R. P. (2018)           | Report/Guideline       |
| Dubai Health Facility. (2023)                         | Report/Guideline       |
| Joseph, A. (2006), July                               | Report/Guideline       |
| Page et al. (2021a)                                   | Systematic Review      |
| Becky Mollenkamp. (2023)                              | Website/Online Article |
| Design Curial. (2019), (February 8)                   | Website/Online Article |
| ETKHO Hospital Engineering. (2023), (October 10)      | Website/Online Article |
| Healthcare Radius. (2021, May 3)                      | Website/Online Article |
| HOK. (2023, October 10)                               | Website/Online Article |
| Interite Healthcare Interiors. (2019, January 29)     | Website/Online Article |
| Journal of Biophilic Design. (2012, July 12)          | Website/Online Article |
| Kaushik, M. (2023, May 8)                             | Website/Online Article |
| Law Insider (2023)                                    | Website/Online Article |
| Phillips, J. (2023)                                   | Website/Online Article |
| Roxanne Squires. (2023, October 10)                   | Website/Online Article |
| Smith, R., and Watkins, N. (2016), (September 22)     | Website/Online Article |

unsettling, or potentially anxiety-inducing sounds and noises, uncomfortable artificial lighting, and strong environmental smells that are frequently familiar due to their association in most people’s lives with illness. Only recently has design begun to take the perspective of the patient, taking into account not only their physical needs but also their social and psychological ones. This has led to interventions aimed at improving the physical, sensory, and psychological comfort, improving wayfinding systems, and enhancing the clarity of the meanings communicated by space design (Totaforti, 2018).

With varying effects depending on the various levels of treatment (diagnosis, therapy, recovery), the disease in question,

TABLE 5 Biophilic design groups and parameters “parameters”.

| Biophilic design groups       | Biophilic design parameters 'patterns'        |
|-------------------------------|---|
| Direct Experience of Nature   | • Light                                       |
|                               | • Air   |
|                               | • Water                                       |
|                               | • Plants                                      |
|                               | • Animals                                     |
|                               | • Weather                                     |
|                               | • Natural Landscape and Ecosystems            |
|                               | • Fire  |
| Indirect Experience of Nature | • Images of nature                            |
|                               | • Natural Materials                           |
|                               | • Natural Colors                              |
|                               | • Simulating natural light and air            |
|                               | • Naturalistic shapes and forms               |
|                               | • Evoking nature                              |
|                               | • Information richness                        |
|                               | • Age, change, and the patina of time         |
|                               | • Natural geometries                          |
|                               | • Biomimicry                                  |
| Experience of Space and Place | • Prospect and refuge                         |
|                               | • Organized complexity                        |
|                               | • Integration of parts to wholes              |
|                               | • Transitional spaces                         |
|                               | • Mobility and wayfinding                     |
|                               | • Cultural and ecological attachment to place |
| Nature in the Space           | • Visual Connection with nature               |
|                               | • Non-Visual connection with nature           |
|                               | • Non-rhythmic sensory stimuli                |
|                               | • Thermal and airflow variability             |
|                               | • Presence of water                           |
|                               | • Dynamic and diffuse light                   |
|                               | • Connection with natural systems             |
| Natural Analogues             | • Biomorphic forms and patterns               |
|                               | • Material connection with nature             |
|                               | • Complexity and order                        |
| Nature of the Space           | • Prospect                                    |
|                               | • Refuge                                      |
|                               | • Mystery                                     |
|                               | • Risk/Peril                                  |

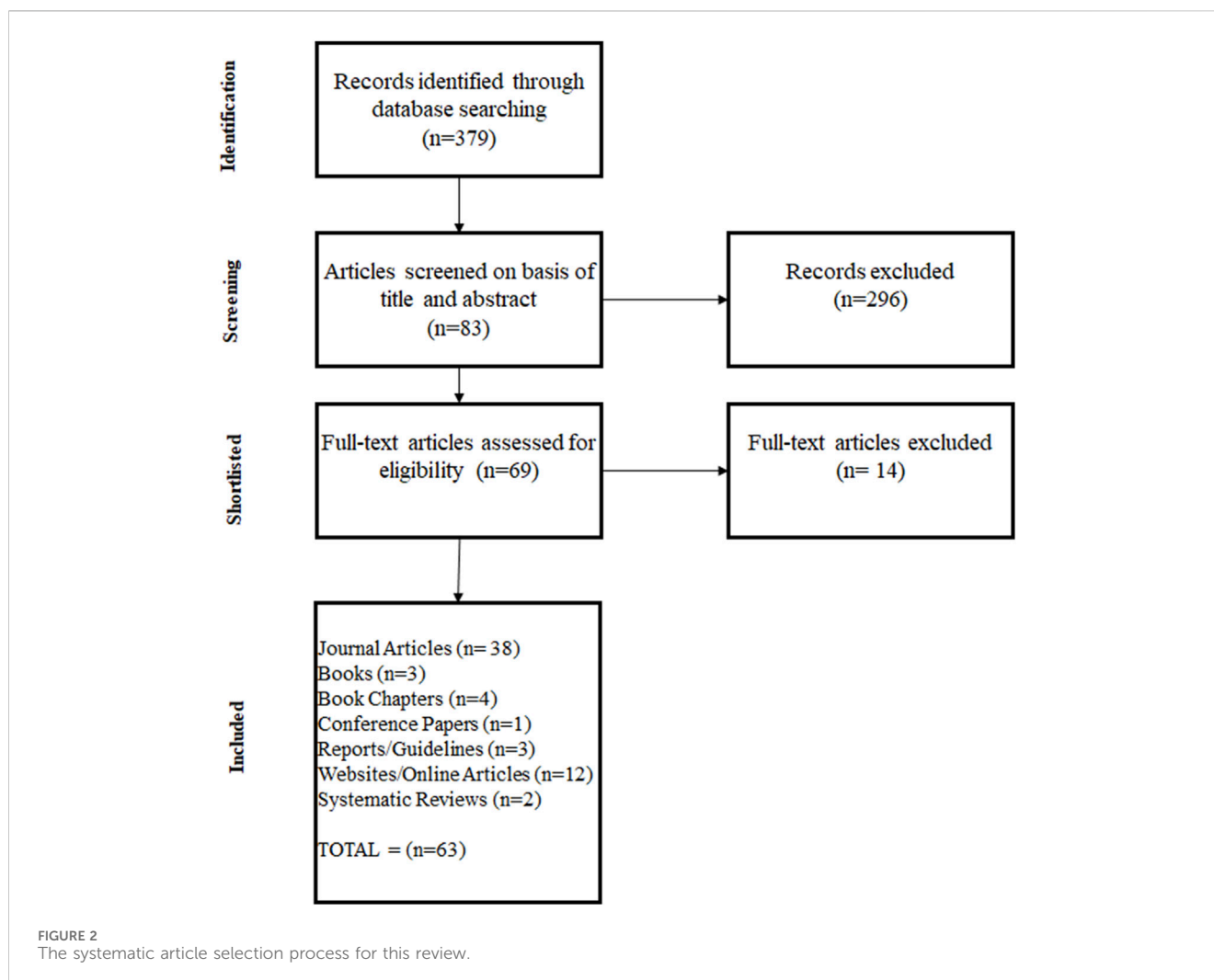
and the hospital's design, humanizing spaces and re-connecting with nature, offers a therapeutic support that positively impact the patients' psychological and physical wellbeing. It also improves their ability to recover (Totaforti, 2018). In addition, by increasing employee wellbeing and lowering healthcare expenses, space design boosts an organization's productivity levels (Brand and Augustin, 2021) and bring about financial gains (Ebaid, 2023). Furthermore, when care providers take breaks, having private outside locations speeds up the process of recharging. These staff break places should, however, be positioned to provide quick and simple access back to the patients (Tekin and Gutiérrez, Human-centered healthcare environments: a new framework for biophilic design, 2023). Additionally, patients develop iatrophobia which is the dread of healthcare providers and doctors. For some people, visiting the doctor's office is a typical experience, but for others, it may be terrifying. This phobia may influence an individual's choice to seek medical attention. Missing a doctor's appointment can have a lot of negative consequences because their job is to assist patients stay healthy. Stress in the medical industry is pervasive. High stakes environments exist in nature, but biophilic design lessen this fear. Including natural elements into healthcare environments benefits both patients and staff, since nature is a tremendous force for good (Journal of Biophilic Design, 2012).

Stress is lowered by biophilia, and stress reduction promotes quicker recovery. Since mental health plays a significant role in the healing process, it makes sense to create healing spaces with as little stress as possible. Making patient rooms to be the first emphasis for these initiatives, with common facilities including entrances, waiting rooms, cafeterias, and hallways coming in second (Becky Mollenkamp, 2023; Muhamad, Ismail, Abul Khair and Ahmad, 2022) further supported this positive impact by demonstrating how biophilic design and passive daylighting techniques in inpatient wards improves patients' physical and mental health, hasten their recuperation, and enhance their sense of connectedness to nature. As a result, using biophilic design and passive daylighting in a medical setting will change the hospital's architecture to make it more environmentally friendly and sustainable (Totaforti, 2018). also added that humanizing hospital environments and allowing patients to spend time in outdoors empower them, lessen pain and stress, and enhance their mental health. As another therapeutical biophilic example, children have benefited psychologically from healing gardens as they attract and provide a therapeutic environment for them (Din, Russo and Liversedge, 2023; Russo and Andreucci, 2023). Moreover, art benefits patients when utilized in hospitals amongst those benefits are the positive impact on patient wellbeing, reduction in hospital stay duration, stress, pain and analgesic usage, so-called mild complications, depressions, anxiety, and mood were observed in some of the early research as mentioned by (Fudickar et al., 2022).

### 3.3 Positive impacts on caregivers

According to (Brambilla, Del Pio, Morosini and Capolongo, 2023) one of the most stressful places on earth is a hospital. Particularly in relation to patients, medical professionals, and nurses, those who occupy them go through a condition of





physical and mental stress. The COVID-19 pandemic made this stress level even worse, hence new approaches must be looked at by hospital administrations to eliminate its implications. The caregivers are more productive and organized in spaces with plants (particularly roses), natural air and light, and interaction with nature. These biophilic design decisions also increase the parasympathetic nervous system's activity, which lowers stress levels and promotes an overall feeling of wellbeing. Biophilic design encourages employee wellness, which lowers sick days while raising satisfaction and attendance *El Messeidy, R. (2019), (Totaforti, 2018), (Lei, Lau, Yuan, and Qi, 2022).*

One problem that has an impact on every hospital building occupant's health and wellbeing is stress. The detrimental consequences of stress are particularly noticeable in the workplace, as stress may impede employee happiness and productivity and serve as a key cause of disease. Occupational stress can stem from a variety of factors, such as job insecurity, long hours, an overwhelming workload, conflicts within the company, looming deadlines, shifting responsibilities, and a lack of autonomy. The working environment itself is one aspect that can lead to total occupational stress, but one that can be lessened via design. Although there are many different reasons why professional stress might occur, designers can take a variety of steps to reduce it *(Norouziyanpour, 2020)*. Biophilic design creates spaces that

orientate, soothe, comfort, and quiet, which is why healthcare settings that focus on behavioral health greatly benefit from it *(Interite Healthcare Interiors, 2019)*. Additionally, a large percentage of hospital staff members report having bad sentiments at work. Anxiety and sadness are expressed by frontline employees. It would be challenging to remain emotionally neutral when working under such terrible circumstances. Employees working in therapeutic settings might feel constrained *(Journal of Biophilic Design, 2012)*.

Based on preliminary evidence, it appears that implementing biophilic design elements can significantly improve wellbeing, reduce stress, increase productivity, encourage a collaborative work environment, and increase workplace satisfaction, increase morale all of which can lead to a high-performance workspace *(Gray and Birrell, 2014)*. The employers can benefit from biophilic design as well. Employers may save money which also enhances job satisfaction, lowers stress, decreases absenteeism and turnover, and promotes concentration and productivity hence directly improving service delivery *(Becky Mollenkamp, 2023)*. *(Lavdas, 2013)* stated that the exposure of hospital staff to fractal visual patterns, seen in nature, architecture, or the visual arts, has beneficial physiological (reduction of stress) and cognitive (improvement of problem-solving ability) impacts. In a similar vein, studies have shown the therapeutic benefits of both natural surroundings which promote quicker

TABLE 6 Systematic review analysis.

| References                           | Key findings   | Methodology  | Sample size                         | Potential biases                   | Validity   |
|--------------------------------------|--|--|-------------------------------------|------------------------------------|--|
| Akpan-Idiok and Ackley (2017)        | Biophilic design reduces stress, enhances patient recovery           | Qualitative study; Surveys and interviews              | 150 participants (patients, staff)  | Response bias, selection bias      | Medium, due to lack of detailed statistical analysis                 |
| Antonovsky (1993)                    | Sense of coherence promotes wellbeing                                | Quantitative study; Psychometric testing               | 400 respondents                     | Measurement bias, self-report bias | High, validated scale with extensive use                             |
| Attia (2021)                         | Biophilic elements improve cognitive function and emotional health   | Mixed-method study; Surveys and observational analysis | 200 patients and healthcare workers | Response bias, observer bias       | Medium, varied data sources but limited statistical rigor            |
| Mollenkamp (2023)                    | Green spaces positively impact patient health                        | Review article; Literature synthesis                   | N/A                                 | Publication bias, selection bias   | High, comprehensive review but relies on secondary data              |
| Berg, Joye and Vries (2019)          | Nature exposure reduces stress, improves mood and cognitive function | Review article; Literature synthesis                   | N/A                                 | Publication bias, selection bias   | High, extensive literature review with strong theoretical foundation |
| Blakemore (2017)                     | Natural light and greenery promote healing and reduce stress         | Review article; Literature synthesis                   | N/A                                 | Publication bias, selection bias   | Medium, relies heavily on secondary sources                          |
| Brambilla et al. (2023)              | Biophilic design supports mental health and wellbeing                | Literature review                                      | N/A                                 | Publication bias, selection bias   | Medium, focuses on pre-COVID-19 data                                 |
| Brand and Augustin (2021)            | Biophilic design elements enhance health and wellbeing               | Review article; Literature synthesis                   | N/A                                 | Publication bias, selection bias   | Medium, critical synthesis but lacks empirical data                  |
| Christensen and Fagan (2018)         | Nature contact reduces stress and improves wellbeing                 | Guidebook/Manual                                       | N/A                                 | N/A                                | High, authoritative source by CDC                                    |
| Design Curial. (2019)                | Biophilic design enhances wellbeing                                  | Descriptive article                                    | N/A                                 | Selection bias, commercial bias    | Medium, informative but not peer-reviewed                            |
| Din, Russo and Liversedge (2023)     | Biophilic design benefits children's health and learning             | Literature review                                      | N/A                                 | Publication bias, selection bias   | High, focused on specific population (children)                      |
| Dubai Health Facility. (2023)        | Green spaces improve patient recovery                                | Regulatory guideline                                   | N/A                                 | N/A                                | High, authoritative source by regulatory body                        |
| Ebaid (2023)                         | Nature-based design improves mental health                           | Framework development; Case studies                    | 5 case studies                      | Selection bias                     | Medium, framework based on limited case studies                      |
| El Messeidy, R. (2019)               | Biophilic design promotes healing environments                       | Literature review                                      | N/A                                 | Publication bias, selection bias   | Medium, synthesis of existing studies                                |
| El-Zeiny (2012)                      | Nature integration in design enhances wellbeing                      | Case study; Observational study                        | Multiple private sector workplaces  | Observer bias, selection bias      | Medium, limited to specific geographical area                        |
| ETKHO Hospital Engineering. (2023)   | Biophilic design reduces stress, improves mood                       | Descriptive article                                    | N/A                                 | Selection bias, commercial bias    | Medium, informative but not peer-reviewed                            |
| Fudickar, Konetzka and Loring (2022) | Nature-based interventions improve health outcomes                   | Review article   | N/A                                 | Publication bias, selection bias   | Medium, synthesis of existing studies                                |
| Ghazaly et al. (2022)                | Green spaces in hospitals improve patient outcomes                   | Literature review                                      | N/A                                 | Publication bias, selection bias   | Medium, broad overview but lacks empirical data                      |
| Gray and Birrell (2014)              | Biophilic elements enhance cognitive function, reduce stress         | Quantitative study; Surveys                            | 250 participants (office workers)   | Self-report bias, selection bias   | High, robust sample size with statistical analysis                   |
| Hartig et al. (2010)                 | Nature exposure improves psychological wellbeing                     | Review article; Literature synthesis                   | N/A                                 | Publication bias, selection bias   | High, comprehensive and multidisciplinary review                     |
| Haverkamp and Kusch (2019)           | Biophilic design enhances wellbeing                                  | Systematic review                                      | Multiple studies reviewed           | Publication bias, selection bias   | High, systematic approach with rigorous analysis                     |
| Healthcare Radius (2021)             | Biophilic design reduces stress and improves healing                 | Descriptive article                                    | N/A                                 | Selection bias, commercial bias    | Medium, informative but not peer-reviewed                            |
| HOK (2023)                           | Biophilic design elements improve wellbeing                          | Descriptive article                                    | N/A                                 | Selection bias, commercial bias    | Medium, informative but not peer-reviewed                            |

(Continued on following page)

TABLE 6 (Continued) Systematic review analysis.

| References                           | Key findings   | Methodology  | Sample size                            | Potential biases                 | Validity  |
|--------------------------------------|--|--|--|----------------------------------|---|
| Huber et al. (2011)                  | Biophilic design enhances health and wellbeing         | Review article; Conceptual analysis                              | N/A                                    | Selection bias                   | High, influential conceptual framework with extensive citation  |
| Interite Healthcare Interiors (2019) | Biophilic design reduces stress, improves wellbeing    | Descriptive article  | N/A                                    | Selection bias, commercial bias  | Medium, informative but not peer-reviewed                       |
| ITO et al. (2022)                    | Biophilic design improves cognitive performance        | Experimental study; Physiological measurements                   | 100 participants (office workers)      | Measurement bias, selection bias | High, controlled environment with robust methodology            |
| Janetius (2020)                      | Biophilic design enhances wellbeing                    | Conceptual book chapter  | N/A                                    | Selection bias                   | Medium, theoretical analysis with limited empirical data        |
| Joseph (2006)                        | Nature exposure promotes healing and reduces stress    | Review article; Literature synthesis                             | N/A                                    | Publication bias, selection bias | High, foundational review in the field                          |
| Journal of Biophilic Design (2012)   | Nature-based design reduces stress, enhances wellbeing | Descriptive article  | N/A                                    | Selection bias, commercial bias  | Medium, informative but not peer-reviewed                       |
| Kaushik (2023)                       | Biophilic design improves mental health and wellbeing  | Opinion article  | N/A                                    | Selection bias                   | Medium, informed opinion but lacks empirical data               |
| Lavdas (2013)                        | Nature contact improves mental health                  | Conceptual analysis  | N/A                                    | Selection bias                   | Medium, theoretical perspective with limited empirical support  |
| Law Insider (2023)                   | Biophilic design enhances wellbeing                    | Legal definition   | N/A                                    | N/A                              | High, authoritative legal source                                |
| Lei et al. (2022)                    | Biophilic design improves mental health, productivity  | Post-occupancy evaluation; Surveys                               | 150 participants (workplace employees) | Self-report bias, selection bias | High, robust sample size with statistical analysis              |
| Liu, Yang and Osmani (2021)          | Biophilic design enhances health, wellbeing            | Review article   | N/A                                    | Publication bias, selection bias | High, comprehensive review with clear focus                     |
| March (1991)                         | Nature exposure reduces stress, improves wellbeing     | Theoretical paper  | N/A                                    | N/A                              | High, foundational theoretical work with extensive citation     |
| McCoy and Evans (2002)               | Biophilic design reduces stress, improves wellbeing    | Theoretical paper  | N/A                                    | N/A                              | High, influential theoretical framework with extensive citation |
| El Messeidy, R. (2019)               | Nature-based design enhances wellbeing                 | Literature review  | N/A                                    | Publication bias, selection bias | Medium, synthesis of existing studies                           |
| Muhamad et al. (2022)                | Biophilic design reduces stress, enhances wellbeing    | Case study; Observational study                                  | 1 hospital (inpatient ward)            | Observer bias, selection bias    | Medium, limited to specific case study                          |
| Nisbet, Zelenski and Murphy (2009)   | Nature contact enhances wellbeing                      | Quantitative study; Surveys                                      | 600 participants (general population)  | Self-report bias, selection bias | High, robust sample size with statistical analysis              |
| Norouziyanpour (2020)                | Biophilic design improves cognitive performance        | Experimental study; Interventions                                | 50 office workers                      | Selection bias, measurement bias | Medium, small sample size but controlled environment            |
| Page et al. (2021b)                  | Nature-based design enhances wellbeing                 | Guideline paper  | N/A                                    | N/A                              | High, authoritative guideline with extensive use                |
| Park and Mattson (2009)              | Biophilic design improves recovery, reduces stress     | Experimental study; Physiological and psychological measurements | 100 patients (post-surgery)            | Measurement bias, selection bias | High, controlled environment with robust methodology            |
| Phillips (2023)                      | Biophilic design enhances wellbeing                    | Opinion article  | N/A                                    | Selection bias                   | Medium, informed opinion but lacks empirical data               |
| Squires (2023)                       | Nature contact improves wellbeing                      | Descriptive article  | N/A                                    | Selection bias, commercial bias  | Medium, informative but not peer-reviewed                       |
| Ruggeri et al. (2020)                | Biophilic design enhances wellbeing                    | Quantitative study; Surveys and statistical analysis             | 21 countries (varied sample sizes)     | Self-report bias, cultural bias  | High, robust cross-cultural analysis                            |
| Russo and Andreucci (2023)           | Biophilic design enhances health and wellbeing         | Review article   | N/A                                    | Publication bias, selection bias | High, comprehensive review with clear focus                     |

(Continued on following page)

TABLE 6 (Continued) Systematic review analysis.

| References                       | Key findings  | Methodology  | Sample size                | Potential biases                 | Validity  |
|----------------------------------|---|--|----------------------------|----------------------------------|---|
| Ryan and Browning (2020)         | Biophilic design enhances health and wellbeing      | Theoretical paper  | N/A                        | N/A                              | High, influential theoretical framework with extensive citation |
| Salingaros (2015)                | Biophilic design enhances wellbeing                 | Theoretical paper  | N/A                        | N/A                              | High, influential theoretical framework with extensive citation |
| Shen, Zhang and Lian (2020)      | Biophilic design improves cognitive performance     | Experimental study; Cognitive performance testing                | 80 office workers          | Measurement bias, selection bias | High, controlled environment with robust methodology            |
| Showkat and Parveen (2017)       | Ethical considerations in biophilic design          | Review article   | N/A                        | Publication bias, selection bias | Medium, focused on ethical considerations                       |
| Smith and Watkins (2016)         | Biophilic design reduces stress, improves wellbeing | Descriptive article  | N/A                        | Selection bias, commercial bias  | Medium, informative but not peer-reviewed                       |
| Tekin and Gutiérrez (2023)       | Biophilic design enhances wellbeing                 | Conceptual framework development; Systematic review              | Multiple studies reviewed  | Publication bias, selection bias | High, systematic approach with rigorous analysis                |
| Terrapin Bright Green LLC (2014) | Biophilic design enhances health and wellbeing      | Guidebook; Conceptual framework                                  | N/A                        | N/A                              | High, authoritative source in biophilic design                  |
| Totaforti (2018)                 | Biophilic design in hospitals enhances wellbeing    | Review article   | N/A                        | Publication bias, selection bias | High, focused on hospital design                                |
| Ulrich (1984)                    | Nature exposure reduces stress, improves recovery   | Experimental study; Observational                                | 46 patients (post-surgery) | Observer bias, small sample size | High, seminal study with significant impact                     |
| Ulrich et al. (1991)             | Biophilic design reduces stress, improves wellbeing | Experimental study; Observational and psychological measurements | 100 participants           | Measurement bias, selection bias | High, robust methodology with significant impact                |
| Wilson (1984)                    | Biophilia hypothesis                                | Theoretical book   | N/A                        | N/A                              | High, foundational work in biophilia                            |
| Zhao, Zhan and Xu (2022)         | Sustainable biophilic design enhances wellbeing     | Review article   | N/A                        | Publication bias, selection bias | High, focused on sustainable interaction in healthcare spaces   |

hospital recovery and pain relief as well as artificial environments that replicate the geometrical features of natural environments. Using wooden components in home design may enhance occupant happiness and cognitive function (Shen, Zhang and Lian, 2020). Seeing vegetation via the window with a balanced quantity of sunshine through the foliage increased employee's perceptions of their indoor environment, ease of work, and self-estimated productivity (ITO, et al., 2022).

(Terrapin Bright Green LLC, 2014) has identified fourteen (14) patterns that summarise the findings and strategies which emerged from the literature review in terms of improving patient care and improving service delivery. Table 7, identifies which patterns are in alignment with the impact of therapeutical biophilic design on health and wellbeing of patients and care providers in hospitals based on the findings of this study.

### 3.4 Additional environmentally sustainable business practices in transforming healthcare facilities

Greening the healthcare sector is essential to encouraging sustainable operations that reduce the industry's environmental impact and improve the environment for patients, healthcare

professionals, visitors, and suppliers as well as the hospital grounds (Kaushik, 2023). Additional to adopting therapeutical biophilic design the following paragraphs highlight additional environmentally sustainable business practices:

Recycling recyclable materials is ensured by reviewing waste management procedure by implementing sustainability standards for waste management and purchasing, particularly if they pair any evaluation with fresh or strengthened sustainability pledges and practices. Some of the single-use medical gadgets that hospitals normally throw away can be reprocessed when they collaborate with medical device manufacturers. Cardinal Health created a zero-waste operation to recycle or reprocess single-use devices in collaboration with healthcare organizations. Through these collaborations, they were able to remove almost 740 tons of discarded medical devices from landfills in 2017. Kaiser Permanente saved around \$11 million annually by recycling some single-use items. In non-clinical settings, such food and dining services, implementing reuse and recycling programs will aid in addressing the single-use plastic problem. Additionally, choosing to buy more food that is grown nearby will lessen the hospital's carbon impact and food waste. Even better, they can work with neighborhood organizations to turn their food waste into compost, which would feed nearby food producers like hospitals or gardens (Phillips, 2023).

TABLE 7 Impact of therapeutical biophilic design on health and wellbeing of patients and caregivers in comparison to Terrapin's 14 patterns (Terrapin Bright Green LLC, 2014).

| 14 Patterns                       | Stress Reducation   | Cognitive Performance   | Emotion, Mood and Preference   |
|-----------------------------------|---|---|--|
| <b>Nature in the Space</b>        |   |   |  |
| Visual Connection with Nature     | Lowered blood pressure and heart rate   | Improved mental engagement/attentiveness  | Positively impacted attitude and overall happiness                       |
| Non-Visual Connection with Nature | Reduced systolic blood pressure and stress hormones   | Positively impacted cognitive performance   | Perceived improvements in mental health and tranquility                  |
| Non-Rhythmic Sensory Stimuli      | Positively impacted heart rate, systolic blood pressure and sympathetic nervous system activity | Observed and quantified behavioural measures of attention and exploration                             |  |
| Thermal and Airflow Variability   | Positively impacted comfort, wellbeing and productivity   | Positively impacted concentration   | Improved perception of temporal and spatial pleasure (alliesthesia)      |
| Presence of Water                 | Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure          | Improved concentration and memory restoration<br>Enhanced perception and psychological responsiveness | Observed preference and positive emotional responses                     |
| Dynamic and Diffuse Light         | Positively impacted circadian system functioning<br>Increased visual comfort                    |   |  |
| Connection with Natural Systems   |   |   | Enhanced positive health responses:<br>Shifted perception of environment |
| <b>Natural Analogues</b>          |   |   |  |
| Biomorphic forms and patterns     |   |   | Observed view preference   |
| Material Connection with Nature   |   | Decreased diastolic blood pressure<br>Improved creative performance                                   | Improved Comfort   |
| Complexity and Order              | Positively impacted perceptual and psychological stress responses                               |   | Observed view preference   |
| <b>Nature of the Space</b>        |   |   |  |
| Prospect                          | Reduced Stress  | Reduced boredom, irritation, fatigue  | Improved comfort and perceived safety                                    |
| Refuge                            |   | Improved concentration, attention and perception of safety  |  |
| Mystery                           |   |   | Induced strong pleasure response   |
| Risk/Peril                        |   |   | Resulted in strong dopamine or pleasure responses                        |

\*Legend: positive impact of therapeutical biophilic design on health and wellbeing of patients and caregivers Source: (Terrapin Bright Green LLC, 2014).

Furthermore, hospitals will operate more sustainably if they share durable assets like buildings, vehicles, medical equipment, and other underutilized resources. Floop2 is a startup that has created a marketplace for sharing resources so that hospitals in its network may share equipment. This lowers the cost of purchasing expensive equipment, such as imaging machines, and the length of time that such equipment is left idle. Asset sharing lowers the total energy used in product manufacture and maintenance, in addition to offering possible cost benefits for all network organizations. Some hospitals are already changing how they utilize their facilities and durable assets because of the coronavirus outbreak. Many providers have embraced telehealth and remote care services for non-urgent treatment, which lowers their energy consumption, physical footprint, and emissions from staff and patient travel to the facility (Phillips, 2023). Hospitals are switching from using fossil fuels to more cost-effective, environmentally friendly energy sources that are also more efficient. Hospitals are putting in smart lighting,

solar panels, green energy, and other clean energy providers. Some health systems even use the on-site incinerators they employ to get rid of garbage to create electricity. Aiming to become net carbon negative by purchasing enough clean energy and carbon offsets to remove more greenhouse gases from the environment than it emits, Kaiser Permanente made one of the biggest pledges to green energy among healthcare organizations in the United States (Phillips, 2023).

Water conservation is another important component of sustainability, as hospitals use a lot of water for gardening, patient care, cleaning, and other purposes. Water use may be greatly reduced by installing low-flow showerheads and toilets, fixing leaks right once, updating irrigation systems, and collecting and recycling rainwater. Sewage treatment systems based on membrane bioreactors can maximize the recycling of treated wastewater. After treatment, wastewater may be utilized for a variety of non-potable uses, such as cooling towers, gardening, and flushing. Medical equipment may also be cleaned and



sterilized with the use of water recycling programs. Hospitals may also take use of the 3Rs concept, which stands for Reduce, Reuse, and Recycle, to help achieve a double-digit decline in freshwater usage (Kaushik, 2023).

Waste Reduction and Recycling is achieved by putting in place recycling programs for paper, plastics, and other materials, hospitals may reduce waste. Healthcare institutions lessen their carbon impact and encourage sustainability by composting yard waste and food scraps. Additionally, reusing materials, buying items with little packaging, and utilizing eco-friendly cleaning solutions are all ways to reduce waste. Hospitals must also have a thorough waste management strategy that includes identifying and classifying garbage into solid waste, biomedical waste, hazardous waste, and e-waste. Similarly, this trash is treated and transformed into manure, which can be utilized for horticulture purposes, using organic waste converters. Reducing the Use of Chemical and Hazardous Materials is achieved by improving sustainability and safeguarding patient safety in hospitals through employing eco-friendly cleaning solutions, minimizing the use of toxic chemicals in medical operations, and putting safe disposal programs for hazardous materials in place, the use of hazardous chemicals and materials may be minimized (Kaushik, 2023).

Sustainable Food Practices through local, organic, and sustainably farmed food is be obtained by hospitals for their patients and employees. Hospitals reduce their carbon footprints related to food transportation by promoting local farmers and businesses through a farm-to-table program. Additionally, composting programs and giving extra food to nearby food banks and charity helps decrease food waste (Kaushik, 2023).

### 3.5 Case studies of therapeutical biophilic design

A consolidated view of the case studies reviewed across the globe to hospital settings that have successfully implemented the biophilic design for a more sustainable therapeutical environment for its patients and caregiver are summarized in [Supplementary Table S1](#). Additionally, the table shows that, to put it simply, biophilic design is the relationship between humans and nature. People benefit from this connection by feeling at ease, appreciating beauty, and fostering interpersonal connections. Thus, using biophilic design in medical settings may facilitate patients' recovery from a variety of illnesses. Employing biophilic design in hospital architecture is more than just adding plants, trees, or green walls; it is a comprehensive strategy that calls for fresh perspectives and creative ways to incorporate nature into medical settings. To be considered biophilic, a design does not have to incorporate every biophilic design pattern. It is not an easy task for architects to play in this situation; it calls for extensive research and analysis of the interaction between humans and the natural world (El Messeidy, R. 2019).

### 3.6 Limitations and future research areas

Although there is noticeable growing interest in the significance of biophilic designs within healthcare, this systematic literature review reveals a scarcity of research conducted in this field. This is seen as the main limitation of this research due to the small number of holistic research that is performed on the implication of

biophilic designs in hospital settings application from the aspects of patient care and service delivery carried out by care providers. There is a potential of further research in this domain, with in-depth analysis of the impact of every biophilic design pillar as a standalone and assess its implication separately on the wellbeing of patient and care providers. Moreover, further understand the challenges that are hinging the wide scale implementation of such designs from the lens of subject matter experts and space users in general or bound to a specific geographical location. Additionally, quantifying the positive impact such as the monetary value of reduced staff absenteeism, workforce productivity, and reduction of hospital stay.

## 4 Conclusion

This Systematic Literature Review paper explored the parameters that define sustainable therapeutic environments in healthcare settings. It outlined various sustainable therapeutic environment initiatives that have been implemented to enhance health and wellbeing. Moreover, it identified and examined the correlation between sustainable therapeutic environments and the health and wellbeing of both caregivers and patients, providing a robust understanding of the positive impacts and effective practices within healthcare settings.

In summary, healthcare facility design has changed despite the worry from their administrations that adding biophilic features will increase the costs (Becky Mollenkamp, 2023). The patient's welfare has taken precedence over functionality without losing ground. One of the most useful, simple, and cost-benefit effective ways to achieve this is through a biophilic design. A location with adequate fresh air circulation, a good portion of exterior doors, and adequate natural lighting is better for the health of patients and healthcare personnel. From reducing patient mortality, suffering, and stress to decreasing hospital stays. A connection to nature has been shown to lessen anxiety and enhance the experiences of patients, their families, and medical personnel. The idea that stress may be significantly reduced by having access to nature and greenery is well supported by the available data (Norouziyanpour, 2020). The cliché "home away from home" is being taken on faith. Therefore, the humanization of hospitals entails the design of interventions targeted at redefining the environment in terms of both the organizational and therapeutic aspects, as well as, more generally, how patients and visitors view the hospital (Totaforti, 2018). Despite the positive impact of sustainable therapeutic environments through biophilic design, implementing biophilic design is still difficult since many healthcare facilities are still considered as sterile settings, and there are worries about higher maintenance costs. Some hospitals prefer to prevent issues like a rise in pests like flies and the quantity of dead leaves, which can clog drains (Roxanne Squires, 2023). Effective biophilic design should enhance patients' daily life and be implemented by those in charge of designing and innovating hospital settings in the future (Ebaid, 2023).

Research in literature review have shown that for hospital settings such as inpatients (feeling calm and at ease, prospect refuge, security and protection, light-daylight, view) are prioritized biophilic design requirements, while for personnel (privacy refuge, tranquility), and outpatients (fresh air, light-daylight, thermal comfort, welcome and soothing). While staff, inpatient, and outpatient users had comparable needs and wants, there were occasionally differences in their priorities, and various

groups required distinct biophilic aspects (Tekin, Corcoran and Gutierrez, 2023). Confirming that the application of biophilic designs in hospital settings has a positive impact on both the patients and caregivers' wellbeing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fbuil.2024.1467692/full#supplementary-material>

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