Biophilic Design as a Framework to Solve Sick Building Syndrome in the Indoor Spaces

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ABSTRACT

Nowadays, humans spend a great deal of time indoors and are more likely to suffer from diseases such as sick building syndrome, due to poor indoor environmental quality and poor environmental settings. Health issues associated with sick building syndrome (SBS) can negatively affect physical and mental health. It refers to circumstances where building occupants are experiencing adverse health or comfort effects due to time spent in the indoor buildings, even though no illness or cause can be identified. As sick building syndrome occurs when occupants stay in indoor spaces for a certain length of time; introducing a natural design strategy will improve the health of the indoor environment. A key component of a healthy building could be the use of biophilic design actions to enhance the well-being and comfort of the occupants in the indoor environment. It is known that humans are innately drawn to nature, and the design strategies provided by biophilic design have multiple benefits such as promoting health, productivity, biodiversity, circularity, and resilience.

As a direct consequence of the Biophilic design approach, nature acts as an active catalyst to enhance human health. Accordingly, this study quests how Biophilic design strategies could be incorporated into indoor spaces so that the issues associated with SBS can be resolved and reduced. And then asks whether the incorporation of nature into interior spaces can enhance human health and wellbeing. To improve the inadequate indoor environmental quality caused by the sick building syndrome, this study aims to develop strategies as well as to provide design solutions/suggestions derived from the Biophilic approach in order to overcome SBS and improve indoor space quality. A qualitative research method has been conducted based on a literature review of the two key concepts: SBS and the Biophilic design approach. As a result of the literature review, analytical frameworks were developed to correlate SBS contributors with the Biophilic Design principles, attributes and the patterns.

Accordingly, this study has concluded that it is effective to use the strategies and approaches of biophilic design, recommendations were developed in order to assist the improvement of the indoor environmental quality whilst open several possibilities for solving SBS contributors.

Keywords: Biophilia, Biophilic Design, Biophilic Design Strategies, Sick Building Syndrome, Indoor Space.

ÖZ

Günümüzde insanlar iç mekanlarda çok fazla zaman geçirmekte ve bu nedenle kötü çevresel hava kalitesi ve kötü çevresel koşullar nedeniyle hasta bina sendromu gibi problemlerle karşı karşıya kalma olasılıkları daha da yükselmektedir. Hasta bina sendromu (HBS) ile ilişkili sağlık sorunları, fiziksel ve zihinsel sağlığı olumsuz etkileyebilmektedir. HBS herhangi bir hastalık veya sebep tespit edilememesine rağmen kullanıcıların kapalı binalarda geçirdikleri süre nedeniyle olumsuz sağlık veya konfor etkileri yaşadığı durumları ifade etmektedir. Bu durum kullanıcıların belirli bir süre kapalı mekanlarda kaldıklarında ortaya çıktığı için, doğal bir tasarım stratejisi olan biyofilik tasarım yaklaşımını sürece dahil etmek iç mekan ortamının sağlığını iyileştirecektir. İnsanlar doğuştan doğa ile doğal bir bağ kurarak yaşama başlar ve biyofilik tasarımın sağladığı tasarım stratejilerinin de bu bağlamda sağlığı, üretkenliği, biyoçeşitliliği, döngüselliği ve esnekliği teşvik etmek gibi birçok faydası olduğu bilinmektedir.

Biyofilik tasarım yaklaşımı ile doğa insan sağlığını geliştirmek için aktif bir katalizör görevi görmektedir. Bu bağlamda bu çalışma, HBS ile ilgili sorunların çözülüp azaltılabilmesi için Biyofilik tasarım stratejilerinin iç mekanlara nasıl dahil edebileceği ve ayrıca doğanın iç mekanlara dahil edilmesinin insan sağlığını iyileştirip iyileştirmeyeceğini sorgulamaktadır. Hasta bina sendromunun neden olduğu yetersiz iç mekan çevre kalitesini iyileştirmek için, çalışmanın amacı HBS'na ilişkin ortaya çıkan problemler ve iç mekan kalitesini iyileştirmek için Biyofilik tasarım yaklaşımı ile çeşitli stratejiler/prensipler, öneriler geliştirmektir. Çalışma nitel araştırma yöntemi ile iki anahtar kavram olan HBS ve Biyofilik tasarım yaklaşımını kapsamlı bir literatür taraması ile araştırmakla başlar. Kapsamlı literatür taraması sonucunda geliştirilen analitik çerçeveler hasta bina sendromu ve biyofilik tasarım kavramlarını ilişkilendirmek ve araştırma sorularını cevaplamak için kullanmıştır.

Çalışmanın sonucunda, biyofilik tasarım stratejilerini ve yaklaşımlarını iç mekan çevre kalitesini iyileştirmede kullanmanın etkili olduğu ortaya konmuş ve hasta bina sendromunun ortaya çıkmasında rol oynayan etkenlerin çözümü üzerinde etkili olduğu tespit edilmiştir. Ayrıca, çalışmanın sonucunda bu stratejilerin/yaklaşımın sürece nasıl ve ne zaman dahil edilebileceğine yönelik öneriler de geliştirilmştir.

Anahtar Kelimeler: Biyofili, Biyofilik Tasarım, Biyofilik Tasarım Stratejileri, Hasta Bina Sendromu, İç Mekan.

DEDICATION

Dedicated to my parents, this thesis is in their honor and in gratitude for their continuous love, support, and care

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BC	Broadcasting Code
BRI	Building-Related Illness
EPA	Environmental Protection Agency
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LED	Light-Emitting Diode
MVOCs	Microbial Volatile Organic Compounds
SBS	Sick Building Syndrome
VOCs	Volatile Organic Compounds
WHO	World Health Organization

Chapter 1

INTRODUCTION

1.1 Background to the Study

The increasing interest in human health and well-being within interior spaces has heightened the need for collaborative empirical research among various fields, like planners, architects, physicians, psychologists, and other fields of interest to create healthy spaces.

In accordance with World Health Organization (WHO), health and well-being are the most important assets to be achieved in indoor environments. Researchers at WHO has found that 30 percent of all types of buildings which studied (including both small and large buildings) exhibit some form of SBS-sick building syndrome which were addressing psychological and physiological well-being of the building occupants (Lindvall, 1986).

The appellation of sick building syndrome established by the WHO as a distinct concept to describe a situation in which people begin to experience acute health symptoms because of amount of time spent inside the building, making it hard to differentiate and define illness or causes related to SBS (Raw, 1992). When the occupants leave the building, the symptoms go away and no other cause can be identified. Experts in the research field, specifically Edwards (1999), claimed that the causes for SBS can be categorized into two categories; the first is a lack of natural factors such as natural temperature, aural, and natural view, and the second is the prevalence of prominent levels of air pollution and dust. Thus, according to psychologists (Hanie, 2010), closed buildings with artificial ventilation and electric lighting are more likely to be SBS than those with normal day-lighting and ventilation, associated with poor indoor air quality and a lack of adequate indoor environmental quality.

There are many fields of study in interior design nowadays, including Biophilic design, which enhances the quality of indoor spaces through the integration of nature. Along with this, the very absence of clearly defined SBS symptoms in the built environment allows recalling a Biophilic design approach as one that defines a clear attribution and an active catalyst of nature to boost human health. The introduction of nature into the built environment was around in the old days when Florence Nightingale (1858/1969), stated that “It is often thought that medicine is the curative process. It is no such thing; medicine is the surgery of functions, as surgery proper is that of limbs and organs. Neither can do anything but remove obstructions; neither can cure; nature alone cures. Surgery removes the bullet out of the limb, which is an obstruction to cure, but nature heals the wound. So it is with medicine; the function of an organ becomes obstructed; medicine so far as we know, assists nature to remove the obstruction, but does nothing more. And what nursing has to do in either case, is to put the patient in the best condition for nature to act upon him."

The ancient Greek language and philosophy behind the word biophilia invite an interesting discussion, in which ‘bio=nature’ and ‘philia=love’. The word was first coined by Edward Osborne Wilson (1984), to describe a sense of belonging, it implies more affection and closeness than love toward life (even though not all life is alive).

Thus, the topic is particularly given the potential for tension between nature and built-environment sectors and disciplines.

It all comes down to human biology. As Edward O. Wilson's (1984) claimed, because of our genetic reliance on nature and other biotic forms for life and personal fulfillment, humans are innately drawn to nature and other forms of life.

To overcome SBS that occurs when the strategies and approaches used in planning, implementation, and maintenance, of buildings (system, and structure) were not provided in line with the checklist developed by the authorities (Marmot & Michael, 2006). In this research, the Biophilic design will be introduced as a biophilia contribution to the indoor spaces.

1.2 Problem Statement

The occupants, suffering from physiological and/or psychological symptoms related to SBS, may find low support on willingness to understand their symptoms, since identifying the source of the problem is not always possible. As a result, according to the collected data, humans nowadays spent almost 90% of their lives indoors; this mean any indoor air quality, and poor indoor environmental setting are likely to affect building occupants (US EPA, 2021).

The problem of sick building syndrome then arises when the physical design of interior spaces negatively affects the interaction between users and the space itself. Thus, the physical structure of the building can cause poor indoor environmental quality (IEQ), such as poor indoor air quality (IAQ), overheating and inadequate ventilation.

In fact, humans have an unconscious need to be in contact with nature, and they tend to occupy and reproduce in environments that are close to those from our ancestral history. Thus, bringing health and green strategies would be one of the best solutions to overcome the problems caused by building construction. Apart from that, the studies done by researchers Amirhosein, et al. (2018), have identified, physical, biological, chemical, psychosocial, and individual parameters as the major contributors to SBS." But there are no attempts found to solve the problems related to SBS through the incorporation of Biophilic design into housing settlements and multi-story offices.

1.3 Research Questions

Humans would be able to engage directly with nature through biophilic design, which uses natural elements, materials and process sourced directly from nature. This would provide an opportunity to use creative solutions to solve environmental challenges. Biophilic design can have many benefits, including a boost in productivity and occupants' wellbeing, however, interior spaces most of the time tend to focus on functionality rather than the overall experience and comfort. This means the natural light, airflow, and atmosphere were not paid a lot of attention in the built environment.

Currently, there is a lot of debate about Biophilic Design. Yet, the question is: How can we incorporate Biophilic design strategies into indoor spaces so that the issues associated with SBS can be resolved and reduced? And; Is it possible to enhance the user's health and well-being by incorporating nature into the interior spaces?

1.4 Aim and the Objectives of the Study

The purpose of this thesis study is to develop strategies to improve the inadequate indoor environment quality caused by sick building syndrome. Moreover, it aims to propose Biophilic Design Approach as a solution/action to defeat the problems found in indoor environments and thus enable occupants to live in a healthy space because of connecting indoor environments with nature. Moreover, the objectives of this study to achieve the stated aim are;

- To conduct literature review and understand the patterns of both the SBS and Biophilic design in relation to the interior spaces.
- To determine problems related to sick building syndromes that occur in indoor spaces.
- To understand Biophilic Design Patterns and later correlate them to sick building syndromes.
- To provide guidelines/strategies which would be derived from Biophilic approach in the form of design solutions/suggestions to overcome a Sick Building Syndrome and hence to improve indoor space quality.

1.5 Limitations

As a major limitation in integrating Biophilic design strategies and actions to solve SBS, the study focused on documentary research by collecting the published data. Furthermore, developing a conceptual framework forces the analysis to selectively select which variables are most relevant and informative. Using a framework, a systematic and comprehensive analysis can be created that is focused on the research question.

Specifically, the study İs limited with the six principles of biophilic design (Kellert et al., 2008); experiences and attributes of biophilic design (Kellert, 2018); and patterns of biophilic design (Browning et al., 2014; Browning and Ryan, 2020), to examine the effects of biophilic design on improving the indoor environment of buildings and by concentrating only on the physical environment of buildings. Moreover, it is limited due to shortage of conducting a field investigation as a type of survey methodology with as a form of case study to examine the real-life situation.

1.6 Methodology

In this study, a qualitative research method is employed. The first stage is identifying relevant publications based on a theoretical understanding of the two key concepts: SBS (in terms of its description/classification, effects on building occupants, and causes and factors), the second key concept is the Biophilic design approach (a description/classification, principles, experiences, and patterns), which are provided in books, journals, articles, and other materials related to the topic.

For the purpose of finding answers to the research questions, the biophilic design is evaluated in terms of its effectiveness in addressing the challenges caused by the SBS. The second stage of the study provided the results of the study. Moreover, an analytical framework based on the two key concepts that have been described in the literature review was developed, to assist in guiding and facilitating sense-making and understanding of the problem/solution process. In this way, the analytical outcomes were used to answer the research questions defined.

1.7 Structure of the Thesis

This thesis consists of four chapters. In Chapter 1, as a background to the study, describe the study motivation, the subject matter, research questions, aims/objectives, limitations, and the type of research methodology used in this thesis. All will be discussed, along with the structure of the thesis.

Chapter 2 would be the literature review of the study, to gain an understanding of the existing research relevant to the keywords of sick building syndrome and biophilic design approach. In part one, sick building syndrome is described, how it affects humans, and the factors that lead to it. A second section will discuss the Biophilic Design approach, including descriptions, principles, patterns, and experiences of biophilic design.

Chapter 3 describes the results of the study. The research questions will be explored in this chapter, by correlating SBS contributors with the biophilic design approach actions and strategies in indoor spaces. The first step would be to define the methods of the study, which provides a specific plan to follow throughout the study. The second step would be through correlating the five SBS contributors with biophilic design actions and strategies. In the final step, the results of the study will be presented by establishing a model/framework for effectively communicating its findings.

Chapter 4 will be the conclusion of the study, by giving summaries and general concluding to the study, and providing remarks and recommendations for further studies.

Chapter 2

UNDERSTANDING THE CONCEPT OF SICK BUILDING SYNDROME AND BIOPHILIC DESIGN APPROACH IN INTERIOR SPACES

Nowadays taking care of human shelters has become a priority. Adapting the physical spaces of a building to the lifestyle the occupants want can be achieved through health and sustainability strategies. Buildings may fail to offer this condition for users for a variety of reasons, which are explored in this study. Being sick in the building may refer to vast factors, including poor environmental quality, psychological issues, noise, external sources of pollution, and so on, but no specific cause has been found and confirmed except the amount of time spent inside the building (Janis, 2011). Due to the amount of time spent in interior spaces, occupants with Sick Building Syndrome (SBS) symptoms have come to assume a decline in physiological and psychological health, caused by poor indoor environmental quality.

Several elements and features have been defined by researchers that might add to the evolution of SBS inside human settlements and workplaces. SBS, on the other hand, has a broader perspective, since Symptoms defining SBS are common to a large number of people, but it is the way they express themselves that leads to a diagnosis, and overly focusing on health and wellbeing issues is a primary concern. Furthermore, since the way users think, judge, memorize, and perceive can be infected by the physical environment they are inserted in; it can be the focus both for researchers and professionals in the field of architecture / interior architecture to design buildings that work on the enhancement of users' lives. For instance, to attain this aim, several approaches are being employed, such as ensuring a prominent level of air quality, proper material choices, providing thermal comfort, organizing the interior layout, and active design (Joel, 2008). Briefly, at first, it is significant to understand what sick building syndrome is, and how it occurs/caused.

If there is a discourse about the health and well-being of people in indoor facilities, there is a need to quest whether the environmental quality of the interior spaces contributes to fatigue (physiological or psychological) in indoor spaces and whether the building's setting and residents play a role. Therefore, the aim of this section is to understand how sick building syndrome can affect design decisions as it occurs in interior spaces. Providing a brief overview of SBS, followed by understanding how it affects the human being, and which characteristics and factors cause SBS, will allow us to link the SBS issues to their effect on occupants' health and well-being inside the buildings.

2.1 Sick Building Syndrome

2.1.1 General Classification/Description of Sick Building Syndrome (SBS)

The phrase Sick Building Syndrome (SBS) refers to circumstances in which building occupants have acute health and comfort consequences that are related to time spent in the building, but no sickness or cause can be established (EPA, 2010). The issues might be isolated to a single space or area, or they could be pervasive across the structure. When symptoms of a diagnosed disease are observed in a building that can be linked to airborne pollutants, the term Building-Related Illness BRI is used. More descriptions of SBS from other researchers may be found in (Table 1) below.

Table 1: Descriptions of SBS By Different Researchers

Allusion	Description	Characterization
EPA. (1991)	A SBS is any situation in which an occupant of a building exhibits acute health or comfort effects that are attributed to their time in that building without any identifiable illness or cause.	• There are no specific signs. • Some signs correspond directly to occupancy in a building. • Residents of a certain building experiencing the same acute symptoms
Rostron, J. (2008)	It is a syndrome that is characterized by symptoms of malaise, which becomes worse when a person occupies certain modern buildings.	• Occupancy directly correlates with certain buildings
Gomzi, M., and J. Bobić. (2009)	The population of a certain building is more likely to experience nonspecific symptoms because of environmental exposure; these symptoms are often not accompanied by clinical signs or objective measurements.	• There is no specific cause for the symptoms. • The signs are a common occurrence among residents of a particular building • Most of these symptoms are not clinical.
Imai, N., and Y. Imai. (2011)	The symptoms associated with SBS are usually related to the indoor environment, including dyspnea, headache, visual disturbance and loss of consciousness after moving into a new house or remodeling one.	• SBS symptoms are primarily caused by the building itself. • The symptoms of SBS can even appear in a newly constructed house or a renovated house
Abdul-Wahab, S. A. 2011 and Clements-Croome, D. (2018)	Generally, a case of SBS occurs when more than 20 percent of building users experience similar medical issues during an unidentified two-week period.	• For at least two weeks, SBS must affect 20 percent of the building residence.
Shan, Xin, et al. (2016)	An occupant of a building can temporarily experiences symptoms of sensory irritations.	• An SBS sign's reach cannot be limited. • They last only a brief period.

In recent years, where individuals spend 90 percent of their time indoors, a healthy indoor setting has become a top priority (Ritchie and Dennis, 2005). Nowadays, buildings designs that choose to save money led to false economics over a superior design that values providing sufficient fresh air, which can cause a cut down in the fresh air by almost 5-10% (Janis, 2011). It is therefore important to understand and report on the arrangements for servicing and maintaining the air conditioning systems to reduce the risk of this syndrome in the design process.

Dirt accumulation all-over air-conditioning diffusers adhering to the ceiling is frequently related to poor air-conditioning. During the process of bringing conditioned air into a room by the grille, velocity variations make dirt present in the air. Carpet fibers, dust, paper fragments, many different equipment such as photocopier or toners and many other things that may become airborne can make up this filth.

The Legislative Assembly (2001) urges all buildings to be built and shaped out by materials which should not contaminate the inside air with SBS, meaning that any contamination of SBS must be avoided at the design stage. SBS could be caused when the planning, implementation, maintenance, and testing of HVAC systems for public buildings and other structures were not provided in line with the checklist developed by the authorities. This technical knowledge would be beneficial to give to the professional who develops and maintains the building ventilation system.

Sick building syndrome (SBS) can be originated by a consolidation of factors, such as poor ventilation and an irritant gas recognized as formaldehyde released by paintwork, furniture, and fittings. Experienced investigators can diagnose the cause of SBS and take appropriate action to eliminate the problem (Jennings, 2010). for example, batteries, used to power emergency backup equipment for telecommunications, were generating fumes. As a result, the room was evacuated after warning signs appeared and ventilation quality was insufficient.

There is a high likelihood of acquiring the sick building syndrome in large open plan offices with more than 10 workstations, if the rooms contain a large amount of open shelving or soft furnishings, or if the furniture or carpets are new according to the Health and Safety Executive (Abdul-Wahab, 2011). Having a poorly maintained air conditioner and poor lighting in a room are also factors contributing to SBS, adding to the list of buildings in which ventilation, temperature, or lighting are uncontrolled, as well as buildings that have poor maintenance. Additionally, the study noted that people with the least control of their working environment and those who used display screen equipment were more likely to experience Sick Building Syndrome.

In an investigation of SBS causes, the US EPA (2010) cites the following four key factors as being crucial;

- Complaints from building occupants
- Insufficient ventilation may also result in Indoor Air Quality (IAQ) issues - heating, ventilation, and air conditioning (HVAC) systems
- A range of other factors may also play a role, such as contracting an illness outside of the building, intense sensitivity (such as allergies), job stress, dissatisfaction, and so on.
- Sources of potential contamination

2.1.2 Affects and Influences of SBS on Human Beings

Human health and wellbeing can be improved by a common authority (national and international regulations) in manufactured habitats, which will contribute to reducing SBS cases. As Rollins and Swift (1997) illustrate, there are a lot of forces in the built environment, both internal and external, which can be controlled to minimize the impact on occupants. Eventually, by identifying the problem areas, appropriate risk control measures could be implemented in the affected areas (Abdul-Wahab, 2011).

According to (Sundell, 2004) over the past decade, indoor environmental factors have become increasingly recognized as influencing health, well-being, and productivity. As the indoor environment becomes poorer, a wide range of symptoms are experienced, including eye, nose, throat, skin, headache, and fatigue frequently denoted as SBS (Peder, Ole, & Bo, 1990).

For instance, A study by Molhaye (1987) put forward that there are *five broad categories of symptoms* that are out there for SBS.

1- Sensory irritability; including the eyes, and upper respiratory tract (nose and throat). Usually, sick buildings are dissatisfied with the following:

- Stuffy nose, sneezing and running nose, as well as dryness.
- Abeyance by irritating, stinging, smarting sensations.
- Expanded by dry coughs with a change in the voice and hoarseness.
- Dry and issues to the people using a contact lens.

2- Symptoms of skin irritation are the hardest symptoms to connect to SBS since it takes a lengthy time to occur/appear and can be associated with additional factors or health conditions, yet, can be classified under the following terms:

- Itchy and dry skin.
- Increase in the redness of the skin.
- A burning, itching sensation.

3- Symptoms of neurotoxicity, like:

- Experiencing mental fatigue
- Focusing and concentration issues,
- Deficiency in memory,
- Exhaustion and headache with pain described as heavy head pressure
- Other uncommon side effects of SBS like dizziness and nausea.

4- An obstacle with smell and taste, because of the following:

- Irritation and sensitivity of some products are caused by the expansion of their odor in closed spaces.
- The diffusion of some inhabitants may cause a kind of nausea.

5- Hyperreactions of unknown kinds of symptoms. For example, due to SBS, nonautomatic people began to have asthma-like symptoms, as well as other respiratory health difficulties such as breathing problems, chest tightness, and allergies, as well as a severity rise in their symptoms.

It is also worth noting that SBS has a distinct impact on various people. While some of the symptoms may be experienced by everyone who spends time in a specific location, they can differ. Some folks may have no symptoms at all. Others may have symptoms after leaving the building in question, which might be the result of repeated or long-term exposure.

2.1.3 Characteristics and the Factors Causing SBS

Individual performance is influenced by the conditions of the environment inhabited (Abdul-Wahab 2011). As the causes and factors are different, the effects and influences on humans will vary. Further, space and environmental quality may have a direct effect on causing SBS.

Based on the study by Joshi (2008), some of the factors that contribute to SBS due to indoor environmental problems have been revealed and identified;

1. Chemical Contaminants

Exterior resources: SBS can be caused by exposure to certain chemicals and dust. Contaminants often enter a building from the outside through vents, ventilation shafts, and other openings, like those around motor vehicles, exhausts, plumbing vents, and building exhausts (bathrooms, kitchens) if they are poorly located. It is possible for combustion by products to arrive into a space from a neighboring place. Building parts such as pipes and openings in poorly designed buildings can let in Radon, formaldehyde, asbestos, dust, and lead paint. For instance, Bo et al. (2013) investigated how Volatile organic compounds (VOCs) in homes correlated with airborne bacteria, molds, formaldehyde, and two plasticizers in Swedish homes. 159 individuals participated in this study from three cities in Sweden, Iceland, and Estonia. In the findings, MVOCs (Microbial Volatile Organic Compounds), formaldehyde, and the plasticizer hexanol all contributed to the development of SBS, specifically mucosal symptoms.

Interior resources: Volatile organic compounds (VOCs) can be named as the highest found contaminants in indoor air. VOCs can be found in adhesives, upholstery, carpets, copy machines, produced wood items, pesticides, cleaning chemicals, and other products. In addition to these, environmental tobacco smoke, respirable particulates, and combustion byproducts from stoves, fireplaces, and unvented space heaters, chemical contamination is increased. Additionally, synthetic fragrances in cleaning or maintenance products can cause contamination or may lead to fine dust (Lim et al., 2015, pp. 353-356). In contrast, research has indicated that SBS can be modified over time. Researchers Samuelberg, Mi, and Norbck (2009) examined to what extent SBS has changed over an eight-year period and found that indoor painting plays a significant role in SBS development.

2. Biological Contaminants

Pollen, bacteria, viruses, fungus, and mold are among the biological contaminants that can affect indoor air quality (IAQ) inside buildings' environments and that put residents' health and well-being in harm. Static water that has accumulated in humidifiers, drainpipes, ducts, or on ceiling tiles, insulation, carpets, and upholstery may contain these contaminants. It has been hypothesized that a variety of factors contribute to the growth of biological factors inside buildings, including structural failure, improper maintenance, and poor ventilation (Pernilla, Annika, & Gunilla, 2014, pp. 404-409). Biological contamination can also come from insects and bird droppings. Fever, chills, cough, chest tightness, muscular pains, and allergic responses are all symptoms of biological contamination.

For instance, Boechat, J. L. et al. (2011) studied the frequency of Sick building syndrome on employees of two buildings in Brazil, and revealed its connection with fungous exposure in the work settings. In a sealed facility, 160 employees were tested, while in a natural ventilation structure, 164 employees were tested. Thus, Non-sealed buildings were found to have the greatest risk of SBS from fungal exposure, whereas sealed buildings had no significant fungi exposure. Additionally, when there is a high density of residents in an office, airborne illnesses caused by fungal exposure can quickly spread from one worker to another. According to Singh (2005), residents who are exposed to these polluted settings on a regular basis may develop health problems such as respiratory and allergy illnesses.

On the other hand, air-conditioning systems may cycle germs and transmit them throughout a building, such as Legionnaire's disease, which is caused by legionella microbes (Wai-On, 1988).

3. Inadequate Ventilation

If the heating, ventilating, and air conditioning (HVAC) systems do not efficiently distribute air to individuals in the building, inadequate ventilation may develop (Hanie et al, 2010). Asthma fatigue, rhinitis and increased susceptibility to influenza and colds can be symptoms of a poor ventilation system (Bakó-Biró et al., 2012).

According to (ASHRAE, 2009), "to remove bio effluents (odors), ventilation standards and guidelines suggest a ventilation rate of 8 liters per second per person." Sundell et al. (2011) found that a greater office ventilation rate, as high as 25 liters per second per person, decreases the prevalence of SBS symptoms, whereas a smaller ventilation rate leads to symptoms like inflammation, asthma, respiratory infections and short-term absences.

4. Electromagnetic Radiation

Electromagnetic radiation from devices such as microwaves, TVs, and computers ionizes the air. In the context of human health, ionizing radiation is defined as a source of energy with high frequency resulting in serious health problems (Christensen et al., 2014). Genius (2008) describes the electromagnetic spectrum as being a group of distinct electromagnetic forms of energy that are emitted from multiple sources and have different frequencies. According to him, there are diverse types of electromagnetic radiation which are;

- High frequencies radiation, like X-rays, gamma rays, and ultraviolet light.
- Low frequencies like microwave radiation.
- Medium frequencies include radiation and light waves that can be perceived by the human eye and ear.
- Infrared rays that can be used to perceive heat.

Human beings are constantly exposed to low levels of natural ionizing radiation, including radioactive materials on the earth's surface, sunlight, natural radioactivity, radioactive gases emitted from the earth, and cosmic rays from outer space entering the ionosphere as stated by Zamanian and Hardiman (2005). In this regard, several initiatives have stressed the importance of addressing human exposure to building materials. Many building materials like cement, and gypsum contain a radioactive gas, and the exposure of the occupants to the indoor radon that separated from those materials. As a result, causing lung cancer related to pathological and functional changes to the respiratory system (Bavarnegin et al., 2013 cited in Amirhosein et al. 2018). For instance, Saad and Hussein (2014) evaluated radon emission rates from 37 samples of different building materials used in the construction and decoration of buildings located in Libya, and hence among the results, they found that the concentration of radon in Italian marble and Indian granite was high. As follows, alternative materials were recommended to be used instead (cited in Amirhosein el al. 2018).

5. Psychological Factors

SBS is frequently linked to excessive work stress or discontent, poor interpersonal interactions, and poor communication. And the matter of monotonous work environment is believed to be one of the psychosocial factors that contribute to the development of SBS (Gül, 2011), thus, the result can be a decrease in productivity rate as employees become mentally disengaged from their work. There may be psychological factors involved; extreme work stress, low job satisfaction, and poor interpersonal relationships and communication may all be factors contributing to SBS symptoms.

It has been suggested by Marmot et al. (2006) that psychological and social aspects of a workplace may have a greater impact on SBS symptoms than physical factors. It is much more likely that the two elements work together to trigger symptoms. In other words, negatively impact occupants' well-being by making them anxious, depressed, uncomfortable in their surroundings, stressed, and reducing their productivity indeed.

6. Illumination Level

SBS may also be caused by inadequate and improper illumination, such as the lack of sunshine. By affecting the occupants' visual comfort, poor light quality can directly impact human health. Several studies have demonstrated that light can act as an alerting stimulus by indirectly modulating the ascending arousal system, thereby facilitating thalamocortical connections (Van Maanen et al. 2016). As an example, research which was carried out by Hwang and Kim (2011), highlighted the significance of interior space lighting level on users’ health.

7. Noise Level

As a stressor, noise is pervasive and has a high potential to distract individuals who are involved in a specific enactment (Takki et al. 2011). Noise exposure at night can have substantial long-term health consequences, including behavioral issues and cardiovascular impacts. Buildings with industrial machinery and ventilation equipment are more likely to generate a low-frequency noise between 20 Hz to 100 Hz (Bluyssen et al., 2011, pp. 280-288). Wong et al. (2009), for example, investigated connection among users' health besides the environment settings in Hong Kong by assessing the prevalence of SBS among 748 families and evaluating indoor environmental quality (IEQ).

Nevertheless, it is important to introduce the approach of IEQ to understand and help developing the environmental quality that maintains the satisfaction of the occupants as it is an important part of spatial comfort. Moreover, a comprehensive approach and maintenance are required for an effective process to improve the perception of indoor climate conditions (Abdul-Wahab, 2011), affecting the health and well-being of humans.

2.1.4 Recommendation for Improving Health and Comfort in Relation to IEQ

There is no doubt that poor indoor environmental quality (IEQ) (occurring due to temperature, acoustics, lighting, and air quality) can seriously impact the comfort, health, as well as building users' productivity (De Giuli et al., 2012, pp. 335-345). In ASHRAE Position Document on Indoor Air Quality (2020), it is described as a perception of the indoor atmosphere that includes aspects of planning, analyzing, and operating energy-efficient, healthy, and comfortable buildings. The performance of occupants in buildings has also been a wide area of focus for researchers and practitioners (Bluyssen et al., 1995) since the quality of a building has a direct effect on the productivity, comfort, and health of its occupants (De Giuli et al., 2012). At the current time, providing a healthy and comfortable indoor climate has become essential, which can be achieved through ensuring a prominent level of IEQ by considering the *four basic environmental factors* (indoor air quality, thermal environment, visual environment, and acoustical environment).

Indoor Air Quality

Three perspectives can be taken into consideration when studying indoor air quality: the human, the indoor air, and the sources contributing to indoor air pollutants (Kurrey et al., 2019). To maintain good indoor air quality, varied factors must be considered, such as “interactions between building materials, building services, location, climate, contaminant sources, and occupancy (Norhidayah et al., 2013, pp. 93-98).

Pollutants that affect indoor air quality come from sources inside buildings, though some originate outdoors, according to the World Health Organization (2017). It has been noted that sources that release gases or particles into the air are the primary cause of poor indoor air quality (US EPA, 1997). According to EPA (1997) Indoor air pollution can come from several sources like;

- Indirect combustion products such as carbon monoxide and particulate matter are released into the indoor air by using tobacco, wood and coal heating and cooking appliances, and fireplaces.
- Cleansing supplies, paints, insecticides, and other commonly used products contain a wide array of chemicals, including volatile organic compounds that are emitted directly into the air.

- Materials used in building construction can also contribute to the release of pollutants, depending on whether they are degrading (e.g., asbestos fibers released from building insulation), or whether they are new (e.g., chemical off-gassing from pressed wood products).
- In estimating interior air pollutant concentrations, the air exchange rate with the outdoors is crucial. Building design, construction, and operational characteristics all have an impact on air exchange rates. Infiltration (air that flows into structures through openings, gaps, and cracks in surfaces), as well as natural and mechanical ventilation, are all factors that contribute to indoor air quality.

Thermal Environment

ASHRAE, (2013) defines thermal comfort as the subjective evaluation of the thermal environment and expresses satisfaction with it. The four primary environmental variables that influence human response to thermal environments are radiant temperature, air temperature humidity, air velocity and personal variables like clothing and activity level. A human body responds to environmental variables in a dynamic interaction while maintaining a state of maximum optimum health. When the response is inappropriate or energy levels are beyond survivable limits, the body is strained, causing the strain to result in death. As a result, human perception of thermal comfort is influenced not only by physical factors, but also by metabolic activity, clothing, and personal preferences. However, there is no universal comfort zone for people of distinct cultures; people in the same family may feel comfortable under different conditions, and keeping everyone happy at the same time is not easy. Various aspects may be underlined under the thermal comfort of an occupant in indoor spaces (Katafygiotou & Despina, 2015);

1. Radiant temperature

Radiant heat is the radiation of heat emitted by a warm object. If there are heat sources in an environment, radiant heat may be present, which plays a more key role than air temperature when it comes to how we lose or gain heat. Solar heat, fire, electric heat, ovens, kiln walls, cookers, dryers, hot surfaces, molten metals, etc. are examples of radiant heat sources.

2. Air temperature

This is the temperature of the air in the immediate vicinity of the body and which is commonly expressed in degrees Celsius (°C). The quality of the interior context has a noteworthy influence on the health and productivity of inhabitants. All building occupants suffer when temperature extremes—too cold or too hot—become the norm. People must expend physiological energy to cope with the environment in extremely hot or very cold spaces, an energy that could be better used to focus on work and learning, especially since research has shown that people simply do not perform as well, and attendance drops, in extremely hot and very cold workplaces.

3. Humidity

The presence of humidity is a function of water evaporating into the environment after being heated. Humidity levels between 30% and 70% do not significantly affect thermal comfort, but if there is no air conditioning or the weather outside affects the indoor thermal environment, relative humidity may be higher than 70% in non-air-conditioned space (Gilmore, 1972, pp. 99). Besides that, the vapor is abundant in high humidity environments, which prevents sweat from evaporating, so it is important to have humidity in hot environments since the sweat evaporates less when humidity is high (60%+), as sweat is the main method of reducing body heat.

4. Air velocity

It represents the speed at which air moves across the inhabitants, and may help them cool down if the air is cooler than the surrounding environment. Thermal comfort is influenced by air velocity. It can be quiet or stagnant air in artificially heated interior situations, which can make individuals feel stuffy and contribute to odor build-up. In hot or humid situations, moving air can enhance heat loss by convection without changing the air temperature. Because physical activity increases air movement, air velocity may be adjusted to take into consideration a person's degree of activity. People are particularly sensitive to small air movements, which can be perceived as a draught in cool or cold environments.

Visual Environment

Visual comfort refers to lighting conditions and views from one's position in an interior area. Insufficient light, particularly daylight or glare, makes it difficult to see objects or details properly (Leech et al., 2002). As a result, visual comfort is critical for the well-being and productivity of building inhabitants (Leech et al., 2002, and Serghides et al., 2015). In regions where natural lighting is lacking or during the evening when natural lighting diminishes, people must have access to both natural and artificial illumination to ensure their well-being (Aries et al., 2010). Afterward, lights have two primary effects on humans; they allow building inhibitors to see clearly and they govern people's bodies' rhythms, such as the sleep/wake cycle. As a result, mixing natural and artificial lighting to produce homogeneous illumination in the interior area is desirable. There are several aspects that influence the lighting comfort within a structure, based on (Kevin, & Mehlika, 2014, pp. 145-164);

- Lighting system design: This impacts the distribution of light across the room. A proper design can help you avoid a gloomy spot or area.
- Light distribution: A non-uniform diffusion of light into the room will accentuate the gloomy part and space.
- Light reflection: The amount of light reflected is determined by the color and finish quality.
- Space area: The wide area is more efficient in utilizing the lighting than the small area.

Acoustical Environment

Acoustic comfort includes providing occupants with a comfortable acoustic environment, while protecting the interior of the building from noise. Acoustics have a significant impact on occupant comfort and productivity and are therefore increasingly being considered in the design of new buildings for offices, healthcare, and educational institutions (Passero & Zannin, 2012, and Shafaghat et al., 2014). As an example, the growth of open-plan office designs has led to concerns about occupant privacy and acoustic comfort (Sundstrom et al., 1994). There are many causes of acoustic problems, including noise from airborne particles, outdoor sound, noise from adjacent spaces, noise from office equipment, and sound from nearby structures (ANSI, 2010). Symptoms including seizures can be triggered by noise and vibration from HVAC systems, vacuums, pumps, and helicopters. Thomas et al., (2018) state that elevated noise in the workplace or home can impair hearing, increase blood pressure, cause ischemic heart disease, cause annoyance, disrupt sleep, or degrade exam performance. As part of addressing acoustic problems, it is necessary to assess what happens indoors and outdoors during the design phase (Bluyssen et al., 2011). In addition, acoustic problems must be addressed during the design phase of the project, since there is a direct relationship between occupant comfort and productivity (Landstrm et al., 1995). Noise pollution has been extensively researched as a form of energy pollution in which irritating, distracting, or damaging sounds are freely audible. An occupant's acoustical comfort can be influenced by several factors as outlined in the following list by Troldtekt, (2016):

1. Appropriate reverberation time: In the enclosed space, reverberation is the persistence of sound after the source of sound has ended. Reverberation time can be affected by many factors in space. In a room, the sound is prolonged based on how many times the wave can reflect off surfaces. Hard, shiny, flat surfaces in space will reverberate longer than a fluffy room. Both tiles and glass have absorption coefficients (Noise Reduction Coefficient) of approximately zero. Noise Reduction Coefficients can be found and used through carpeting and ceiling tiles.
2. A suitable sound level: Too little, as well as too much sound, can be detrimental to health, and it was found that noise was significant for coronary heart disease (Nina, et al. 2017). To avoid noise-induced hearing loss, the EPA (the United States Ambient Protection Agency) and the WHO (World Health Organization) (1995), suggest that environmental noise be kept below 70 decibels for 24 hours. Speech interference and annoyance limits were set at 55 decibels for outdoor activities and 45 decibel indoor activities.
3. Echo: When a reflected sound wave hits the ear at the same time as the original sound from the same source, an echo is created. There must be no echo in an acoustically good environment. If there is a huge smooth, hard wall at one end of a dampened room and you are at the opposite end, you may hear an echo.

Installing sound-absorbing material on one of the walls, on the other hand, will effectively eliminate the flutter echo. Furthermore, rough, and porous interior surfaces are used to scatter echoes' energy.

Incorporating complex interactions among these sub-systems, their underlying variables, attributes, and the environment's properties could result in overall perception of indoor comfort, as human comfort is a multifaceted concept that has ramifications on the components of the environment's physical attributes and properties. Temperature and humidity, for instance, are factors that can improve acoustic comfort. It has been shown that the location of a room (facing the street or facing a quiet side), impacts both thermal comfort and acoustic comfort. A room facing south has more natural light and thermal comfort than one facing north. Temperature, acoustics, and visual comfort are all affected by the size of the room (Yue, et al., 2019). On the other hand, lighting should be analyzed carefully to reduce annoying glares and reflections, based on the design of the indoor building. A better understanding of the interactions between IEQ contributors is provided in Figure,1.

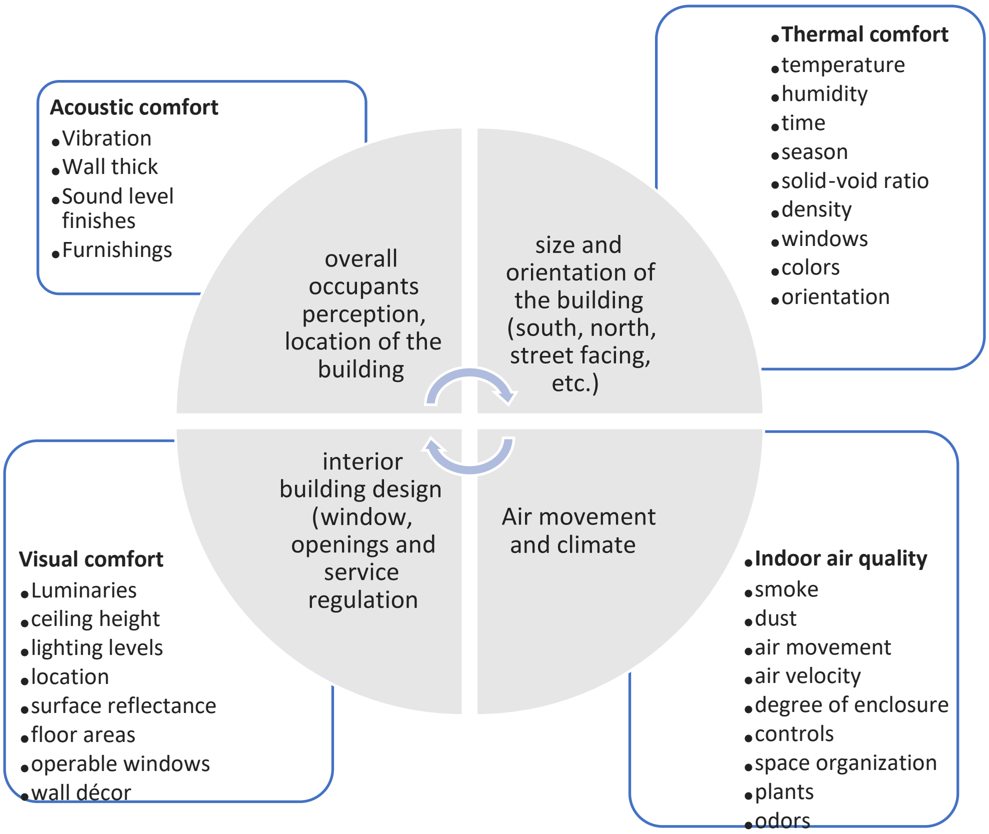


Figure 1: Interactions Among These Subsystems Define the Physical Environment That Affects the Overall Perception of Indoor Quality

2.1.5 Framework Development to Control SBS Occurrence

The literature review in this section supports the understanding of the possible issues in order to prevent SBS occurrence in indoor spaces. The final purpose is to provide framework as proposed in Table (2, 3, 4, 5, 6, 7, 8, 9, 10, 11) in order to correlate SBS issues with the biophilic approach to enhance the indoor environments and occupants' well-being. To find strategies to come up and help in the mitigation of SBS issues, it is important to address the matters having links with SBS.

Accordingly, the goal is a healthy building that avoids hazardous materials, attributes, and processes. As a result, for the building to maintain the health and comfort of its occupants throughout its lifecycle, it is important to include subjective aspects, such as attributes that have a direct effect on the physical building character and hence the occupants. In short, the present study provides a matrix for analyzing contributors and mitigation approaches to SBS from factors affecting exterior and interior resources, stage of handling contamination, and then suggests solutions/synthesizes/actions that can aid in solving SBS issues in interior buildings. It includes a matrix for SBS evaluation involving a critical analysis of the effectiveness and complexity of easing principles as part of a livable built environment, demonstrating the importance of later using an implementation of the Biophilic design to solve some of the SBS issues inside buildings.

Additionally, each of the five SBS frameworks will be accompanied by a brief summary. As a starting point, the summary will describe and conduct the research studies and perceptions of the five SBS contributors, in the form of achievable actions. It would provide the study with a way to build on and a guideline to follow, and suggest possible solutions/synthesis that can be taken by each contributor in a form of frameworks. Based on the literature review, frameworks first define the factors affecting and whether they are external or internal resources. Then the frameworks define the stages of dealing with contaminations to include practical solutions/synthesizes and actions that can resolve SBS contributor issues. Noted that the suggested solutions/synthesis added for the SBS contributors would be used later on and aligned with the biophilic design approach. Specifically, correlate the keywords in italics in the tables with the biophilic design approach.

It is important to note, however, that because all of the four basic environmental factors (indoor air quality, thermal environment, visual environment, and acoustical environment) interact, the physical contributor that affects the perception of indoor climate would be defined by the interactions between those four subsystems. Thus, a summary would be better if the authorities' guidelines and studies are introduced at the beginning of the section on physical contributors.

Table 2: An Analysis Matrix for Chemical Contributors

	Factors of affecting		Stage of dealing with the contamination	Solution/synthesis and actions
Chemical	building material and contaminants like MVOCs, formaldehyde, plasticizer Texanol, fine dust, and concentrations of CO2 in C14 3–OH and C18 3–OH	Exterior resources	Design stage	• Selection of *building materials* and construction methods that minimize the *exposure* to *indoor chemicals.* • Controlling *air pollution* within a building by adjusting the design of supply and exhaust *flow rates.* • Building *air intakes* should not be situated where *outdoor pollutants* from motor vehicles and manufacturing can be a problem. • Preventing the onset of SBS can be achieved with *low-VOC paints.* • To reduce the deposit of particulate matter on carpeting, *mineral* floor surfaces could be used on *entry-level floors.* • To eliminate long-term emission of VOCs, *high volatility* solvents for rapid emission were selected in interior *finish materials.*
	VOCs, concentrations of C18 3–OH CO2, C14 3–OH, fine dust, and NO2 (from cooking with gas or cigarette smoke)	Indoor resources	Use stage	• Maintaining a clean *environment* and improving *hygiene.* • Users' impact on the environment through *furniture layout* and *interior layout*; control of air pollution emissions; smoking restrictions; and utilization of *indoor plants*. • It is required that all chemicals be *stored* in *areas* that are *ventilated*. • Cleaning with chemicals requires *good ventilation*. • Consider purchasing *carpet* and *furniture* made with low levels of *VOCs*, to minimize the effects of indoor air pollution. • Usage of acceptable *materials without toxicity*, microbes, dampness, mold, and other problems.

Summary to chemical contributor

SBS by the chemical contaminations can be caused by exposure to certain chemicals and dust. It could be an interior or exterior resources. As a major contributor to SBS, Takigawa et al. (2009), point out to the existence of chemicals (e.g., symptoms of indoor aldehydes, volatile organic compounds, airborne fungi, and dust mite allergies). It was suggested to consider an indoor chemical mitigation strategy as a remedy for reducing the availability of SBS in recently constructed houses.

Although chemicals can be produced for up to five years after a new carpet is placed, the bulk of off-gassing occurs in the first few months. The EPA advises that strong ventilation be used for at least three days following the installation, that bare floors with rugs be used instead, or that natural fiber carpets be chosen. Alongside the stated issues, different nanoTiO2 particle-based 2 photocatalytic paint formulations are still being researched to enhance indoor and outdoor air quality. In the presence of UV irradiation, photocatalytic paints containing the mineral silicate binder emitted few VOCs (Julien et al., 2019).

Based on the information collected, we can see that theirs is common solutions and actions that can be taken to solve chemical contributors in both the design and use stage. Moreover, in the design stage, factors affecting the human health and wellbeing in the indoor space like (building material and contaminants like MVOCs, formaldehyde, plasticizer Texanol, fine dust, and concentrations of CO2 in C14 3–OH and C18 3–OH) would be solved through; the selection of building materials and construction methods that minimize the exposure to indoor chemicals; controlling air pollution within a building by adjusting the design of supply and exhaust flow rates; building air intakes should not be situated where outdoor pollutants from motor vehicles and manufacturing can be a problem; preventing the onset of SBS with low VOCs paints; and the use of low VOCs emission for interior finishing materials.

During the use stage, factors affecting human health and wellbeing in the indoor space like (VOCs, concentrations of C18 3–OH CO2, C14 3–OH, fine dust, and NO2 (from cooking with gas or cigarette smoke)) would be solved through; maintain a clean environment and hygiene; through the use of the indoor plants to control air pollution emissions; all chemicals should be stored in areas that are ventilated; finally, the use of non-toxic materials.

Table 3: An Analysis Matrix for Biological Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Biological	Molds, fungus, and mites are all types of microorganisms that may be found in the environment, as well as 6-pentyl-2-pyrone.	Indoor resources	Construction stage	• Proper care and maintenance of *exterior walls and roofing systems,* controlling condensation, and observing construction defects such as *window problems*. • Regular *maintenance* is required to prevent *plumbing leaks* • A frequent *cleaning regimen* and improved *hygiene* • If *mold* and *humidity* are present, they should be reduced. • proper *cleaning* of the *HVAC* system. • Controlling the *interior* air *temperature* using a functional *control system*. • In locations that are likely to become wet, *monolithic flooring* is recommended.

Summary to Biological Contributor

Regarding the growth of biological factors inside buildings, there are several contributing factors. The failure of structural components, inadequate ventilation, or improper building maintenance are examples of these problems (Johansson et al., 2013; Vereecken & Roels, 2012).

Lu et al. (2016) explained reducing household molds and moistness, controlling air pollution emissions from home renovations, and improving building ventilation by frequently opening windows and using an exhaust fan in bathrooms can help reduce SBS symptoms. The 6-pentyl-2pyrone produced by mold can cause symptoms of SBS to appear. It is a compound emitted from building materials that might cause mucosal damage and irritation (Viviana et al., 2011). Lu et al. (2016) offers suggestions to reduce SBS: mold/dampness reduction, reduction of air pollution from home renovations, and enhanced ventilation of buildings.

A research study performed by Lim et al. (2015) found that the use of a thermostat coupled with frequent house cleaning in tropical office environments can reduce house dust mite allergens. In humid environments, microorganisms like mildew and mold can grow up and pose a serious threat to residents' health (Robert, Glenn, & Kyle, 2016 cited in Amirhosein et al., 2018).

It is evident from the data collected that there is a common solution and action that can be taken to address biological contributors at the construction stage. As well, factors affecting human health and well-being in the indoor environment like (Molds, fungus, and mites are all types of microorganisms that may be found in the environment, as well as 6-pentyl-2-pyrone) would be solved by actions such as; proper care and maintenance of exterior walls and roofing systems, controlling condensation, and observing construction defects such as window problems; regular maintenance is required to prevent plumbing leaks; controlling the interior air temperature using a functional control system; finally, in locations that are likely to become wet, monolithic flooring is recommended.

Table 4: An Analysis Matrix for Electromagnetic Radiation Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Electromagnetic radiation	Cement, gypsum, granite, sand, and all types of rocks release radionuclides of 226Ra, 232Th, and 40K, which can be detected in construction materials.	Indoor resources	Design stage	• Control of electromagnetic *radiation*. All electrical *appliances* and *wiring* have been placed and designed in such a way that electromagnetic *fields* are kept to a *minimum*. This is advantageous since all electrical *lines are earthed* and secure. • For a house with proper *air exchange*, *construction materials* utilized in the living environment have no substantial *impact* on indoor *radon* level.
			Construction stage	• *Non-toxic* indoor *materials*, such as *glass fiber* core materials, are preferred since no dangerous *gases* are generated during short- or long-term use (used as *insulation*, *cladding*, *surface coating* and *roofing raw* material in construction). • The use of safe finishing building materials with a *low radioactivity* contents like *brick* and *cement*, using of *granite* or silicic *alkaline* igneous *rocks* with a high radioactivity content. *Metamorphic rocks* and *limestone* also have low uranium levels.

Summary to Electromagnetic Radiation Contributor

The electromagnetic spectrum as being a group of distinct electromagnetic forms of energy that are emitted from multiple sources and have different frequencies. Accordingly, there are diverse types of electromagnetic radiation which are (Cement, gypsum, granite, sand, and all types of rocks release radionuclides of 226Ra, 232Th, and 40K, which can be detected in construction materials).

However, the electromagnetic contributor can be in both the design and the construction stage solved through; placing and designing the electrical appliances and wiring in such a way that electromagnetic fields are kept to a minimum, as well the electrical lines are earthed and secure; for a house with proper air exchange, construction materials utilized in home decorating have no substantial impact on indoor radon level; also, the use of non-toxic indoor materials, such as glass fiber core materials, is preferred since no dangerous gases are generated during short- or long-term use (used as insulation, cladding, surface coating, and roofing raw material in construction).

Table 5: An Analysis Matrix for Psychological Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Psychological	Occupational stress and a monotonous work environment	Both indoor and outdoor resources (and the development should be interior and exterior)	Design stage	• Establishes the minimum height of windows for exterior views. • proper *landscape allocation*, as well as potential natural contact • the appropriate use of *color* in *relation* to the *function* of the space • Biophilic design is used to improve the psychological and social aspects of space by ensuring *adequate ventilation*, providing maximum access to *natural light* and *views* to the *outdoors*, eliminating or controlling sources of *indoor* air *contamination*, preventing water leaks and unwanted moisture accumulation, and improving the *psychological* and *social* aspects of *space*.

Summary to Psychological Contributor

A psychological factor is linked to excessive work stress, dissatisfaction, and poor interpersonal interactions. Thus, one of crucial negative effect of SBS is the decline in the productivity rates of occupants. The implications are particularly relevant for those who have continuous exposure to a sick environment (such as employees or pupils) (Lan et al., 2011). The expenditures on reducing workers' productivity could be reduced by almost 10%-30% by having healthier and more efficient interior settings. To reap the full financial, physical, and psychological advantages of healthy buildings, projects must use a complete, integrated design and development approach that focuses on improving the psychological and social components of space (William J. and Arthur, 1997). As well, by providing a view of a pleasant outdoor sight or interior space, the eye can amend and refocus, leading to improved health and higher productivity in workplaces (Kaplan 1992; Van & Bergs 2001).

However, the psychological contributor can be in the design stage solved through; establish the minimum height of windows for exterior views; proper landscape allocation, as well as a potential natural contact, and the appropriate use of color in relation to the function of the space; use the biophilic design to improve the psychological and social aspects of space by ensuring adequate ventilation, providing maximum access to natural light and views to the outdoors, eliminating or controlling sources of indoor air contamination, preventing water leaks and unwanted moisture accumulation, and improving the psychological and social aspects of space.

Table 6: An Analysis Matrix for Physical (Ventilation) Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Physical (Ventilation)	Air flow rate is less than 8 l/s per person due to poor ventilation	Both indoor and outdoor resources (temperature, wind pressures and humidity)	Design stage	• Utilization of *passive design techniques* to optimize the *spatial layout* and maintain a comfortable temperature in the living environment by *using* the *local climate.* • A *smart/responsive* building *skin* is integrated with an advanced *ventilation system* and physical modifications, like using *greenery* in buildings, should be considered. • For *dust* and *toxic gases* or fumes to remain at a safe level, adequate *ventilation* is required, including *air circulation* and air changes. • Maintaining good *indoor air quality* with A fresh and clean air supply and a proper ventilation (*cross ventilation* is most effective).
			Construction stage	• Air *duct installation* and *ventilation* equipment quality. *Heat* and *pollutants* are transported away from the inhabited zone by *buoyant air movement.* Thus, a mixed layer of warmed air forms in the upper half of the room.
			Use stage	• enhancing *room ventilation* by *opening* the building's *windows* and *doorways*. • Maintain a *clean exterior* area near the *air intake* of the *HVAC systems.*

Table 7: An Analysis Matrix for Physical (Illumination Level) Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Physical (Illumination level)	Poor lighting quality and levels of illumination. For greater performance and wellness, 1000 lux is recommended.	Both indoor and outdoor resources (natural and artificial light)	Design stage	• To *increase daylighting*, small optical *light shelves*, light-directing *louvers*, *light-directing glass*, *skylights*, roof monitors and clerestories, *heliostats* and *light tubes* are used. • The use of modern *daylighting solutions* that are both innovative and practical to *boost* the quality of *light*. • An adequate *amount* of *daylight* with no *glare* (i.e., Choosing the right *window size* is important and should be considered carefully). • *management* of *solar gain* (excessive glass might cause interior warming).

Table 8: An Analysis Matrix for Physical (Noise Level) Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Physical (Noise level)	Exposure to low frequency noise between 20 Hz to 100 Hz, at night.	Exterior resources	Design stage	• Minimum amount of *external noise* and an adequate *acoustic level.* • Designing and integrating *acoustic technologies.* • Using *ceiling tiles*, to *absorb* the *sound*. • Using work station *panels* and *workspace design*, to block the unwanted sound. • Electronic *sound masking techniques* are used to cover up noise.

Table 9: An Analysis Matrix for Physical (Indoor Air Quality) Contributors

Contributor	**Factors of affecting**		**Stage of dealing with the contamination**	**Solution/synthesis and actions**
Physical **(Indoor air quality)**	The indoor air quality is poor due to CO_2, SO_2, O_3, and PM10	Both indoor and outdoor resources	Design stage	• Specifies a *minimum ventilation* rate based on the *space functions* of a building type and *activity rates* of occupants (referred to as Ventilation Rate Procedure). • A key aspect of maintaining *good indoor air* quality is the introduction of outdoor air, whether this occurs *naturally*, such as through *windows and doors;* by *mechanical* means, such as through outside air intakes connected to *HVAC systems*; or through infiltration, a process by which outdoor air is drawn into the house through *cracks* and *openings in walls*, *floors*, and *ceilings*, and around windows and doors. • The *lobby/entrance* should be designed so people are aware that removing shoes is a requirement
			Use stage	• The reduction or *elimination* of individual sources of *pollution*. • The use of *air Purifier* to collect the pollutants from the *indoor air*. • Support *cleaner fuel technologies*, like kerosene and LPG/gas, instead of traditional biomass fuels. • *User behavior* can be modified to reduce *exposure* to indoor air *pollutants* by open doors and windows to improve ventilation in the indoor environment • *Housekeeping practices* such as wet mopping and *vacuuming* could *decrease* the number of *heavy metals* in a home environment. • To get rid of cooking fumes and steam in bathrooms, *run fans to the outside.* • *Smoke* and *pollen* in the air require more frequent *air filter changes.*

Table 10: An Analysis Matrix for Physical (Air Temperature) Contributors

Contributor	Factors of affecting		Stage of dealing with the contamination	Solution/synthesis and actions
Physical (Air temperature)	Temperatures that are above or below thermal comfort thresholds (hot or cold).	Exterior resources	Design stage	• The *use* of *cool colors* in senior condominiums can significantly alter skin temperature, heart rate, and blood pressure. • Controlling the *temperature* of indoor air by a *functioning control system.* • Implementation of *passive design* techniques for optimal *use* of *sunlight*. • Using smart/responsive building skins and the constant *opening* of *windows* is among the features integrated into *advanced ventilation* systems to control the indoor temperature. • Assess the potential for *open- or closed-building ventilation* (A *closed-building* approach is more suitable *in hot*, dry climates in which there is a significant difference in diurnal temperature. An *open-building* approach is more suitable in *humid, warm* locales where there is a small temperature difference between day and night).

Table 11: An Analysis Matrix for Physical (Humidity) Contributors

Contributor	Factors of affecting		Stage of dealing with the contamination	Solution/synthesis and actions
Physical (Humidity)	When relative humidity exceeds 60% in a living environment, it becomes uncomfortable for humans.	Both exterior and interior resources	Design stage	• *Dehumidifiers* and *air conditioners* can help to reduce moisture in the air, especially in *hot, humid conditions.* • *Mold* and many of these recognized biological pollutants may be controlled by keeping *relative humidity* values between 30% and 60%. • Promote air and *heat circulation* by using *fans* and moving *furniture away from wall corners.* • If carpets are to be installed over *concrete floors*, then a vapor barrier (plastic sheeting) will need to be placed over the concrete and covered with under-flooring (*insulation covered with plywood*) to *prevent moisture* problems.
			Use stage	• *Maintaining plants* brings additional benefits to the home, such as *increase humidity* by a process recognized as transpiration (like Areca Palm, Rubber Plant, Peace Lily, English Ivy, and Spider Plant). • On the opposite reaction, some *plants* can be set to act as a *dehumidifier* by absorbing water from the air (like Xerophytes, Epiphytes, Tillandsia, Boston Fern, and Reed Palm).

Summary to Physical Contributor

In order to describe the perception of indoor climate, we need to identify the interactions between those subsystems (ventilation, illumination, noise level, indoor air quality, air temperature, and humidity). Accordingly, to control the physical living environment conditions, Crook and Burton (2010) recommended minimizing the interior building products and decreasing moisture accumulation during construction, to minimize the possibility of mold growing indoors, as well as, balancing HVAC systems to maintain a comfortable temperature and humidity.

To avoid exposure to dust and harmful gases or fumes, enough ventilation, including air circulation and air changes, is essential to cure materials, disperse humidity, and prevent the buildup of particles, dust, fumes, vapors, or gases. In tutorial rooms, Shan et al. (2016) noted that a good ventilation system, as well as a well-designed room including thoughtful seating arrangement, may help to prevent SBS symptoms. Frequently cleaning the premises and improving indoor hygiene are also recommended by Dan (2009). In order to ensure a comfortable indoor climate, a proper control system should be used (Nor Dina Md, Zainal Abidin, & Wahid, 2015).

A study by Désirée and Allan (2007) found that improper lighting levels are one of the main contributors to employee dissatisfaction, along with poor interior climate, poor air quality, and high ambient noise levels. Gases and particles that are released into the air usually contribute to poor indoor air quality. Most pollutant buildup is caused by inadequate ventilation. As part of their study, Piers et al. (2016) collected and tracked participants' health self-reporting, and heart rate using IEQ test. According to the study, participants reported fewer symptoms under green building settings. Thus, it is important to control the factors that influence indoor air quality, like HVAC systems, and pollution sources.

Physical contributors (ventilation, illumination, noise level, indoor air quality, air temperature, and humidity) It is evident from the data collected that for the physical contributor (ventilation, illumination, noise level, indoor air quality, air temperature, and humidity) there is a common solution and action that can be taken to address at different stages (design, construction, and use stage). In short, the solutions can be through; the design of a smart/responsive building integrated with an advanced ventilation system and physical modifications, like using greenery in buildings, should be considered; the key aspect of maintaining good indoor air quality is the introduction of outdoor air, whether this occurs naturally, through windows and doors, or by mechanical means, such as through outside air intakes connected to HVAC systems; using smart/responsive building skins and the constant opening of windows are among the features integrated into advanced ventilation systems to control indoor temperature; dehumidifiers and air conditioners can help to reduce moisture in the air, especially in hot, humid conditions; finally, some plants can be set to act as a dehumidifier by absorbing water from the air (like some plants).

2.2 Biophilic Design

The earliest cities emerged around 6500 BC and marked a defining moment in human history when humans started building habitats away from the natural environment. Through agriculture and trade, people have evolved into more formal and sophisticated beings. Thus, as humans developed, they developed building materials such as concrete and metals. It was the technological innovations and social developments associated with urban development in the 20th century that led to the emergence of skyscrapers (Sarah & Carl, 1999). Yet humans are creatures of the earth, which means they are sensitive to its natural features, which can also be included in the constructed design, rather than relegated to the background. The revolutionary construction methods of these buildings set off a new level of flat, reflective glass skins and massive steel skeletons, and their relationship with the environment is usually not carefully considered (Jean, 1966).

Natural elements are healing and incorporating them into the design would enhance the quality of life in indoor spaces. Within a given setting, natural elements like light, water, wind, plants, and stones can contribute to the health and well-being of the human being, as these are crucial to human survival. By integrating these elements into one's built environment, the designer can facilitate the well-being of occupants. In this way, new buildings could be built and old ones could be modified to promote health and healing (Chris, 2002).

2.2.1 General Classification/Description of Biophilic Design

Biophilia is defined by Wilson, Edward O. (1993) as... "... the innate affiliation people seek with other organisms and especially the natural world" (p. 31). As Wilson has also noted, studies have shown that, when given the opportunity, people prefer to live and work in places that have three primary characteristics: high locations, open terrain with scattered trees, and a proximity to open water.

Over the last few years, multiple studies have demonstrated that green spaces have a positive impact on the life’s quality of human beings, as they lower stress levels, reduce anger, and improve productivity and creativity, while improving occupants' well-being and speeding healing (Ian et al., 2014).

According to the Collins Dictionary of Environment and Ecology (Collin, 2004), it is not a contemporary idea to affix nature into places. Biophilia and Biophilic Design are terms inferred from the prefix "bio," which means "relating to living" and the suffix "philia," which suggests "fascination to or adore for something". According to biophilia, which is the 'love of life', living organisms have two general tendencies: sustaining life, and integrating with other species (Erich, 1974). Various researchers try to translate humans' attraction and desire to connect with Nature, namely biophilia, into the design of environments. Nevertheless, to justify the effectiveness of the biophilic design, it has been formulated with various perceivable and cognizable characteristics of natural spaces. In conclusion, biophilic design entails more than building with vegetation; it encompasses different forms of natural elements on all levels, including physical, sensory, material, and spiritual elements.

There are many studies that have focused on the concepts of biophilia and biophilic design and a different classification/description have been added on biophilia by different researchers. According to Heerwagen & Hase, (2001), the concept of biophilic design describes how incorporating natural features into our daily lives improves our psychological and physical well-being, suggesting that the placement of indoor plants and photos of nature in windowless spaces offers a double benefit. They showed that 'nature' can be conceptualized differently in architecture. There attribution to the to the concept characterized by the defining the eight biophilic properties were defined as habitability, natural elements, design process, geometric design, joy, and enticement, thus defining what biophilic buildings are.

Kellert (2008) description to the biophilic approach as being an approach to architecture has been proposed as a way to satisfy this desire for 'nature' in buildings. He defined the two basic dimensions, six elements, and more than seventy attributes associated with biophilic design (dimensions, elements, and attributes of biophilic design). Whereas, Heerwagen and Gregory (2008) explain why nature inspired architecture, as being a necessary concept to identify survival-advantageous characteristics. An evolutionary theory can offer insights into why certain elements in nature (such as sunlight, water, and vegetation) are beneficial in terms of stress reduction and health. In his classification Biophilic structures can be characterized by a variety of perceivable and cognizable qualities that can be incorporated into their spatial layouts (sensory aesthetics and survival-enhancing characteristics). It was the same year that Cramer and Browning (2008) defined biophilia within an architectural context by focusing on the emotional aspects of human interaction with nature within a building environment. They also provided three preliminary categories for biophilic buildings (biophilic building categories).

Browning et al., (2014) define biophilic design as it is in the connection between human biological sciences and nature to build environment design, provides a series of tools for enriching design opportunities, and means for applying design to enhance the health and happiness of individuals, communities, and the environment. It is characterized by the classification of 14 patterns of biophilic design (categories and patterns of biophilic design).

Kellert (2018) define the aim of biophilic design includes promoting engagement with natural environments, making healthy use of natural environments, and designing environments that are visually appealing, physically accessible, practical, and engage all senses. His definition is characterized by creating a connection with nature from an individual (health and well-being of users) to a societal (Occupational health) perspective, as an experience of biophilic design characteristics.

As to Fei et al., (2019), in terms of green building design, building and nature integration is a paradigm that compensates for the loss of green space during urban development. The integration of those natural elements into systems and infrastructure to create "life" in buildings and cities you can feel and measure; also involves supporting work-live-play integration in both buildings and cities; as a result, it influences occupant engagement in green spaces that have a long-term effect (developed categories in the biophilic framework).

The biophilic design framework is unified by the concept of incorporating a range of 'natural' experiences into the design, ranging from both physical and sensory experiences to metaphorical, morphological, and material experiences. In certain elements (such as air, daylight, plants, and landscape), design strategies can have multiple benefits, this includes promoting health, productivity, biodiversity, circularity, and resilience. By understanding biophilic design from a comprehensive perspective, it would be possible to move toward a more innovative design and improve the quality of buildings in the pursuit of sustainable architecture. In this study, we included three of the numerous biophilic design interpretations since they have been adopted for studies of biophilic design in health and well-being (Browning and Ryan, 2020; Kellert, 2008; Kellert, 2018).

2.2.2 Interpretation 1: The Principles and Elements of Biophilic Design

The term biophilic does not refer to any certification or a treatment. The term refers to the approach to designing and building structures to be harmonious with the natural world. Biophilic design requires adherence to certain principles. Such principles represent the basis of effective biophilic design. According to Kellert (2008), biophilic design is based on six primary principles (Table 12). The following is a brief explanation of each principle.

Table 12: 2 Dimensions, 6 Elements, and 72 Attributes of Biophilic Design (Kellert, 2008).

I. Organic or Naturalistic				II. Place-based or Vernacular	
1. Environmental features	2. Natural shapes and forms	3. Natural patterns and processes	4. Light and space	5. Place-based relationships	6. Evolved human-nature relationships
• Color • Water • Air • Sunlight • Plants • Animals • Natural materials • Views and vistas • Façade greening • Geology and landscape • Habitats and ecosystems • Fire	• Botanical motifs • Tree and columnar supports • Animal (mainly vertebrate) motifs • Shells and spirals • Egg, oval, and tubular forms • Arches, vaults, domes • Shapes resisting straight lines and right angles • Simulation of natural feature • Biomorphic • Geomorphology • Biomimicry	• Sensory variability • Information richness • Age, change, and the patina of time • Growth and efflorescence • Central focal point • Patterned wholes • Pounded spaces • Transitional spaces • Linked series and chains • Integration of parts to wholes • Complementary contrasts • Dynamic balance and tension • Fractals • Hierarchically organized ratios and scales	• Natural light • Filtered and diffused light • Light and shadow • Reflected light • Light pools • Warm light • Light as shape and form • Spaciousness • Spatial variability • Space as shape and form • Spatial harmony • Inside-outside spaces	• Geographic connection to place • Historic connection to place • Ecological connection to place • Cultural connection to place • Indigenous materials • Landscape orientation • Landscape features that define building form • Landscape ecology • Integration of culture and ecology • Spirit of place • Avoiding place-lessness	• Prospect and refuge • Order and complexity • Curiosity and enticement • Change and metamorphosis • Security and protection • Mastery and control • Affection and attachment • Attraction and beauty • Exploration and discovery • Information and cognition • Fear and awe • Reverence and spirituality

- *Principle 1:* "Environmental features"

By incorporating natural characteristics into your built environment, biophilic design encourages continuous and repeated engagement with nature. For instance; integrating color with earth tones as well as water features, sunlight, and/or vegetation.

- *Principle 2*: "Natural shapes and forms"

In biophilic design, the focus is on how humans have adapted to the natural world to improve health, fitness, and well-being over evolutionary time. A type of design that uses shapes from the natural world, such as spirals, shells, columns, ovals, arches, animal motifs, and biomimicry (imitating the living organisms) can be given as an example where using straight lines and right angles are the exact opposite of these that are rarely found in nature.

- *Principle 3*: “Natural patterns and processes”

Biophilic designs encourage mutual reinforcement, interconnection, and integration of design elements. And hence it is significant to use natural properties instead of representations when designing. A central focal point, patterned wholes, and clear boundaries are considered important to vary the sensory experience via transitions and complementary contrasts.

- *Principle 4*: “Light and space”

In this principle it is essential to design a space by using several principles of light, such as natural light, diffused light, shadow, expansiveness, spatial harmony, and indoor/outdoor space.

- *Principle 5*: "Place-based relationships"

The biophilic design stimulates an emotional bond with certain settings and places. It is the desire to establish a territorial identity that drives the combination of culture and ecology. This principle entails aspects of unique connections to place, indigenous materials, and landscape orientation and ecology, as well as avoiding place lessness.

- *Principle 6*: "Evolved human-nature relationships"

Biophilic design promotes positive human/nature interactions that foster a sense of community and responsibility between people and the natural world. This idea emphasizes the natural bond that exists between humans and nature. Aspects that promote self-esteem, aesthetic attraction to nature, exploration and discovery, fear and awe, and spirituality are among the environmental values.

2.2.3 Interpretation 2: Biophilic Design Experiences

The primary proponents of categorizations recently reached an agreement on providing succinct explanations. Kellert (2008) used a hierarchy in his framework starting with fundamental distinctions (elements) and progressively moving down to subdivisions (attributes). According to Kellert, "those dimensions that directly, indirectly, or symbolically resemble natural forms can be described as organic or naturalistic dimensions." (Kellert, 2018) identifies three types of biophilic design experiences as in (Table 13):

- *Direct experience of nature*, to take part in 'contact with basic features and characteristics of the natural environment.
- *Indirect experience of nature*, to synthesize concepts, images, and feelings into symbolic and metaphorical forms.
- *Experience of space and place*, to comprehend 'how people manage their physical environments.

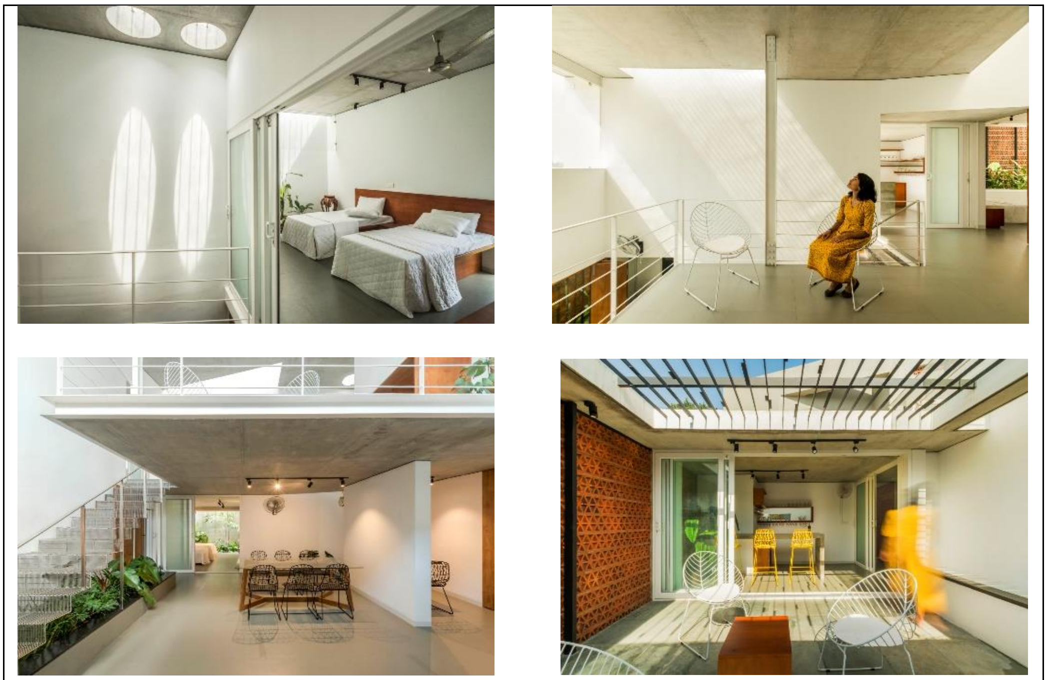
Table 13: 3 experiences and 25 attributes of biophilic design (Kellert, 2018).

1. Direct Experience of Nature	2. Indirect Experience of Nature	3. Experience of Space and Place
• Light • Air • Water • Plants • Animals • Landscapes • Weather • Views • Fire	• Images • Materials • Texture • Color • Shapes and forms • Information richness • Change, age and the patina of time • Natural geometries • Simulated natural light and air • Biomimicry	• Prospect and refuge • Organized complexity • Mobility • Transitional spaces • Place • Integrating parts to create wholes

A. Direct Experience of Nature:

"Direct Experience of Nature" is of the most fundamental and effective types, so it brings biophilia into the human environment to improve health and well-being, and to experience nature directly, one must be in contact with nature and its processes (Wilson & Stephen, 1984). Both other features, the experience of the spatial environment and indirect experience of nature contain manufactured elements, but plants in the physical context and natural landscapes besides ecosystems have been the most studied attributes in psychological and physiological research in this experience category. As explained by Kellert (2018), the attributes of direct experience of nature can be summarized as follows:

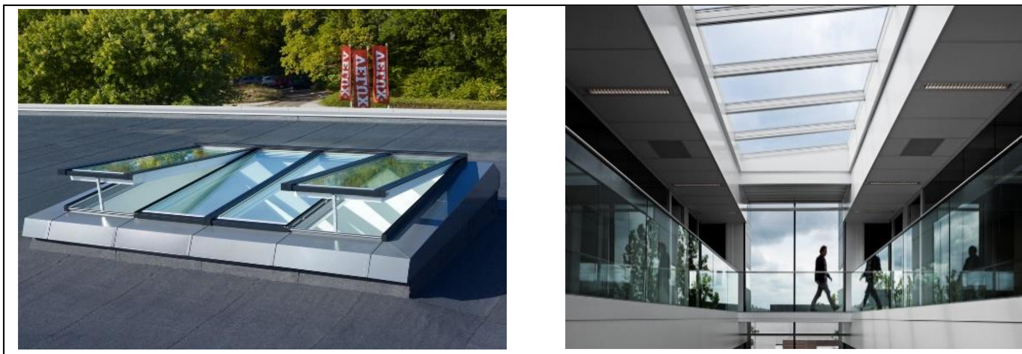
- *Att.1 Light:* To be able to perceive the day, night, and seasons, people need exposure to natural light. The benefits of natural light are widely recognized by various disciplines, including psychology and physiology, for building occupants' health and wellbeing (Rikard & Carin, 1992). In indoor spaces, a creative interplay of light and shadow can create aesthetically pleasing forms and shapes from natural light beyond simple exposure. By reflecting colors, materials, and other design elements, glass walls and clerestories can enable natural light to penetrate deep into interior spaces. For instance, circadian lighting which is a type of daylight spectrum light that modulates throughout the day to mimic natural light; might be one way to reap the benefits of natural light in indoor spaces.



Diffusion of natural light through the house. A seamless flow between spaces as well as natural light and ventilation enhance the overall experience of the user. The transparent stairs allow light to penetrate the courtyard below.

Figure 2: An Example of The Light: of Buoyant Hue House / Mindspark Architects (URL 1)

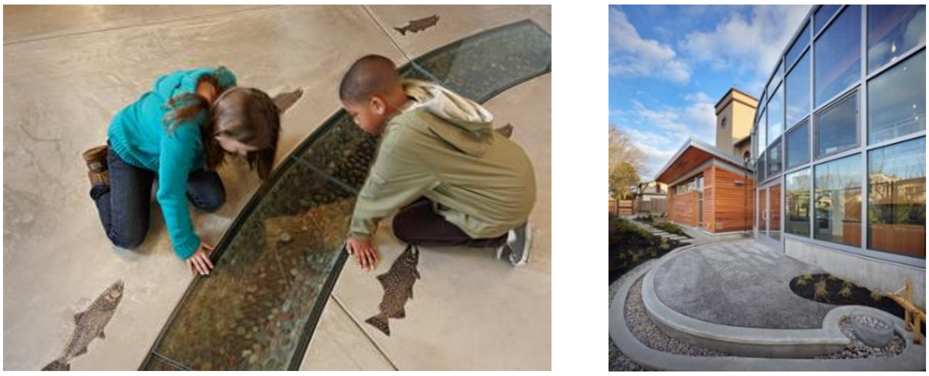
- *Att.2 Air:* Natural ventilation is important for human comfort and productivity, and variations in airflow, temperature, humidity, and barometric pressure can be used to enhance the natural ventilation experience. To reach these conditions, one can either use simple strategies, such as operable windows or use more sophisticated engineering and technological approaches.



Designed to allow plenty of natural light and fresh air into the building.

Figure 3: An Example of The Air: Long-Light 5-30° - Modular Skylights (URL2)

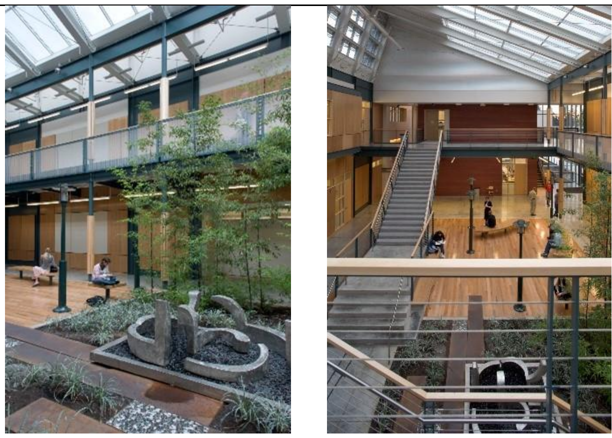
- *Att.3 Water*: Besides being essential to life, water enhances the built environment and relieves stress, promotes satisfaction, and improves health. Views of the water and the sounds of water have also been found to be restorative (Roger S. et al., 1991). It can be particularly compelling to be attracted to water when experience is combined with sight, sound, touch, taste, and movement. Being near water is associated with reduced stress and obesity, improved mental and emotional health, and general well-being, according to Roy (2021). There is a multitude of design strategies that satisfy an individual's desire to experience water, including views of the water, like ponds, fountains, aquariums, and constructed wetlands. Humans are biologically designed to respond to water, particularly to moving water.



The rain which falls on the building is collected and directed in the classroom to a whole wall of tropical plants, so even when inside, students are immersed in nature.

Figure 4: An Example of Water: The Bertschi School Science Wing, Washington (URL 3)

- *Att.4 Vegetation:* The use of vegetation to enhance the indoor environment has proven to be one of the most effective strategies for bringing nature into the designed environment. Plants are beneficial in reducing stress, enhancing pain tolerance, improving physical health, improving comfort, and enhancing productivity and performance (Tina, Hartig, & Grete G., 2009). According to Larsen et al., dense plant amounts in an office setting would enhance productivity, while at the same time it increased positive effects on the overall office atmosphere (Larissa et al., 1998). Jun et al., (2014) tested distinct types of plants based on psychological and physiological assessments to identify the most beneficial type. It was found that small, green, lightly scented plants were optimal for health and wellbeing.



Inviting winter garden on campus. This unique winter garden can be enjoyed year-round as a temperate gathering space.

Figure 5: An Example of Vegetation: Technology Classroom Building Portland Community College Sylvania (URL 4)

- *Att.5 Animals*: Throughout history, non-human animals have played an integral part in human existence. It can be difficult to integrate animals within the built environment even though they are sometimes effective as feeders, aquaria, aviaries, green roofs, etc. Animals in building interiors can often be seen in a representational rather than literal form, and in many cases through ornamentation, decoration, art, and through highly stylized and metaphorical representations. Despite this, the presence of animal forms is often regarded as an emotional attraction, a source of satisfaction, pleasure, and stimulation.

Animal metaphors are used like ornamentations on the roof, as well as in the painting to design the residential indoor space.

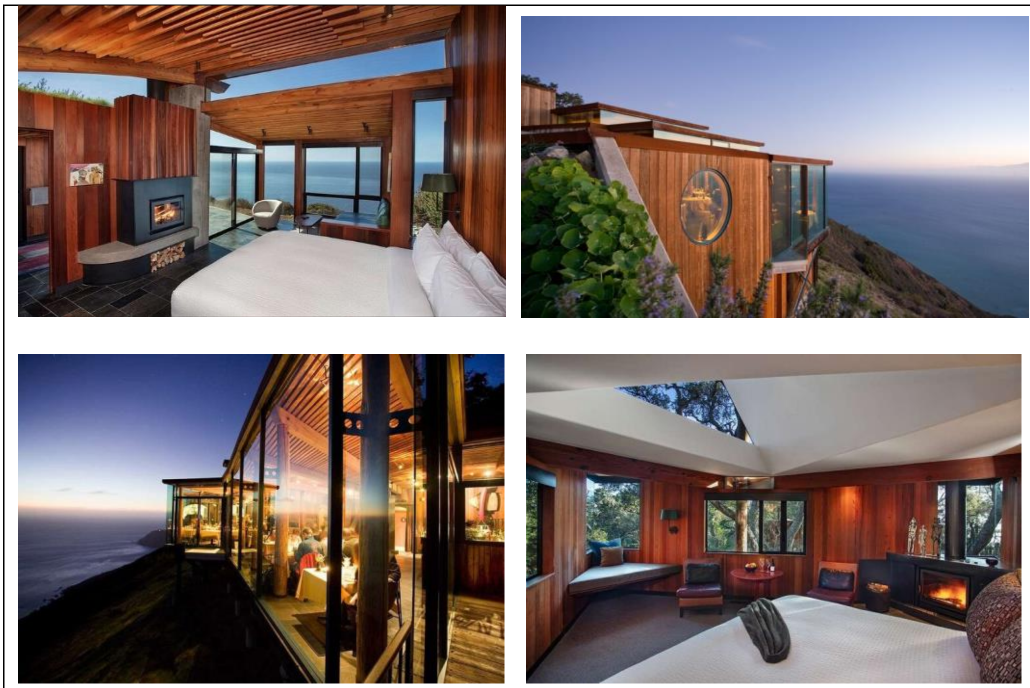
Figure 6: An Example of Animals: Ermetika's Absolute Evo (URL 5)

- *Att.6 Ecosystems and natural landscapes*: Ecosystems and natural landscapes are composed of interdependent elements, including plants, animals, water, soil, rocks, and geological formations. Humans are more likely to prefer landscapes that have an open understory, spreading trees, forested edges, water, and other features that are perceived as being important to human evolution. In built environments, self-sustaining ecosystems can be achieved through the creation of constructed forest glades, wetlands, grasslands, and green roof environments. The environment can be viewed, observed, directly interacted with, and even actively participated in by views, observation platforms, and direct interaction.

With its pixelated window patterns and open-air atriums, the multi-use building brings a pop of greenery to its designs. Bright green plants stand out against the building's stark white exterior, and their irregular placement gives the structure an overall appealing appearance.

Figure 7: An Example of Ecosystems and Natural Landscapes: Jean Nouvel Nicosia Cyprus Green Tower (URL 6)

- *Att.7 Weather*: It has always been vital to human fitness and survival for people to be aware of and respond to weather changes. This means; it is both pleasing and stimulating for people to interact with the weather in a built environment. By manipulating airflow, temperature, barometric pressure, and humidity, it is possible to duplicate weather-like conditions in an indoor environment. Thus, there is an array of exterior design strategies such as views to the outside, balconies, porches, operable windows, colonnades, decks pavilions, and more.



Through the design, guests can connect with the environment and experience the weather from the comfort of their rooms or communal areas, like the on-site restaurant.

Figure 8: An Example of Weather: Post Ranch Inn, California (URL 7)

- *Att.8 Views:* Exterior views are preferred by people more than interior views, especially if they include natural features and vegetation. The benefits of green views were studied by Ulrich, (1984) regarding apostasy after gallbladder surgery. He found that the recovery was faster for patients who were looking out at green trees than for those who were looking at the brick walls. Human experience often results in the most satisfying views when the scale, range, or proportion corresponds with human experience - for example, not being overly constrained, unfamiliar, or way out of proportion. Nevertheless, it has been found that green roofs have been restored in areas where green nature is difficult to view (Emma V. & Birgitta, 2011).

Using a module system called Green Parks, design low-maintenance rooftop gardens. Green roofs reduce storm water runoff, reduce cooling loads, and fight the heat island effect in New York City.

Figure 9: An Example of Views: Avenue Of The Americas / Cookfox, USA (URL 8)

- *Att.9 Fire:* The use of fire in constructed environments is often preferred due to its benefits for heating and cooking, despite being a complicated and intricate design challenge (Kellert, 2008). For centuries, fire has been manipulated within interior spaces to provide warmth, color, and movement, a sign of comfort and civilization. Fire can be brought into the built environment, especially in cold climates, using fireplaces and hearths, as well as simulated through lighting, color, movement, and varied materials that achieve different degrees of heat conductance.

Two main gathering spaces are created with the two-way fireplace in the home: an outdoor living space and a living room adjacent to the kitchen and dining area.

Figure 10: An Example of Fire: Fielding House, New Zealand (URL 9)

B. Indirect Experience of Nature:

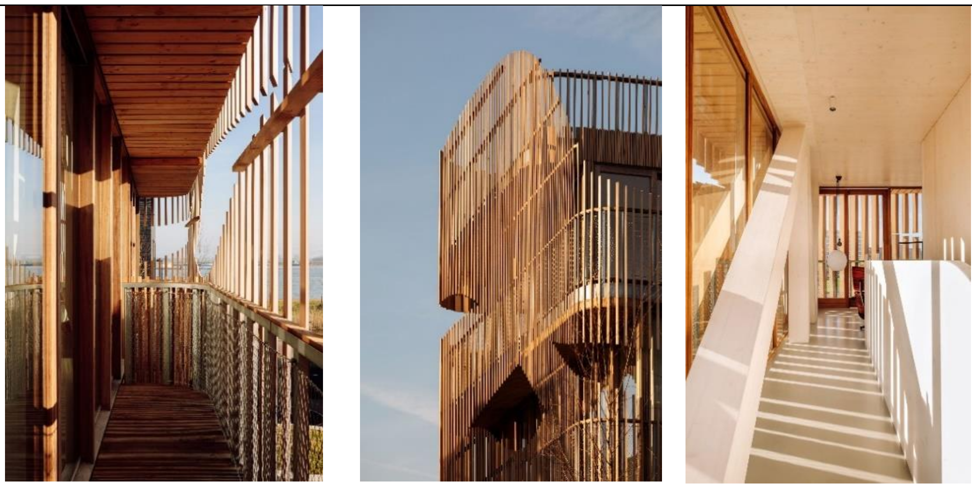
In the design, the sense of indirect experience of nature is presented, as well as attribution to the elements of nature. These methods include images, materials, and natural colors, as well as stimulating natural light, natural shapes and forms, evoking information richness, natural geometries, change, aging, the patina of time, and biomimicry.

- *Att.10 Images*: Nature images have been found to reduce stress as much as viewing actual landscapes in certain circumstances (Anette & Hanne, 2010). Building occupants alike can benefit from images of nature to increase their connection to the natural world in a setting where direct exposure to the outdoors may not be possible. Biophilic features can be permanently incorporated into the built environment so that everyone can benefit from natural contact.

A visual connection to the natural world blurs the lines between inside and outside in transitional settings. Photographs are used as visual elements in the design to depict scenes of nature in laminated architectural glass.

Figure 11: An Example of Images: Zoom Digital Darkroom for Levele Elevator Interior

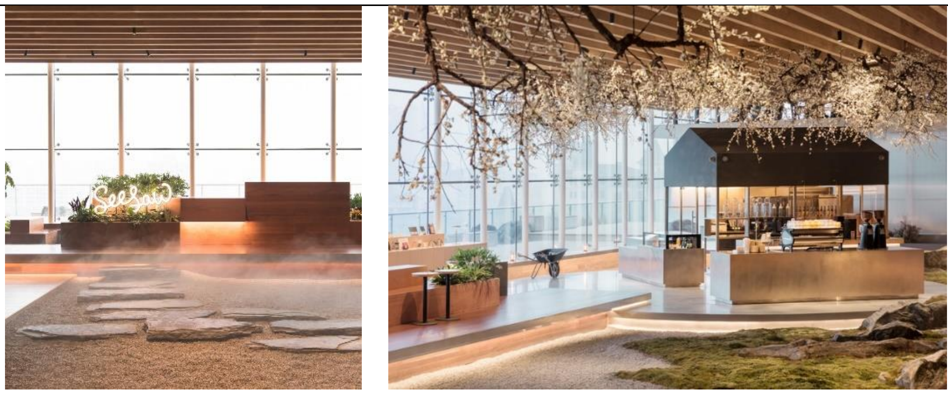
- *Att.11 Materials*: Even when the artificial form seems almost identical to the natural one, people prefer natural materials such as natural stone, hemp, strawbale, various clays, and diverse types of wood over artificial ones. Some of the aversion may be a result of the inability of artificial materials to communicate the natural processes of aging, weathering, and other dynamic features found in natural materials, including stones.



Open-planned organic curves design featuring the natural element - wood - of the nearby water.

Figure 12: An Example of Materials: Freebooter Apartment Complex, Amsterdam (URL 11)

- *Att.12 Texture*: People tend to prefer shapes, patterns, and textures that are reminiscent of nature, even if the exact reason for this is unknown. This in turn can reduce stress and boost concentration. In addition, textures stimulate touch, as a sense that affects our emotions directly. Natural textures also enhance the light-shadow effect. As a result, they are particularly fascinating to watch, stimulating another sense other than sight. There are several ways to incorporate natural textures into interiors, including wood floors and walls and natural stone cladding. Reproducing a natural texture on varied materials can also be done.



Using texture to create a full sensory experience within a built space, the shop is materialistic and ambiance oriented.

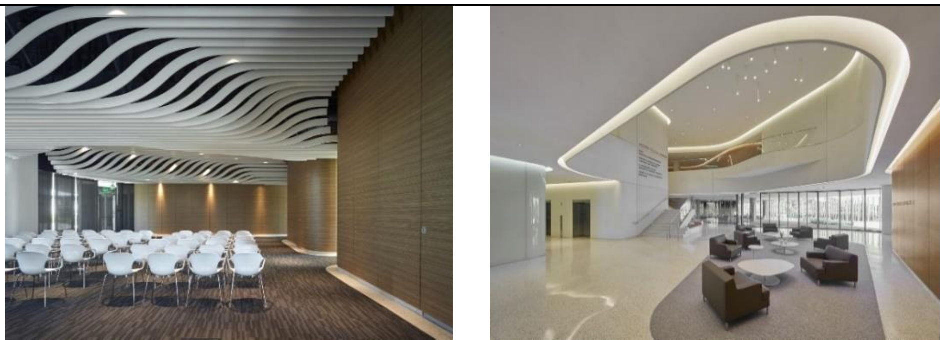
Figure 13: An Example of Texture: Seesaw Coffee / Nota Architects in Chaoyang, China

- *Att.13 Color:* A color's effectiveness in aiding human survival and evolution has been well documented. Colors enhance a person's ability to locate food, resources, and water; identify danger; facilitate visual access; promote mobility, etc. It is no wonder that people find themselves attracted to nature since it is full of colorful features, including bright flowers, rainbows, glistening waters, blue sides, and other features that attract people. Hence, earth tones and other natural colors are often used by designers for beneficial effects.

Using a rich color scheme inspired by nature.

Figure 14: an example of Color: Bar Botanique Cafe Tropique in Amsterdam (URL 13)

- *Att.14 Shapes and forms*: Forms can be sculpted that are dynamic and stimulating when lit by natural patterns and structures. Natural patterns and structures are recognized by our senses as order, pattern, and structure. Seeing these same characteristics in non-natural materials stimulates a positive response - allowing us to apply familiar logic to their interpretation.



Through its organic curvilinear structure, the building's form interacts artistically with its environment.

Figure 15: An Example of Shapes and Forms: Jacobs Medical Center, California (URL 14)

- *Att.15 Information richness*: Despite living in a modern information age, the natural world continues to be one of the most intellectually challenging environments available to humankind. When incorporated into the built environment in either a representational or literal manner, this attribute can stimulate curiosity, imagination, discovery, exploration, and problem-solving. Buildings and landscapes should therefore have information richness, variety, texture, and detail that mimic natural patterns when displayed.

Structure design inspiration taken from natural patterns such as holes in tin roofs to letting light in.

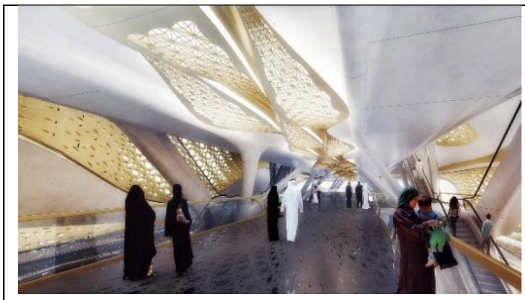
Figure 16: An Example of Information Richness: Shibori Office, Gandhinagar, India (URL 15)

- *Att.16 Change, age, and the patina of time*: Especially in organic forms, aging is a fundamental characteristic of the natural world. Despite the inevitable occurrence of senescence, death, and decay, this dynamic progression evokes feelings of familiarity and satisfaction in people. The patina of time is a characteristic of natural materials, including inorganic ones, and one reason for which artificial products rarely elicit sustained positive reactions even when they are exact replicas.

It features a barn-like form using antique timbers juxtaposed with more complimentary, contemporary materials in the new additions, such as the layered concrete between the barn and the farmhouse.

Figure 17: An Example of Change, Age, and The Patina of Time: Home Farm By John Pawson's In Cotswolds, England (URL 16)

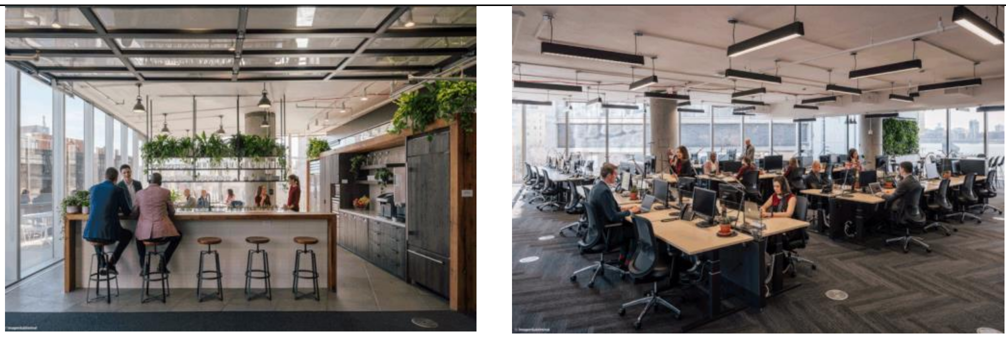
- *Att.17 Natural geometries*: Often, organic abstractions are better suited to design than literal representations of nature. Biomorphic forms and patterns such as the Golden Angle (137 degrees), curves and angles of 120 degrees, and Fibonnaci sequences are used in natural geometries because nature dislikes right angles and straight lines. These geometries can be used when designing staircases and window details, designing ceilings, and arranging wood flooring.



Through its organic curvilinear structure, the building's form interacts artistically with its environment and expresses a sense of motion. producing dynamic rather than static forms by intersecting paths, routes, and volumes.

Figure 18: An Example of Natural Geometries: Inaugural Exhibition in The Gulf By Zaha Hadid, (2010) (URL 17)

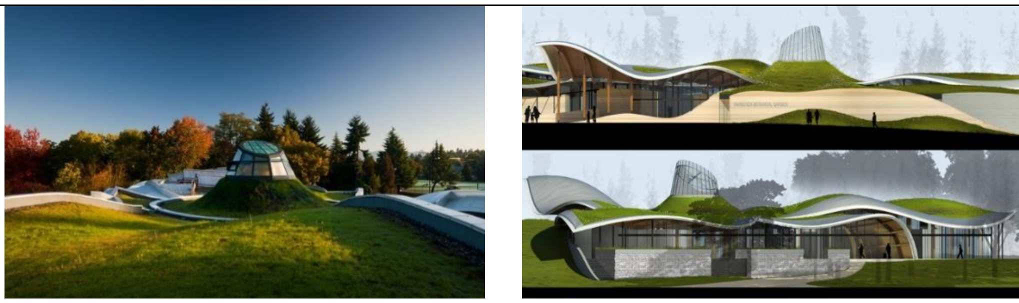
- *Att.18 Stimulated natural light and air*: It involves reproducing natural lighting and airflow within buildings using simulated natural lighting and airflow. Employing technological innovations, it imitates the changing lights and air conditions of nature throughout the day. As an example, various LED lighting companies now offer their users the ability to replicate the dynamic quality and different qualities of natural light indoors with their innovative tunable white light LED products.



The use of innovative technologies to allow employees access to natural light and good air quality throughout space.

Figure 19: An Example of Stimulated Natural Light and Air: Delos Headquarters New York (URL 18)

- *Att.19 Biomimicry*: Several successful designs draw from adaptations functionally found in nature, particularly in other species. These can include mounds, hives, webs, shells, and crystals, which can be incorporated into the built environment and have structural and bioclimatic properties (Janine, 1997).



Based on a native orchid, the living roof was designed to resemble organic petals.

Figure 20: An Example of Biomimicry: Vandusen Botanical Garden Center Vancouver, Canada (URL 19)

C. Experience of space and place:

As the name implies, this criterion is concerned with the relationships between space, place, and meaning in the natural environment. Human populations are accustomed to natural settings such as elements named as prospect and refuge, organized complexity, integrating parts into wholes, trans-national spaces, mobility, and wayfinding, as well as cultural and ecological attachment to places (Vivian, 2020, pp. 1-16).

- *Att.20 Prospect and refuge*: Prospect emphasizes the ability to detect distant objects, habitats, and horizons -a process evolutionarily important in locating resources, facilitating movement, and identifying threats. In contrast, a refuge is a structure or environment that provides a safe, secure, or protected environment. These are sometimes achieved through the design of comfortable and nurturing interior spaces and hidden landscape areas. The best buildings and landscapes express the complementary relationship of prospect and refuge.

With so many students and faculty attending events at, built-in booths provide much-needed refuge, while the organic feel and openness of the learning environments enhance prospects.

Figure 21: An Example of Prospect and Refuge: Saint Louis University Center For Global Citizenship, Missouri (URL 20)

- *Att.21 Organized complexity*: The degree of complexity depends on the degree of detail and variability. In addition to being challenging, excessive complexity can sometimes lead to a sense of chaos and a feeling of inadequacy. Therefore, successful designs combine organization and complexity in ways that stimulate the feel of a controlled and understandable spaces.

The four floors are organized in a spectrum of 'Fun' to 'Serious' on a spectrum from digital, analog, to group, to individual interaction areas which represents an organized complexity.

Figure 22: An Example of The Organized Complexity: Calgary New Central Library, Canada (URL 21)

- *Att.22 Mobility*: People's comfort and well-being depend on being able to move between diverse and often complicated spaces easily and efficiently, which is why the design of buildings should support the easy and efficient movement of occupants between areas. Ideally, the biophilic design would incorporate clear pathways and points of entry to allow seamless transitions between spaces, while lacking these features often causes anxiety and confusion.

Pavilion combines an abundance of open spaces, and clean lines throughout the exterior and interior.

Figure 23: An Example of Mobility: Allegheny Health Network, Wexford Health & Wellness Pavilion, Wexford, PA (URL 22)

- *Att.23 Transitional spaces*: The purpose of transition spaces is to create a smooth transition from the interior to the exterior of a building. Those spaces facilitate an easy and clear transition between the inside and the outside of the building and help the occupants navigate their environment. These spaces can take the form of patios, gardens, pavilions, balconies, porches, and indoor/outdoor rooms.

Featuring an open floor plan, this home is equipped with large windows and glass doors to seamlessly connect the inside and outside

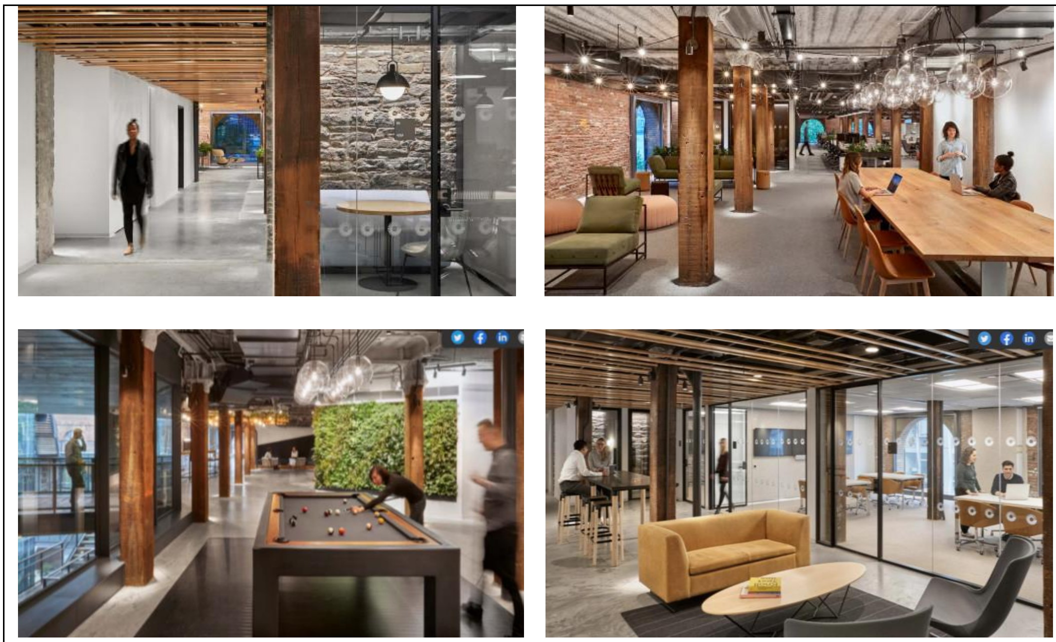
Figure 24: An Example of Transitional Spaces: Whisper Rock Ranch, Pioneertown, CA (URL 23)

- *Att.24 Place*: It is the cultural and ecological ties that bind people to places that drive them to protect and sustain both built and natural environments. Culture and ecology both play a vital role in enhancing this territorial nature, which can be enhanced by the attachment to familiar places. A setting with a distinct human identity, a place with culturally relevant designs encourages a sense of belonging. Likewise, ecological connections can lead to an emotional attachment to a place, particularly when one is sensitive to the local landscape.

Visitors become engrossed in the prairie experience, as they notice patterns and textures everywhere, from the wood grain on the exposed timbers to the shifting clouds.

Figure 25: An Example of Place: Betty and Josey Clint Pavillion, Texas (URL 24)

- *Att.25 Integrating parts to create wholes*: humans crave environments where disparate parts are integrated into a cohesive whole and a central focus, whether it can be functional or theme-based, and can enhance this pleasing integration of space. It can often be achieved by linking sequentially and successively spaces as well as by clearly distinguishing boundaries.



The design creates connections throughout space to uniquely convey UTC's heritage and evolution into the digital age.

Figure 26: An Example of Integrating Parts to Create Wholes: United Technologies Digital Accelerator, New York (URL 25)

Even though the above characteristics are in line with human experience, it can also be seen that some elements are in common, regardless of their terminology. For example, light, air, and water are like 'dynamic and diffuse light', 'thermal and airflow variability, and 'existence of water'; weather, ages, besides time patina are distinguished as 'connection with natural systems'; natural shapes, forms, and geometrics are categorized as 'biomorphic forms and patterns; and natural 'materials' are viewed as 'material connection with nature. Nature can also be experienced psychologically through a deliberate arrangement of spatial features, such as by creating a space with 'prospects', 'refuges', 'complexity and order', or an 'organized complex' (Browning et al. 2014; Browning and Ryan, 2020; Kellert, 2018).

2.2.4 The Categories and Patterns of Biophilic Design

With reference to Alexander et al., 1977 "A Pattern Language," Browning and Ryan (2020) emphasize the functional value of nature in architectural design. Kellert (2008 and 2018) Analyzes and divides nature into concrete, emotional, simulated, and categories. This classification is usually referred to as 'attributes of biophilic design'. Various physical, metaphorical, symbolic, and emotional characteristics of nature and their emotional reactions have been categorized by Browning and Ryan (2020) into three types: "nature in the space," "natural analogues," and "nature of the space". Using this framework, a range of spatial characteristics of nature can be described as a combination of sensory aesthetic properties as well as survival benefits (Heerwagen and Gregory, 2008; Hildebrand, 2008).

Additionally, they reflect emotional aspects of space, such as "mystery", "dangers", and one specific pattern, "awe". It implies multisensory interaction and coordinated contact with the components of nature. According to (Browning et al. 2014; Browning and Ryan, 2020), the framework consists of 14 biophilic plan patterns as in the following (Table 14).

Table 14: 3 Categories and 15 Patterns of Biophilic Design (Browning and Ryan, 2020)

1. Nature in the Space	2. Natural Analogues	3. Nature of 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	• Biomorphic forms and patterns • Material connection with nature • Complexity and order	• Prospect • Refuge • Mystery • Risk/Peril • Awe

A. Nature in the space

The multi-existence of nature within the inside environment, like physical, transitory, and direct is the center of this approach. It implies multisensory interaction and coordinated contact with the components of nature. Concurring to Browning et al. (2014), there are seven distinctive varieties of "nature within the space". Plants, water, animals, wind, noises, scent, and other natural highlights like butterfly gardens, vertical gardens, and green rooftops are all included. According to (Browning et al., 2014), nature within space includes seven biophilic patterns as in the following;

1. Visual connection with nature (VCN)

It is characterized as a view of nature, living systems, and natural processes (Browning et al. 2014). Natural light, vegetation, or pictures of nature can provide direct contact with nature; living close to open spaces, or natural features like natural light and natural ventilation can ensure direct contact with nature. This connection with nature includes potted plants, trees, moving water, ambient light, and water fountain can promote “extreme biophilic attention (Browning et al., 2014) and ‘fascination’, thereby leading to positive changes in one's mood (Dmitri, and Ronald, 2008). In terms of stress reduction, both experiencing real nature and seeing images of nature have been proven to be beneficial (Peter et al., 2008).

Earlier research by Xiaomin, Edward and Irving (2006) suggest that viewing scenes of nature stimulates more of the visual cortex and triggers more pleasure receptors in the brain than viewing non-nature scenes; and that viewing real nature does not negatively affect a viewer's interest over time, in contrast to non-nature viewing. Even so, it can often be difficult to incorporate real nature into the built environment (Richard et al., 2007).

Visual connections to nature, even in a small occurrence, can have restorative effects. This finding is important given the limitations of and demands on city and interior space. This means physiological recovery was greater with a longer window viewing time (Peter et al., 2008).

It is surrounded by woods and is filled with natural light that reflects on the rich interior colors. The office is sunk into the ground and has curved glass that opens to spectacular views of the woods.

Figure 27: An Example of VCN: Selgascano Offices, Spain (URL 26)

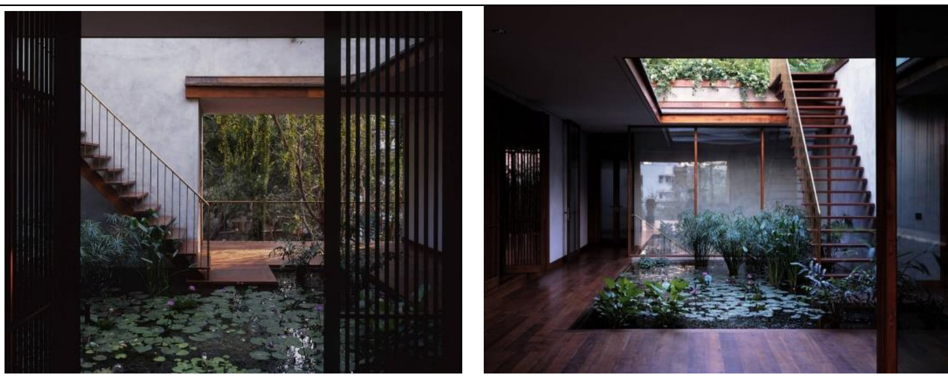
2. Non-visual connection with nature (NVCN)

"Non-Visual Connection with Nature is the auditory, haptic, olfactory, or gustatory stimuli that engender a deliberate and positive reference to nature, living systems, or natural processes" (Browning et al., 2014). As is conversed below, each sensory system has a substantial amount of research to support its benefits.

Auditory; according to the researcher (Jesper, Stefan, and Mats, 2010, pp. 1036-1046), tuning in to characteristic sounds speeds up physiological and mental recuperation by up to 37% after a psychological stressor. The sound designs of sea waves and vehicle activity may be very vying. Members in one investigation who tuned in to river sounds or observed a nature video highlighting river sound amid a post-task restoration time reported having more energy and motivation than those who simply listened to office noise or quiet during the restoration period (Helena et al., 2011). Further support appears from Ravi, Rui, and Amar (2012), whom documented that moderate (70 decibels) ambient noise caused creative performance to be better than either low (50 decibels) or high (>85 decibels) ambient noise. Examples of auditory as naturally occurring are songbirds, flowing water, the weather of rain and wind, a crackling fire, and natural ventilation provided by operable windows and breezeways.

Olfactory; Plant oils have long been used to soothe or invigorate individuals in traditional cultures. Olfactory exposure to herbs and phytoncides can improve both the healing process and human immune function according to Li et al. (2012). This study discovered that the sense of smell elicits strong memories in the brain, particularly when both visual and non-visual stimuli are associated with nature. This combined psychophysiological response is more potent than either response alone. Naturally occurring examples are fragrant herbs and flowers such as lavender, rosemary and so far, or it could be mechanically stimulated by releasing natural plant oils.

Haptic; Pet therapy, gardening, and horticultural activities have been demonstrated to promote environmental stewardship in children and adults, as well as relieve tiredness and preserve joint flexibility (Yamane et al., 2004). The act of touching real plants rather than fake plants has also been shown to help people relax (Kazuko, and Yutaka, 2013). Natural examples include textures in natural materials (stone, wood, fur) or through the tactile feel of sun patches and cool/warm surfaces. It can also be accomplished through highly textured fabrics/textiles that mimic natural materials.



It integrates water and natural ventilation with architecture, creating an immersive, non-visual experience using sound, smell, and touch; providing a seamless transition between spaces.

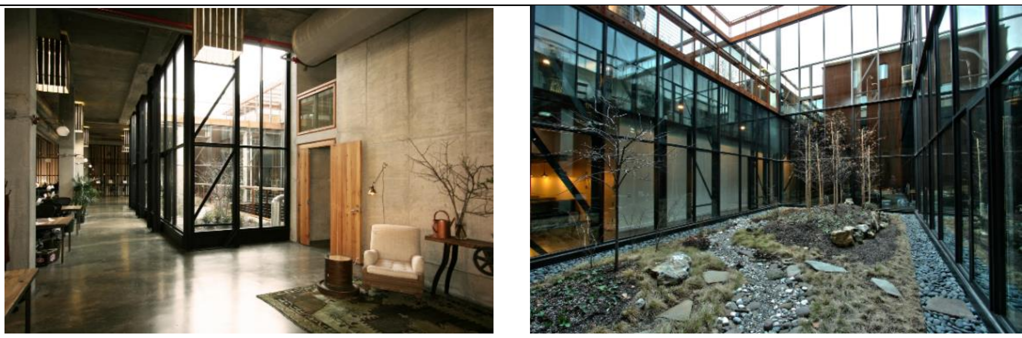
Figure 28: An Example of NVCN: Houses, Mumbai, India (URL 27)

3. Non-Rhythmic sensory stimuli (NRSS)

When a Non-Rhythmic-Sensory-Stimulus pattern is integrated into a space, it gives momentarily feelings like, energizing, and freshness can be noticed by eye reflexes, heart rate, and blood pressure (Browning et al., 2014). In other words, connections between people and nature may be analyzed statistically but not predicted precisely.

Furthermore, some of the naturally existing examples can be cloud movement, water babbling, insect and animal movement, plant life rustling, and birds chirping, and a few examples of stimuli can be shadows or dappled light that changes with movement or time, mechanically released plant oils, or a reflection of water on a surface.

Concurring to Browning et al., (2014), consolidating Non-Rhythmic-Sensory-Stimulus patterns into interior settings can emphatically impact a variety of health concerns, including heart rate and so on. Thus, the pattern is intended to encourage the use of natural sensory stimuli that unobtrusively attract attention, allowing individuals to recharge from mental fatigue and physiological stress, allowing them to complete focused tasks more effectively. For instance, Clancy and Nestor (2015) found that the waterfall produces non-rhythmic sensory stimulation by capturing people's consideration visually (streaming water droplets and light reflections) and auditory (sound of the waterfall). As a result, it may offer help with stress reduction.



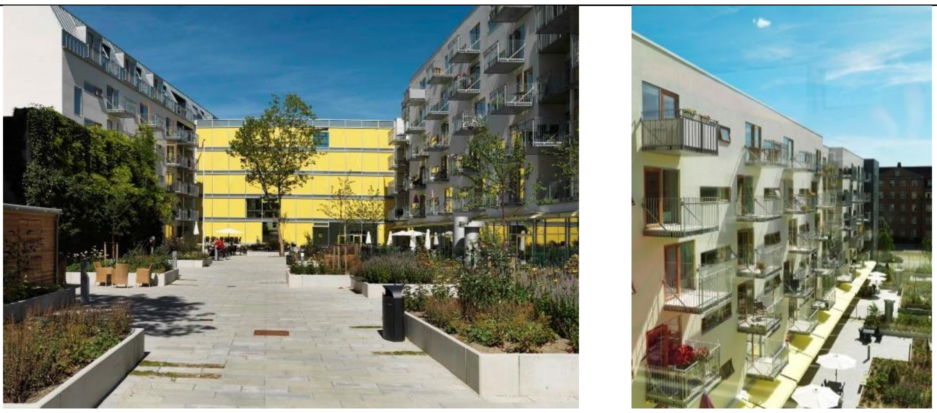
Habitat is provided for local and migratory species, including birds and insects, using native vegetation.

Figure 29: An Example of NRSS: Kickstarter Commercial Headquarters, New York (URL 28)

4. Thermal & Airflow Variability (TAV)

Natural environments can be felt through a change in relative humidity, air temperature, the flow of air on the skin, and the temperature of its surface. Hence, using such a pattern can lead to feelings of freshness, aliveness, comfort and health, and energy (Browning et al., 2014).

Headaches, colds, mucosal symptoms, by sick building syndrome can all be reduced with natural ventilation. Seppanen and Fisk (2002) after conducting research on natural ventilation have demonstrated that this is helpful in the recovery of various health issues, such as headaches and colds. Examples on this subject can be numerous such as the examinations of the positive impacts of ventilating the interior utilizing natural solutions and changes in thermal concerns (Hans, 2005). Offering variable conductivity materials, seating with varying degrees of solar heat gain (inside or out), or access to operable windows could enhance the satisfaction of a space.



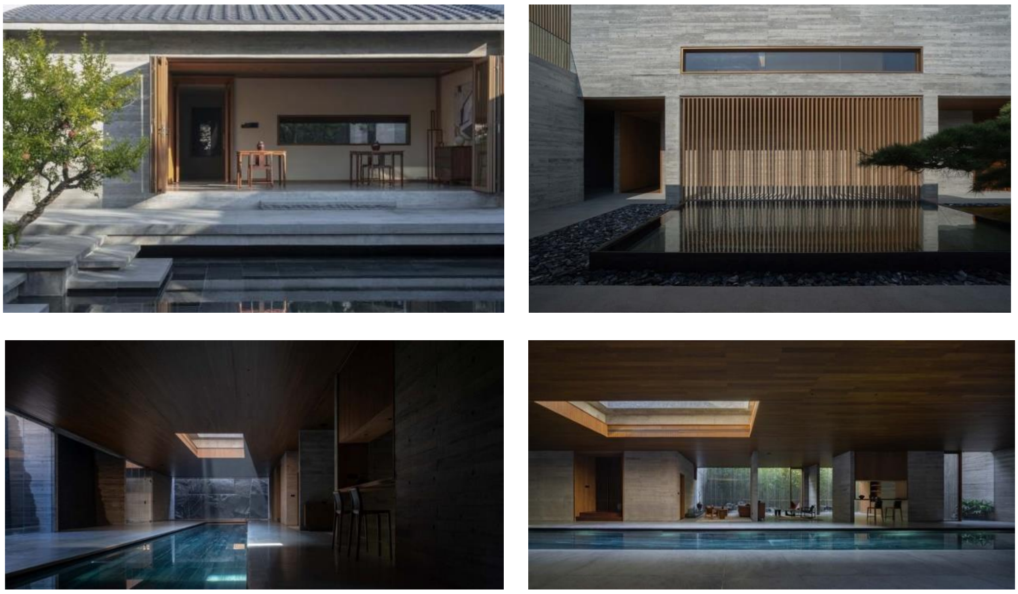
This nursing home features balconies and operable windows adjacent to courtyard spaces with the aim of providing each apartment with access to the outside, and with passive natural ventilation in every room.

Figure 30: An Example of TAV: Hørgården Care Centre, Denmark (URL 29)

5. Presence of Water (PW)

Experiencing a location with a high Presence of Water can be fascinating and captivating since humans have positive emotional responses to watery environments. Locations can be exciting, soothing, or both at the same time based on factors like fluidity, sound, lighting, accessibility, and mobility.

Landscapes with water evoke a stronger restorative reaction among populations than landscapes without water as stated by Heerwagen & Orians (1993). The presence of water improves self-esteem, increased feelings of tranquility, and lower heart rate and blood pressure over activities administrated in green surroundings without it while auditory access and perceived or prospective tactile access to water also are said to lower stress (Jo, and Jules, 2010). This pattern uses the multi-sensory attributes of water to enhance a place's experience in a way that encourages tranquility, inspires contemplation, and enhances mood.



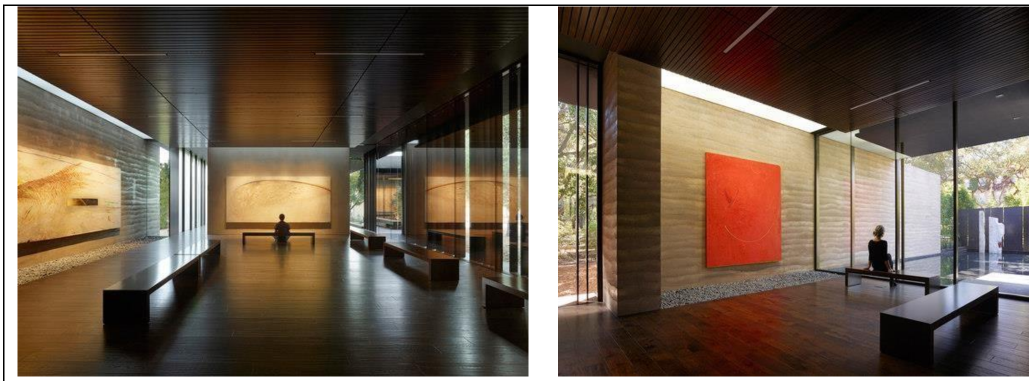
With vague boundaries, it allows two areas, a central pond yard and a sunken courtyard, to flow freely into one another, creating a peaceful ambience. Around this pond yard, a tea room and a grand dining area with the best views are planned. In addition, the waterscape skylight above the swimming pool lets in ample light.

Figure 31: An Example PW: The Flowing Garden House, China (URL 30)

6. Dynamic & diffuse light (DDL)

As well as evoking a calming sense of serenity, the lighting creates a sense of time and motion in an environment that is dynamic and diffuse.

A study by Michael and Gary (1996), revealed that well-lit work environments had a positive effect on productivity, and well-lit shops had a positive impact on sales. Moreover, it has been provided that in school settings a well-lit space is a design variable in which children do better in classrooms with outside views. Sleep quality, mood, alertness, depression, cancer, and other health problems are all connected to serotonin and melatonin balance. The impact of light on the circadian system functioning in a person's sleep cycle can be influenced by light perception (Kandel et al., 2013).



A building with an eastern orientation benefit from the daytime position of the sun, which is collected by the vertical louvers along the eastern wall, creating a connection between visitors and the sun's diurnal patterns.

Figure 32: An Example of DDL: Windhover Contemplative Center, United States (URL 31)

7. Connection with natural systems (CNS)

According to the definition, it is a place with a strong connection to natural systems that evokes a sense of belonging to a larger whole and makes one aware of seasons and life cycles (Browning et al., 2014). The experience is usually anticipated and is often soothing, nostalgic, deep, or illuminating.

This pattern is like the Presence of Water pattern, which is thought to boost good health responses. Kellert defines this as "Natural Patterns and Processes" in Biophilic Design (Kellert et al., 2008), were observing and comprehending natural processes may cause a perceptual change in what is seen and perceived. It is a significant progressive component that may be represented culturally, as an example of this pattern can be climate and weather patterns like rain and wind, diurnal patterns like light color and shadow casting, seasonal patterns, and wildlife habitats like flowering vegetation.

B. Natural Analogues

The term "natural analogue" can be applied to both natural and manufactured materials if the processes that change them are natural. Within the interior space, nature tends to suggest indirect ideas and non-living objects. Forms, colors, sequences, patterns, and abstract ideas of nature often connect this category to nature; examples include furniture finishes and upholstery materials that have a direct connection to nature (Wilson E. O., 1984). Providing rich and ongoing information is key to analogue experiences (Windhager, Sonja, et al., 2011). There are three patterns in this category as in the following;

8. Biomorphic Forms and Patterns (BFP)

By using nature's symbolic design rudiments, designers can illustrate the vernacular nature of their designs. These are patterns found in nature that are represented by patterns, contours, textures, colors, or numerical arrangements preserved in nature (Edward, Gabrielle, and Nava, 2012). When applying this pattern to designs, there are three things to keep in mind: generating a broad variety and incidence of exposure by using two or three planes and dimensions; avoiding using extreme patterns that are visually toxic; introducing conservative intercessions in the preliminary stages of design to enhance cost-effectiveness; and layering simple modules into a sophisticated pattern that is not immediately offensive.

The building characterized by; a bare stone cut into rigid straight lines to resemble a skeleton. The branching columns of the nave, meanwhile, are meant to mimic the shapes of trees and branches.

Figure 33: An Example of BFP: Sagrada Família, Spain (URL 32)

9. Material Connection with Nature (MCN)

Natural materials and elements reflect the local ecology or geology through minimal processing, creating a sense of place through their connection with nature. Creating a definite impression of a place by cloning native biological and geographical elements. Biological and cognitive responses can be stimulated by surveying geological materials (Terrapin Bright Green, L. L. C., 2014). It feels rich, warm, authentic, and a sensory stimulating space that has a good material connection with nature. Utilizing materials such as fixtures, fittings, and furnishings to achieve the intended functionality of a specific space by using natural elements as the finishing material. This design argues that creativity is not bound by the use of synthetics materials, on the contrary, it would be through the use of natural materials with a connection to nature.

By defining its own architectural universe, the building creates an architectural space distinct from the rest of the context by creating a set of walls that trap vegetation while offering windows to frame the environment around it.

Figure 34: An Example of MCN: Casa Reticular, Mexico (URL 33)

10. Complexity and Order (CO)

In nature, complexity and order are examples of a spatial hierarchy that adheres to rich sensory information. Nature's complexity and order result from a dimensional pyramid-like structure of information handling (Carina Tenngart, and Caroline, 2008). By arranging the patterns in an articulated pyramid format, the aim is to create a graphically stimulating environment that stimulates an optimistic reaction in the mind (Nikos, 2017).

With a spectrum of interventions-from mimicking to inserting overtly new elements-the design aims to create a more organically connected facility that engages the community. This is accomplished by two 2,90m high passes that play over structure and surface, aperture, and closure, down to the pattern of the floor materials that in turn reflect the location of seating.

Figure 35: An Example of CO: Cusanus Academy, Italy (URL 34)

C. Nature of the Space

Spatial planning and configuration are related to this category (Ryan, Catherine O., et al., 2014). In applying strategies in the spatial array, the human mind is engaged by elements of interest and unknowingness. They can also stimulate phobias in a controlled environment while maintaining a sense of safety (Terrapin Bright Green, L. L. C., 2014).

11. Prospect (P)

For reconnaissance and design, a prospect allows an unrestricted view over a space. To possess optimal prospects, open and liberating spaces must convey a sense of security and control. In unfamiliar or alone situations, it helps to feel open and free, yet provides a sense of security. By orienting the building, its openings, hallways, and terminals toward views of the landscape and points of interest in the surrounding area, it is possible to maximize visually accessible interior and outdoor environments (Thomas and Anna, 2007).

Built on a windy hill in a small but efficient building on a warm and sunny site. Throughout the home, windows are positioned to provide views of the landscape, capture winter sun, and to direct cool breezes.

Figure 36: An Example of Prospect: Prospect House, Australia (URL 35)

12. Refuge (R)

Refuge is a place to withdraw from environmental conditions and the main flow of activity, where an individual is protected and sheltered from all around. Meditative, cozy, and defensive spaces make up a decent refuge that differentiates itself from its surroundings without being isolated. In refuge design, we have seen progress from research on visual inclination and spatial reactions to natural environments, as well as their relationship to prospect conditions (Patrik, and Ulrika, 2010). Basic refuge examples include the lean-to, benches by bay windows, and fireplaces with inglenooks. In areas with several activities, it is crucial to introduce refuge spaces that meet diverse needs through the manipulation of lighting, dimensions, and camouflage rate (Helena et al., 2009).

The building rests on a raised plinth, a concrete container with precise openings that frame the landscape, and all the frames that appear in space engage in a dialogue with the existing house and with nature. A large sliding window in the refuge creates a clear boundary between the hard exterior and a soft, isolated interior.

Figure 37: An Example of Refuge: HOUSES. BONHEIDEN, Belgium (URL 36)

13. Mystery (M)

Using hidden views and other sensory devices to entice users deeper into its spaces, mystery offers intrigue by creating ambiguity through the manipulation of information (Masatake, 2005). Patterns created by curiosity are based on the human need to investigate (Thomas, and Anna, 2007). This pattern also plays with light and shade to enhance the experience of mystery, and by manipulating the size of spaces, the elements can create a sense of speed as they move through an area.

Even the slab steps and beams in this building appear to be useless objects which deviate from the rationale of the structure, and there are other solids both inside and outside of the structure that does not allow easy exploration of the design basis, like concrete that lies there as if it were stone plates, and walls chipped in an irregular fashion.

Figure 38: An Example of Mystery: Mixed-Use Architecture, Residential. JAPAN (URL 37)

14. Risk/Peril (RP)

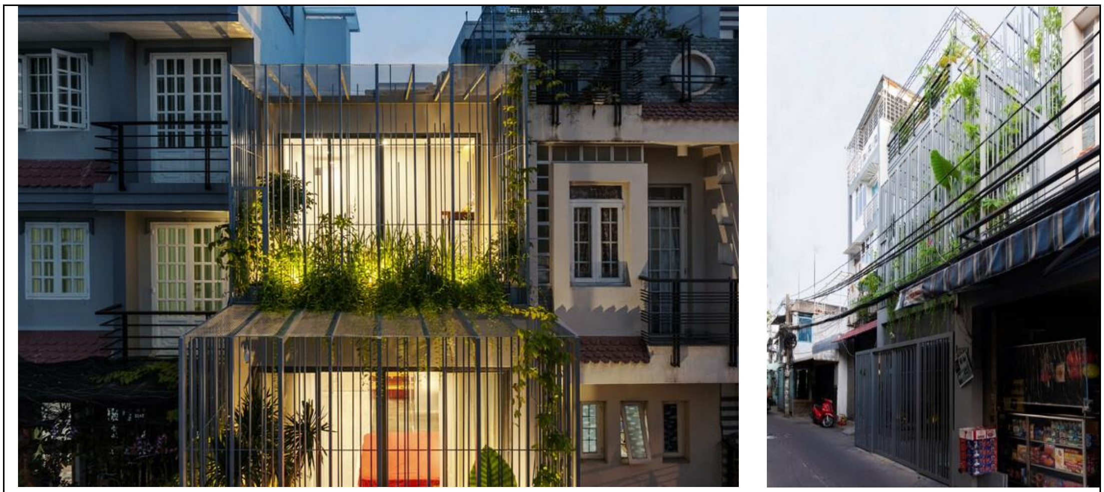
The concept of risk/peril refers to a recognizable danger associated with a trustworthy measure of safety and control (Agnes and Marlien, 2005). By avoiding direct danger, indirect danger induces an exciting feeling. However, the threat is dormant or passive due to the precautions taken. As well as stimulating attention, this pattern helps to restore memory and problem-solving abilities. Among these are cantilevered walkways and zoos can be given as an example of risk/peril.

The building is composed of two volumes clad in standing seam zinc that rises from the ground and forms a bridge between two solid volumes. The decks offer a welcome exterior space that is shaded from the blazing summer sun while blurring the lines between public and restricted areas.

Figure 39: An Example of Risk/Peril: Glen Ellen Aerie House, United States (URL 38)

15. Awe (A)

It is 'stimuli that cause a change in perception and defy existing frames of reference' through cultivating wonder, connection, and empathy (Browning and Ryan, 2020). In his perspective, Timothy B., (2020) defined awe as a constellation of terms including wonder, magic, curiosity, wildness, fascination, discovery, and radical amazement. Prioritizing awe has multiple benefits. According to research, generosity, kindness, and other prosocial behaviors are associated with awe. Thus, a sense of wonder can be brought into our daily lives by cultivating practices of wonder, teaching wonder, and designing wonder in places where we live and work.



It concentrates on many terraces with green plants and vibrant flowers hidden behind a metal facade. With these landscape areas, the noise from the busy traffic below has been reduced, and the privacy and security of the interior spaces have been enhanced. Additionally, they act as important green buffers that can positively influence the streetscape.

Figure 40: An Example of Awe: Of Cage House, Vietnam (URL 39)

2.2.5 Incorporating Biophilia into Design Actions

Based on Wilson (1986), and Kellert (2012), biologically, people tend to affiliate with nature, but this natural tendency must be nurtured and developed for it to be useful. Nature has been treated either as an obstacle to overcome or as a side issue in modern building and landscape design. As a result, people are increasingly disconnected from nature in the built environment as reflected by poor access to direct contact with nature that puts building residents in a good health by providing vegetation, ventilation, materials, natural light, natural shapes, views, and forms. Many of today's-built environments are so sensory-deprived, that they remind one of the old-fashioned zoo cages that were labeled as cruel (Kellert and Finnegan, 2011). In addition, modern agriculture, manufacturing, education, healthcare, and urban development are all marked by this increasing separation from nature.

In the last decade, biophilic design has been widely discussed and explored as a sustainable approach in architecture, in response to several issues such as climate change, resource scarcity, and SBS (Simon, and Steven, 2005). Various approaches have been applied to adopting smart, responsive, renewable, biodegradable, and recyclable materials, such as energy-efficient, high technology, and vernacular methods. (Simon, and Steven, 2007). Hence, it is possible to unpack and understand the contested notion of sustainability in architecture by bridging a variety of challenges and design intentions or goals.

To overcome the fuzzy notion of indoor environmental quality, this study investigated biophilic design's potential positive indoor environmental quality, which is a key element in reducing sick building syndrome. This study examined the principles, attributes, and patterns of biophilic design to understand its contribution and its utility in solving SBS issues. As a result, the most relevant biophilic design elements/attributions are chosen by correlating many different benefits to them.

2.3 Summary of the Chapter

To understand the concept of sick building syndrome and its integration into the biophilic design approach in interior space, the chapter takes charge to explain in detail the two key concepts of sick building syndrome and the biophilic design approach.

The sick building syndrome section starts by generally describing and classifying the concept as it is a syndrome that refers to circumstances in which building occupants have acute health and comfort consequences that are related to time spent in the building, but no sickness or cause can be established. For a better understanding of the concept, the key factor defined SBS existence has been mentioned as can see in a form of complaints from building occupants when a certain time is spent in indoor spaces. Though, the literature review concentrates on the five SBS contributors (chemical, biological, psychological, electromagnetic radiation, and physical) as being the factors that caused indoor environmental problems.

The second section of the chapter talks about the biophilic design approach starting with a general description of the concept. In general, can be defined as the innate affiliation people seek with other organisms and especially the natural world. The connection of humans with nature within the design of interior living has multiple benefits including promoting health, productivity, biodiversity, circularity, and resilience. In spite of this, the study specifically included three of the numerous biophilic design interpretations since they have been adopted for studies of biophilic design in health and well-being (Browning and Ryan, 2020; Kellert, 2008; Kellert, 2018)

Chapter 3

CORRELATING SBS AND BIOPHILIC DESIGN CONCEPTS: REVEALING STRATEGIES TO SOLVE THE SBS OCCURRED IN INTERIOR SPACES

This chapter aims to correlate sick building syndrome and the biophilic design concepts and hence to use biophilic design as a strategy to solve the issues caused by the physical indoor environment.

Specifically, it is divided into three main sections. The first part defines the methods used in the study and would provide the main tools to understand the ways to collect the data. In short, this study uses the literature review collected in chapter 2 to create a result for the study, and by the creation of the analytical frameworks.

The second section of the chapter creates the frameworks, by the use of the five SBS contributors that are chemical, biological, electromagnetic radiation, psychological and physical, which have been outlined at the end of the literature review in the sick building part, to be correlated with the actions and strategies provided by the Biophilic Design approach.

The final part of this chapter is to collect the data from the frameworks for taking the findings and dividing them into three sections (i.e.the mostly used, rarely used, and never used Biophilic attributes, principles, and patterns) which would allow the determination of what actions/solutions can be taken in the design, construction, and use stage.

3.1 Method of Study

This study has worked toward the following specific goals:

<u>First Stage: Identifying relevant publications for a theoretical basis</u>

Firstly, the previous chapters present a theoretical basis for the relationship between humans, health, and nature by considering theories related to the SBS and biophilia concepts. Through literature reviews, it derives the characteristics of the sick building syndrome that harm the occupants of the built environment and the potential to implement biophilic design strategies. Diverse search, screening, and selection methods have been used in the first stage of the study. The key terms ‘SBS’ ‘SBS factors’ ‘SBS causes’ ‘health and wellbeing issues as well as the key terms of ‘Biophilic design’ ‘Biophilia’ and ‘Biophilic in interior spaces’ and by using these databases, papers were initially found. As part of the general inclusion criteria, the study focused on describing the concept of SBS and its factors and causes on the occupants as the first aspect of the issue. And then it focused on the description of the concept of biophilic design, within the scope of interior architecture to create a nature-related solution.

<u>Second Stage: Developing an analytical framework</u>

To overcome the fuzzy nature of SBS and hence develop a more analytical approach and understand how biophilic design can aid in solving the challenges caused by each of the SBS contributors, the study identified the benefits of the biophilic design approach in addressing each of the challenges caused by the SBS. Accordingly, an analytical framework has been developed for both key concepts (SBS and Biophilic

Design) to guide and facilitate the problem/solution process to aid the correlation of SBS Contributors and the Biophilic actions and solutions at distinct stages as it was categorized in the previous chapter: Design Stage, Construction Stage, and Use Stage. Accordingly, five (5) SBS contributors which are chemical, biological, electromagnetic radiation, psychological and physical, which have been outlined at the end of the literature review are correlated with the Biophilic Design Principles, Attributes, and Patterns. This correlation, by using keywords, intends to explore whether the biophilic approach can implement solutions/actions like the suggested ones in the SBS framework. Correlation is first presented in schemes and then is discussed to explore how the proposed biophilic action and solution would help to solve the SBS.

3.2 Correlating Five SBS Contributors with Biophilic Actions and Solution

In order to build the analytical framework, keywords related to possible solutions/synthesizes and actions have been gathered from the tables at the end of the literature review on sick building syndrome. The keywords have already been defined for each of the five SBS contributors (chemical, biological, electromagnetic radiation, psychological, and physical), namely the stages of dealing with the contributor (design, construction, and use stage).

Following that, the selected keywords for SBS actions were correlated with the Biophilic design actions of its principles, attributes, and actions. It is through this procedure the study was able to gain a better understanding of what can be done by biophilic design actions in order to solve SBS contributors.

3.2.1 Correlating Chemical Contributor with Biophilic Actions and Solutions

Table 15: Correlating Chemical Contributor at Design and Use Stage with Biophilic Actions and Solutions

Chemical contributor Design stage — Biophilic actions and solutions

Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Building materials . Exposure to indoor chemicals	Principle 5	. Att.11 . Att.12	. P.2 . P.9
. Control air pollution . Control flow rates	Principle 1	. Att.2 . Att.18 . Att.6 . Att.22 . Att.7	. P.1 . P.4 . P.10
. Air intakes . Outdoor pollution	Principle 1	. Att.4 . Att.23 . Att.6 . Att.22	. P.1 . P.10 . P.2 . P.7
. Low VOC paints	- non	- non	- non
. Mineral entry-level floors	Principle 5	. Att.11	. P.9
. High volatility finish material	Principle 5	. Att.11	. P.9

Use stage

Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Clean environment . Hygiene	Principle 1	. Att.4 . Att.21 . Att.6 . Att.25 . Att.17	. P.1
. furniture layout . interior layout	Principle 2	. Att.21 . Att.22 . Att.25	- non
. Storge area . Ventilation	Principle 1	. Att.2 . Att.18	. P.1 . P.4
. Good ventilation	Principle 1	. Att.2 . Att.18	. P.1 . P.4
. low level VOC in furniture and carpet	- non	- non	- non
. Non-toxic materials	Principle 1	. Att.11	. P.9

Table 16: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** **PRINCIPLE 2** **Natural shapes and forms** PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space **PRINCIPLE 5** **Place-based relationships** PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE Att.1 Light **Att.2 Air** Att.3 Water **Att.4 Plants** Att.5 Animals **Att.6 Landscapes** **Att.7 Weather** Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** **P.2 Non-Visual Connection with Nature** P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images **Att.11 Materials** **Att.12 Texture** Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time **Att.17 Natural geometries** **Att.18 Stimulated natural light and air** Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns **P.9 Material Connection with Nature** **P.10 Complexity & Order**
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge **Att.21 Organized complexity** **Att.22 Mobility** **Att.23 Transitional spaces** Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS- HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': Natural features such as air, sunlight, plants, and façade greening can be utilized to reduce indoor air pollution and optimize indoor air quality. Incorporating natural characteristics into a built environment increases the well-being of the occupants and reduces sickness caused by the indoor environment.

Principle 5 'Place-based relationships': This principle can be adapted to the indoor design process to reduce exposure to indoor chemicals, for instance, by choosing safe building materials and finishing materials that are natural and have a high volatility level. This principle describes how culture and ecology are successfully mated in a geographical context. Despite their evolution, people remain connected to places to establish territorial control, facilitate control over resources, ensure safety, and achieve security during the long course of our species' evolution. The utilization of local and indigenous materials is associated with improving the relationship between place and people. Indigenous materials are often resonant reminders of local culture and environment, as well as requiring less energy during manufacturing and transportation.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.2 'Air': By utilizing natural ventilation in the indoor environment, it is possible to control air pollution, as well as control the airflow inside buildings through parameters such as quality, flow, and movement. In general, natural ventilation is preferred to processed air.

Att.4 'Vegetation': Even though plants may be able to reduce indoor pollutants (Majbrit, 2014), it is not the most reliable way of ensuring clean air. It is however much more effective to reduce indoor air pollution by using plants through Phytoremediation (defined as using plants to reduce the concentration or breakdown of pollutants in the air, soil, and water), and a process called Biofiltration (the biological process that eliminates toxic nitrogenous waste), side by side with ventilation, such as opening a window or turning on an exhaust fan.

Att.6 'Ecosystem and natural landscapes': Air pollution is controlled by the interconnected elements of this attribute, such as plants, water, soil, and geological formation. Creating buildings and landscapes that are connected to local habitats and ecosystems tends to be highly effective in influencing the quality of the air that flows into the indoor spaces.

Att.7 'Weather': By controlling atmospheric pressure and airflow through exterior design strategies like operable windows, decks, and balconies, indoor environments can be duplicated to be like outdoor ones, thus, controlling indoor air pollution.

Att.11 'Materials' and Att.12 'Texture': A design that uses natural materials would reduce the number of chemicals present in indoor air. The biophilic design strategy emphasizes a limitation on the use of dangerous materials in living spaces, and it can be achieved by incorporating natural materials in the design, which are high-volatility finish materials.

Att.18 'Stimulated natural light and air': Utilizing technological innovations, it is possible to reproduce natural lighting and airflow, thus reducing indoor air pollution and keeping the environment ventilated.

Att.22 'Mobility' and Att.23 'Transitional spaces': The design of an easy and efficient movement of occupants between areas inside a building and from the interior to the exterior would control flow rates and air pollution. SBS can be troublesome if there are no clear pathways and entry points enabling seamless movement between spaces under a biophilic design that provides healthy ventilation.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': Direct contact with nature would provide features like natural light and natural ventilation. By adding plants and trees to the landscape near buildings and other sources of pollution, air pollution can be reduced significantly. The connection to nature is achieved through green walls, potted plants, green roofs, and large atriums that can control flow rates and air pollution indoors.

P.2 'Non-visual connection with nature': non-visual connections with natural features can help in psychological issues, including an improvement in attention, lower stress, and a better mood. Specifically, auditory stimulation that is naturally occurring can be achieved using operable windows and natural flow rates and reduce the concentration of air pollution in the space.

P.4 'Thermal and airflow variability': sick building syndrome can all be reduced with natural ventilation and that helps in the recovery of various occupants' health issues caused by air pollution. The benefits of natural ventilation and the alteration of thermal concerns can be achieved through access to operable windows that could improve the satisfaction and the health of a space.

P.7 'Connection with natural systems': a place having strong links to natural systems that evokes control over the percentage of pollution. This pattern is strongly related to landscape ecology, and effective place-based design can reinforce this by considering factors such as ecological connectivity, biological corridors, re-source flows, biodiversity, optimal scale, and size, ecological boundaries, and other factors that function as natural regulators of the air pollution.

P.9 'Material Connection with Nature': By using materials that reflect the local ecology and geology and are minimally processed, a sense of place that is rooted in nature is created. Creating an impression of a place by cloning its native biological and geographical features. A survey of geological materials can stimulate biological and cognitive responses while reducing exposure to indoor chemicals and is beneficial to the occupants of the building.

P.10 'Complexity and Order': The pattern is responsible for the spatial hierarchy within the indoor space and the building form and layout of the landscape. By arranging the spaces in an articulated pyramid format according to their function, the aim is to create a stimulating environment that is responsible for controlling flow rates within the building and reducing the possibility of air pollution by dust accumulation.

Use stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': The biophilic design encourages continuous and repeated engagement with nature, encouraging continuous and repeated engagement with natural elements that present an earlier stage of solutions to SBS issues like hygiene, clean environments, and adequate ventilation to protect occupants' health.

B. Solutions/synthesis of Biophilic attributes

Att.2 'Air': Encourage a healthier lifestyle in indoor spaces by making the users aware that opening the windows will provide them with fresh air by providing natural ventilation.

Att.4 'Vegetation': The rate of air purification can be influenced by the number of plants in a room, and two "good-sized" plants per 9 square meters are recommended (US EPA, 1988).

Att.6 'Ecosystems and natural landscape': The attribute, since it is composed of interdependent elements, including plants, will not only produce more oxygen into the environment through photosynthesis but will also clean the air from VOC toxins.

Att.11 'Materials': The use of natural design finishing materials like wall coverings, brick, carpet, tile, window furnishing...etc. Paying attention to the material quality is significant, for better conservation, maintenance, and controlling aging conditions, to have the ability to reuse natural materials.

Att.17 'Natural geometries and Att.21 'Organized complexity': To avoid the risk of dust accumulation and the difficulty of maintaining proper hygiene, natural geometry designs which use forms and patterns that are biomorphic with curvilinear shapes, side by side with furniture organization and interior layout.

Att.22 'Mobility 'and Att.25 'Integrating parts to create wholes': Using furniture and layouts that make it easy to move between diverse and often complicated spaces, thereby linking the physical nature of the building with the goal of health and providing decent, safe, and sanitary living environment, clean and weathertight conditions, in accordance with local and state building and health codes.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': The most common tactic is to incorporate natural characteristics into the built environment. Indoor environments often incorporate natural elements, such as water, flora, and sunlight, to maintain the cleanliness of the environment and to provide a healthy living space.

P.4 'Thermal and airflow variability': Open more than one window on different sides to benefit from natural cross ventilation. The wind blowing against the building forces air through open windows on the exposed side while creating a vacuum effect on protected side that forces air out of the windows.

P.9 'Material connection with nature': Floors, paint, and other home furnishings contain many chemicals linked to health problems. When choosing materials, remodeling a building or buying furniture, we should be aware of the links between our health and the environment and make more informed choices.

3.2.2 Correlating Biological Contributor with Biophilic Actions and Solutions

Table 17: Correlating Biological Contributor at Construction Stage with Biophilic Actions and Solutions

Biological contributor Construction stage	Biophilic actions and solutions		
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Exterior walls . Roofing system . Window construction	Principle 3	- non	. P.1
. Maintenance . Plumping leaks	- non	- non	- non
. Cleaning regimen . Hygiene	Principle 3	. Att.4	. P.1
. Mold and humidity	Principle 1	. Att.1 . Att. 6 . Att. 2 . Att.7 . Att. 4 . Att.18	. P.1 . P.4 . P.9
. Cleaning HVAC	- non	- non	- non
. Interior air temperature	Principle 4	. Att.18 . Att. 25	- non
. Monolithic flooring	Principle 1	. Att.11 . Att.12	. P.9

Table 18: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** PRINCIPLE 2 Natural shapes and forms **PRINCIPLE 3** **Natural patterns and processes** **PRINCIPLE 4** **Light and space** PRINCIPLE 5 Place-based relationships PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE **Att.1 Light** **Att.2 Air** Att.3 Water **Att.4 Plants** Att.5 Animals **Att.6 Landscapes** **Att.7 Weather** Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** P.2 Non-Visual Connection with Nature P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light P.7 Connection with Natural Systems
	INDIRECT EXPERIENCE OF NATURE Att.10 Images **Att.11 Materials** **Att.12 Texture** Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries **Att.18 Stimulated natural light and air** Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns **P.9 Material Connection with Nature** P.10 Complexity & Order
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity Att.22 Mobility Att.23 Transitional spaces Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS- HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Construction stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': By controlling the indoor climate and ventilation, it would be possible to avoid humidity and mold problems. When the humidity is high, mold thrives, particularly when the air is wet and damp. As a result, it is important to manage the conditions inside, such as air, water, natural materials, and sunlight, so that they cannot grow and spread.

Principle 3 'Natural patterns and processes': To solve health issues, biophilic designs reinforce, interconnect, and integrate design elements. Natural materials for exterior walls, roofing systems, and window construction would reduce the need for maintenance since the use of suitable design elements prevents health problems for occupants of the buildings.

Principle 4 'Light and space': Indoor temperatures and daylight conditions both contribute equally to the overall comfort perception. To resolve the SBS issue, indoor factors like natural light, reflected light, inside-outside spaces, and spaciousness, should not be considered separately in the construction stage, but together. It is possible to improve comfort in buildings by integrating the interactions between indoor factors.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.1 'Light', Att.2 'Air' and Att.7 'Weather': Mold is easier to prevent than to remedy, and by controlling airflow, barometric pressure, and humidity, it is possible to replicate weather-like conditions in an indoor setting. It is possible by letting in some sunlight, sunlight can be the enemy of mold, so open the windows, curtains, and blinds and let some light in. Besides allowing fresh air into the room, circulating fresh air also minimizes mildew and mold growth, since a cool breeze through a room or air movement caused by ceiling fans can help.

Att.6 'Ecosystem and natural landscapes': It is impossible to eliminate mold or mold spores in an indoor environment, but controlling indoor moisture can limit the growth of mold. The ecosystem and natural landscape provide humidity control by adding or removing water vapor to or from indoor air to keep it within proper ranges, through interactions between plants, animals, soil, rocks, and geological formations.

Att.11 'Materials' and Att.12 'Texture': Among the most important applications in construction is waterproofing, which increases the durability of many different surfaces. Floors that are not monolithic can allow dirty water to seep through, which means dirty water can seep through both the top and bottom of the floor. Monolithic floors do not have any seams or joints, whereas tile floors are made up of many pieces with grout between them, thus, water and dirt can seep through them in time.

Att.18 'Stimulated natural light and air': When the building envelope is closed it is important to exchange the indoor air to prevent biological contamination. Moreover, it is important to mix both natural and stimulated air and light in an indoor environment. As well, relative humidity should fluctuate between 30% and 60%.

Att.25 'Integrating parts to create wholes': Various spaces can be linked sequentially and successively, in the construction stage to control the air temperature within. In addition, it creates a sense of organization in the indoor space, eventually, giving the occupants control over their environment.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': A building constructed in direct contact with nature must have exterior walls, a roofing system, and window construction that minimize mold growth and humidity. As part of the building construction, there would be structural requirements to prevent air leaks, maintain continuity and integrity of the insulation, and prevent water penetration, while providing visual links to natural aspects.

P.4 'Thermal and airflow variability': It is possible to enhance the environmental conditions for the occupants of a building by offering variable conductivity materials and seating with varying degrees of solar heat gain (inside or out). Natural roof ventilators reduce humidity by removing moist air from the building, and a ventilator pushes humid air outside instead of trapping it in, therefore both methods are necessary for maintaining maximum control over building conditions, especially in the workplace.

P.9 'Material connection with nature': In connection with natural elements, natural materials provide a sense of place through their connection with the environment. This type of building material clones native biological and geographical elements to produce a definite impression of the place while fighting moisture and mold.

3.2.3 Correlating Electromagnetic Radiation Contributor with Biophilic Actions and Solutions

Table 19: Correlating Electromagnetic Radiation Contributor at Design and Construction Stage with Biophilic Actions and Solutions

Electromagnetic radiation contributor	Solutions/synthesis and actions	Biophilic actions and solutions: Biophilic principles	Biophilic attributes	Biophilic patterns
Design stage	. Control radiation . Secured electrical lines	- non	- non	- non
	. Air exchange . Construction materials with low radon impact	Principle 1	. Att.2 . Att.6 . Att.16	. P.4 . P.9
Construction stage	. Non-toxic materials	- non	- non	- non
	. Low radioactivity (brick, cement), metamorphic rocks and limestone	Principle 1	. Att.11 . Att.12 . Att.16	. P.9

Table 20: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space PRINCIPLE 5 Place-based relationships PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE Att.1 Light **Att.2 Air** Att.3 Water Att.4 Plants Att.5 Animals **Att.6 Landscapes** Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION P.1 Visual Connection with Nature P.2 Non-Visual Connection with Nature P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light P.7 Connection with Natural Systems
	INDIRECT EXPERIENCE OF NATURE Att.10 Images **Att.11 Materials** **Att.12 Texture** Att.13 Color Att.14 Shapes and forms Att.15 Information richness **Att.16 Change, age, the patina of time** Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns **P.9 Material Connection with Nature** P.10 Complexity & Order
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity Att.22 Mobility Att.23 Transitional spaces Att.24 Place Att.25 Integrating parts to create wholes	NATURE OF THE SPACE PATTERNS-HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': By incorporating natural characteristics of air and natural materials into the built environment, the biophilic design will reduce the amount of radon level in the indoor environment. Using fans and vents to circulate air inside the house and open windows increases airflow. In any case, "radon exhalation from building materials does not significantly affect the indoor air quality, but the absence of ventilation can cause health hazards owing to the accumulation of radon gas, even in circumstances with low exposure to radon" (Jiwon, et al., 2022, p. 2). In addition to choosing natural materials with low radon levels, seal cracks in floors and walls with caulk, plaster, or other materials designed for this purpose.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.2 'Air': To reduce radon levels temporarily, would be possible simply by opening the windows. Ventilation and air circulation improve indoor air quality, helping to remove radon from the living environment and mixing it with radon-free air from the outdoors, more effectively when the basement windows are open all-day.

Att.6 'Ecosystem and natural landscape': By vaporizing, some of the radon that is found in the soil will move to the surface, and when radon compounds are in the air, they attach to dust and other particles. It is safe to assume that having a natural landscape with tree features can help in this regard since plants naturally remove heavy metals from the air, soil, and water through a process known as phytoremediation.

Att.16 'Change, age and the patina of time': With proper construction materials used in home decorating, radon levels in a building are not affected, particularly on the occupants. When organic components are used in the design, therefore, aging is a fundamental aspect of nature. It is a quality of natural materials that has a patina of time. For this reason, it is preferable to use natural organic products in decorating or designing indoor spaces.

C. Solutions/synthesis of Biophilic patterns

P.4 'Thermal and airflow variability': In each house, air-change rates are inversely correlated with radon levels. Consequently, if the ventilation rate is reduced from, say, one air change per hour to one-half change per hour, airborne radon levels will double. Thus, radon exhalation from building materials has little impact on indoor air quality in a living environment with good air exchange.

P.9 'Material connection with nature': Natural design and finishing materials with low radon impact.

Construction stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': The use of natural characteristics materials into the built environment.

B. Solutions/synthesis of Biophilic attributes

Att.11 'Materials' and Att.12 'Texture': The use of safe natural finishing building materials provided by the biophilic design, with a low content of radioactivity, such as brick and cement.

Att.16 'Change, age and the patina of time': Natural materials with properties of aging through the time would be used in the construction stage.

C. Solutions/synthesis of Biophilic patterns

P.9 'Material connection with nature': Natural materials in building construction that frame the natural environment in indoor spaces are the most preferable to be used.

3.2.4 Correlating Psychological Contributor with Biophilic Actions and Solutions

Table 21: Correlating Psychological Contributor at Design Stage with Biophilic Actions and Solutions

Psychological contributor Design stage	Biophilic actions and solutions		
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Exterior views . Window height	Principle 1	. Att.6 . Att.8 . Att.23	. P.1 . P.10 . P.7
. Landscape allocation . Natural contact	Principle 5	. Att.3 . Att.4 . Att.6	. P.1 . P.2
. Color relation to space function	Principle 1	. Att.12 . Att.13	. P.1
. Adequate ventilation . Natural light . Views . Improve the psychological and social aspects of space	Principle 1	. Att.1 . Att.2 . Att.6 . Att.8 . Att.20 . Att.22	. P.1 . P.4 . P.6

Table 22: An Overview of Framework Shortcuts

Principles of Biophilic design	Attributes/Experience of Biophilic design	Patterns of Biophilic design
PRINCIPLE 1 Environmental features PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space **PRINCIPLE 5 Place-based relationships** PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE **Att.1 Light** **Att.2 Air** **Att.3 Water** **Att.4 Plants** Att.5 Animals **Att.6 Landscapes** Att.7 Weather **Att.8 Views** Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** **P.2 Non-Visual Connection with Nature** P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water **P.6 Dynamic & Diffuse Light** **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials **Att.12 Texture** **Att.13 Color** Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns P.9 Material Connection with Nature **P.10 Complexity & Order**
	EXPERIENCE OF SPACE AND PLACE **Att.20 Prospect and refuge** Att.21 Organized complexity **Att.22 Mobility** **Att.23 Transitional spaces** Att.24 Place Att.25 Integrating parts to create wholes	NATURE OF THE SPACE PATTERNS-HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': When creating a place where people feel good and perform well, designers must balance strategies that promote efficiency, connection to nature, and meeting the needs of occupants, as well as promoting well-being. A pleasing nature scene can reduce fatigue and headaches and boost the overall performance of people when looking at it; therefore, effective strategies for improving occupant comfort and letting them control their environment are required. Specifically noted that there are many factors affecting psychological wellbeing in living environments related to the physical and social environment of each area. As a result, every domestic component has significant environmental characteristics that can influence the psychological health of occupants. It is possible that these features vary from one space to another based on occupants' needs and demands.

Principle 5 'Place-based relationships': landscape orientation, landscape features that define building form, and landscape ecology are all attributes of biophilic design that would define the proper landscape allocation for the mental health of occupants, by defining the potential natural contact. It is characterized by a sense of place carried throughout the built environment, which makes the biophilic principle an ideal way to transform built environments into spaces to which individuals can relate emotionally and psychologically.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.1 'Light': By providing access to natural sunlight, building residents will become healthier, safer, and more comfortable. In terms of interior design, the lighter and brighter the space, the more comfortable it is. Humans benefit from natural light in indoor environments by improving their circadian rhythms, and sleeping patterns, focusing better, and being more productive. To maintain our physical and psychological well-being, it is important to get enough of this essential resource.

Att.2 'Air': A person's mood will improve significantly when they breathe in the fresher air. It is often because of this that we feel better, more relaxed, and more refreshed after spending some time outside. A natural airflow not only improves human well-being emotionally, but also physically, lowering blood pressure, heart rate, and stress hormone levels.

Att.3 'Water': When paired with other sensory experiences including sound, sight, touch, taste, and movement, views of the water and the sound of water may improve the built environment, reduce stress, foster satisfaction, and improve health and performance. Overall, views of water features are linked to lowered stress levels, decreased obesity, and enhanced mental and emotional health.

Att.4 'Vegetation', Att.6 'Ecosystem and natural landscape' and Att.8 'Views': Plants and a natural environment help reduce depression and anxiety, improving mood and overall health. By using views, observation platforms, and direct engagement, one may examine, observe, directly interact with, and even actively participate in the environment. Exposure to indoor or outdoor plants hence reduces signs of stress, increases comfort, increases pain tolerance, and improves productivity and performance.

Att.12 'Texture' and Att.13 'Color': The use of natural paint colors, like green, blue, and yellow, will brighten the space and ensure light is reflected throughout the room. Bringing in daylight and bringing outdoor elements indoors, shapes, patterns, and textures that are reminiscent of nature will create a bright, functional, and productive place that is also comfortable and satisfying.

Att.20 'Prospect and refuge': Create interior-exterior connections in spaces that transition from interior to exterior, such as porches, balconies, patios, gardens, courtyards, pavilions, entryways, foyers, atriums, etc. Designing spaces that incorporate two complementary features: the possibility of open views/vistas (prospect) and the comfort/safety of shelters/safe spaces (refuge), would consider a stress reduction and mentally improve spaces.

Att.22 'Mobility' and Att.23 'Transitional spaces': It is possible to evoke a positive or negative emotional reaction through the amount of movement and the ability to move through interior design elements and from outside to inside. With this feature, it becomes possible to design spaces in which functional and decorative design elements are thoughtfully manipulated to encourage health improvement and stress reduction.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature' and P.7 'Connection with natural system': The use of plants, aids to strengthen the appearance of buildings by installing large atriums, green walls and facades, and green roofs. Natural daylight and vegetation in working spaces can improve creativity and productivity, while it brings calm and comfort to rest areas. For easy access to natural features, green walls and potted plants can bring nature indoors.

P.2 'Non-visual connection with nature': Think beyond materials to textures like light, color, and sound. The psychological restoration can be achieved by providing views of forests, seascapes, and waterscapes, as well as by providing windows showing the beauty of nature.

P.4 'Thermal and airflow variability': Strategies of design depend on living area orientation to improve livability and climate comfort, would enhance thermal comfort, which is a feature that has a profound influence on humans' health and psychology.

P.6 ‘Dynamic and diffuse light’: Diffused or filtered sunlight can stimulate the connection between interiors and exteriors, particularly areas inside and outside. Mitigate the effects of SBS, improve occupant health and well-being, and help reduce psychological and mental sickness.

P.10 ‘Complexity and order’: The pattern looks for natural forms, patterns, and shapes, especially in exposed construction details, façades, and building structures that are beneficial for a better mental state, less stress, increased well-being, better attention, and provide a faster healing rate.

3.2.5 Correlating Physical Contributors with Biophilic Actions and Solutions Ventilation, Illumination, Noise, Indoor Air Quality, Air Temperature and Humidity

Table 23: Correlating Physical Contributor (Ventilation) at Design, Construction and Use Stage with Biophilic Actions and Solutions.

Physical contributor (Ventilation)		Biophilic actions and solutions		
Stage	Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
Design stage	. Passive design techniques . Spatial layout . Using local climate	- non	. Att.1 . Att.2 . Att.4 . Att.7 . Att.22 . Att.23 . Att.25	. P.1 . P.4 . P.10
	. Smart/responsive building skin . Ventilation system	Principle 1	. Att.2 . Att.4 . Att.6 . Att.18	. P.1 . P.7
	. Adequate ventilation . Air circulation . Prevent dust and toxic gases	Principle 5	. Att.2 . Att.18 . Att.22 . Att.23 . Att.25	. P.4
	. Cross ventilation . Good indoor air quality	Principle 5	. Att.2 . Att.22 . Att.23	. P.4 . P.10
Construction stage	. Duct installation . Buoyant air movement	- non	. Att.18	. P.4
Use stage	. Room ventilation . Open windows and doorways	- non	- non	- non
	. Cleaning outside areas	- non	- non	- non

Table 24: An Overview of Framework Shortcuts

Principles of Biophilic design	Attributes/Experience of Biophilic design	Patterns of Biophilic design
PRINCIPLE 1 Environmental features PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space **PRINCIPLE 5 Place-based relationships** PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE **Att.1 Light** **Att.2 Air** Att.3 Water Att.4 Plants Att.5 Animals Att.6 Landscapes Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** P.2 Non-Visual Connection with Nature P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns P.9 Material Connection with Nature **P.10 Complexity & Order**
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity **Att.22 Mobility** **Att.23 Transitional spaces** Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS-HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': This is a technique for controlling the environmental quality inside the building. It is the process of using environmental features and natural ventilation (external air movement) to improve air quality in a building. Environmental ventilation improves indoor air quality and provides an advanced ventilation system.

Principle 5 'Place-based relationships': The principle supports the biophilic design strategies to maintain good indoor air quality and natural ventilation through its features of landscape orientation, landscape features that define building form, and landscape ecology. Providing those features in the design of indoor space would define the dominant wind speed, direction, and orientation. Additionally, buildings and landscapes that are connected to the local environment add to the sense of place.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.1 'Light': The use of passive design strategies to lit the living environment, such as using a clever breezeway or wooden shutters. Those design elements would provide natural ventilation and reduce heat accumulation.

Att.2 'Air' and Att.7 'Weather': Introducing passive design strategies into a building's design ensures adequate ventilation by channeling natural resources. Here, passive design is heavily focused on cross ventilation. Architects used existing operable windows and skylights, as well as bifold exterior doors, for maximum natural ventilation.

Att.4 'Vegetation' and Att.6 'Ecosystem and natural landscape': Vegetation and natural ecosystems will be used to provide cooling to both the outside and inside of the building. The strategy can be achieved by placing plants along the property boundaries, near the windows for air filtration, and by strategically planting near the boundaries, etc. the plants will serve as windbreaks, protecting the residence from strong prevailing winds. Also, by strategically placing plants in the landscape to channel breezes, air will be funneled into the residence for cooling.

Att.18 'Stimulated natural light and air': Employing technological innovations of a smart/responsive building skin integrated with an advanced ventilation system and physical modifications imitates the changing lights and air conditions of nature throughout the day. In addition to being an aesthetically pleasing element of a design, a building's skin plays a crucial role in the overall technical function of the building and its interior. With smart/responsive building skin, it can automate various processes inside a building, including heating, cooling, security, lighting, and ventilation. As a result, the process can help the environment and building occupants.

Att.22 'Mobility', Att.23 'Transitional spaces' and Att.25 'Integration parts to create wholes': An effective building design would keep its spaces open interior and exterior for maximum cross ventilation and good indoor air quality. Passively ventilating a building can be accomplished by keeping the main living area free of walls and any other barriers and capturing the natural breezes.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': Since the pattern is characterized as a view of nature, living systems, and natural processes, means it has direct contact with nature and natural features like natural light and natural ventilation. A natural ventilation system can be driven by wind pressures or pressures generated by differences in density between indoor and outdoor air. To achieve effective airflows, this procedure uses passive elements such as "building orientation and form, appropriately-sized and oriented openings, the benefits of local materials, and mass for night cooling" as also stated by Loftness, (2020).

P.4 'Thermal & Airflow Variability': Through the orientation of the working and living areas, thermally zoned buildings can reduce the need for ventilation, resulting in improved livability and climate comfort. Strategies of passive cooling designs to fetch in natural light and view via clerestories, glass walls, skylights, atria, reflective colors, and materials and that assist in insulating the interior climatic conditions as also stated by Zong et al. (2022).

P.7 'Connection with natural systems' and P.10 'Complexity and Order': Pattern strategies include controlling building form and layout to maximize daylighting and solar gain, modifying the building fabric to facilitate natural ventilation schemes, and reducing peak temperatures by effectively using thermal mass.

Construction stage

B. Solutions/synthesis of Biophilic attributes

Att.18 'Stimulated natural light and air': Innovative technology is used to allow occupants access to natural ventilation throughout the space, as well as make sure heat and contaminants are moved away from the inhabited area through buoyant air movement.

Physical Contributor (Illumination)

Table 25: Correlating Physical Contributor (Illumination) at Design Stage with Biophilic Actions and Solutions.

Physical contributor (Illumination) Design stage	Biophilic actions and solutions		
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Increase Daylight (louvers, light-directing glass, skylights, heliostats, light tubes	Principle 4	. Att.1	. P.1 . P.6 . P.12
. Boost light quality	Principle 4	- non	. P.6 . P.7
. Increase daylight . No glare . Window size fit purpose	Principle 4	. Att.1	. P.6 . P.12
. Management of solar gain	Principle 4	- non	. P.6

Table 26: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 Environmental features PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes **PRINCIPLE 4** **Light and space** PRINCIPLE 5 Place-based relationships PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE **Att.1 Light** Att.2 Air Att.3 Water Att.4 Plants Att.5 Animals Att.6 Landscapes Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** P.2 Non-Visual Connection with Nature P.3 Non-Rhythmic Sensory Stimuli P.4 Thermal & Airflow Variability P.5 Presence of Water **P.6 Dynamic & Diffuse Light** **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns P.9 Material Connection with Nature P.10 Complexity & Order
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity Att.22 Mobility Att.23 Transitional spaces Att.24 Place Att.25 Integrating parts to create wholes	NATURE OF THE SPACE PATTERNS-HUMAN SPATIAL RESPONSE P.11 Prospect **P.12 Refuge** P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 4 'Light and space': Using several principles of light, such as natural light, diffused light, shadow, Light and space expansiveness, spatial harmony, and indoor/outdoor space to increase daylighting in an indoor environment, as well have management over solar gain.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.1 'Light': Using the biophilic design feature allows natural light to penetrate deep into interior spaces with strategies like glass walls and clerestories, which reflect colors, materials, and other elements.

C. Solutions/synthesis of Biophilic Solutions/synthesis patterns

P.1 'Visual connection with nature': The highest windows on a wall or on a roof monitor or clerestory will increase daylight penetration, reducing excessive brightness and providing a direct connection with nature.

P.6 'Dynamic & diffuse light' and P.7 'Connection with natural system': A building's form and orientation on its site determine the amount of daylight the building receives. The selection of the site also contributes to the amount of daylight. A biophilic design is used to maximize available daylight in a room by reflecting daylight within the room to increase its brightness. Visual comfort depends, however, on avoiding direct beam daylight and glare. Experiencing excessive brightness differences near critical visual tasks will result in poor visibility and discomfort. Direct sunlight can be diffused through vegetation, curtains, louvers, etc., which will soften the harshness of the light.

P.12 'Refuge': Design spaces that incorporate two complimentary features: the possibility of open views/vistas and the comfort/safety of shelters/safe spaces. It provides a view from windows, balconies, courtyards, colonnades, etc., thus providing an inside and outside experience. These interior-exterior connections in spaces that connect one interior to another, would provide an adequate amount of daylight.

Physical Contributor (Noise level)

Table 27: Correlating Physical Contributor (Noise Level) at Design Stage with Biophilic Actions and Solutions.

Physical contributor (Noise level) Design stage	Biophilic actions and solutions		
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. External noise . Acoustic level	Principle 1	. Att.6	. P.2 . P.15
. Acoustic technologies	- non	- non	- non
. Ceiling tiles absorb sound	- non	- non	- non
. Panels in workspace design	Principle 6	. Att.22 . Att.25	. P.11 . P.12
. Sound making techniques	- non	- non	- non

Table 28: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space PRINCIPLE 5 Place-based relationships	DIRECT EXPERIENCE OF NATURE Att.1 Light Att.2 Air Att.3 Water Att.4 Plants Att.5 Animals **Att.6 Landscapes** Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION P.1 Visual Connection with Nature **P.2 Non-Visual Connection with Nature** P.3 Non-Rhythmic Sensory Stimuli P.4 Thermal & Airflow Variability P.5 Presence of Water P.6 Dynamic & Diffuse Light P.7 Connection with Natural Systems
PRINCIPLE 6 **Evolved human-nature relationships**	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns P.9 Material Connection with Nature P.10 Complexity & Order
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity **Att.22 Mobility** Att.23 Transitional spaces Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS- HUMAN SPATIAL RESPONSE **P.11 Prospect** **P.12 Refuge** P.13 Mystery P.14 Risk/Peril **P.15 Awe**

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': The biophilic design features of water, plants, views and vistas, habitats, and ecosystems would work on reducing the amount of external noise and provide an adequate acoustic level. Noise can be reduced rapidly due to trees' parts such as the thick branch's ability to absorb sound.

Principle 6 'Evolved human-nature relationships': Imposing structure and organization principles to the living environment to create and achieve order between indoor spaces and indoor-outdoor spaces would create noise comfort level. Designs that effectively meld order and complexity with nature tend to be successful in blocking unwanted sound.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.6 'Ecosystems and natural landscapes': The use of natural ecology and landscape to block the unwanted source of the noise. A noise barrier blocks sound waves from directly reaching homes and workspace along a highway. Noise barriers, however, do not eliminate noise, they only reduce it.

Att.22 'Mobility' and Att.25 'Integrating parts to create wholes': The panels on the workstations and the enclosed walls of the building could be lined with sound-absorbing materials. It is crucial to isolate the spaces that produce significant levels of noise and ensure their separation from the surrounding areas to minimize noise pollution.

C. Solutions/synthesis of Biophilic patterns

P.2 'Non-visual connection with nature': N-VCN is the auditory experience of nature, living systems, or natural processes such as songbirds, running water, the weather of rain and wind, a crackling fire, and natural ventilation through operable windows and breezeways. The acoustic pattern reduces noise or unwanted sounds and provides the desired natural acoustics.

P.11 'Prospect' and P.12 'Refuge': In making a space that provides both prospects and refuge, both patterns balance each other, creating a feeling of openness and freedom, while simultaneously imparting a sense of security. The building, its halls, and terminals are oriented to give residents a view of scenic landscapes and nearby natural environment attractions. In a place where one is sheltered and protected from all the surrounding conditions and activity, an individual can withdraw from the outside noise.

P.15 'Awe': Planters with green plants and vibrant flowers are hidden behind a metal facade. Due to these landscaping spaces, the noise from the busy traffic outside will be reduced, and the interior spaces' privacy and security will be enhanced.

Physical Contributor (Indoor air quality)

Table 29: Correlating Physical Contributor (Indoor Air Quality) at Design and Use Stage with Biophilic Actions and Solutions.

Physical contributor (Indoor air quality) Design stage / Biophilic actions and solutions

Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Minimum ventilation . Space function and activity rates	Principle 5	. Att.2	. P.4 . P.10
. Natural air (windows, doors) . Stimulated air (HVAC) . Openings (walls, floor, ceiling)	Principle 1	. Att.2 . Att.25 . Att.4 . Att.6 . Att.7 . Att.18 . Att.23	. P.1 . P.4 . P.7 . P.10
. Lobby/entrance design	- non	- non	- non

Use stage

Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Eliminate pollution	- non	- non	- non
. Air purifier	- non	- non	- non
. Cleaner fuel technologies	- non	- non	- non
. User behavior in space	- non	- non	- non
. Run fans to the outside	- non	- non	- non
. Frequent air filter change	- non	- non	- non

Table 30: An Overview of Framework Shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space **PRINCIPLE 5** **Place-based relationships** PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE Att.1 Light **Att.2 Air** Att.3 Water **Att.4 Plants** Att.5 Animals **Att.6 Landscapes** **Att.7 Weather** Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** P.2 Non-Visual Connection with Nature P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries **Att.18 Stimulated natural light and air** Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns P.9 Material Connection with Nature **P.10 Complexity & Order**
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity Att.22 Mobility **Att.23 Transitional spaces** Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS- HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': Increasing the amount of outdoor air entering the building has been shown to improve indoor air quality by eliminating individual sources of pollution or reducing their emissions. As another strategy to improve indoor air quality, environmental features control humidity, ventilation, and shading in the building through plants, air, sunlight, geology, and landscape.

Principle 5 'Place-based relationships': Aims to cultivate an indoor-outdoor and build nature connections to establish a territorial identity through the factors of unique connections to place, landscape orientation, and ecology. Manage the place and landscape orientation/features/ecology that is driven by a building's space function and activity requirements, and that determines the minimum ventilation necessary.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.2 'Air' and Att.18 'Stimulated natural light and air': For diverse types of buildings, several types of ventilation can be provided. Air-conditioned spaces with mechanical ventilation in office buildings are one type. Enclosed conditioned spaces with no mechanical ventilation would rely on open doors/windows to provide natural ventilation. As well as, naturally ventilated premises with windows and doors or through infiltration, which is a process by which air from outside is drawn into the building through openings, cracks, and cracks in walls, floors, and ceilings as similarly stated by (Abdul-Wahab 2011).

Att.4 'Vegetation', Att.6 'Ecosystem and natural landscape', and Att.7 'Weather': Each of these attributes has the same goal, to create greenery and vegetation views both inside and outside. Thus, plants as the main feature would improve air quality primarily through photosynthesis, which absorbs carbon dioxide and releases oxygen, and passively absorbs pollutants through their leaves and soil roots.

Att.23 'Transitional spaces' and Att.25 'Integrating parts to create wholes': The purpose of transition spaces is to create a smooth transition from the interior to the exterior of a building, helping in extending the exposure to natural ventilation equipped with large windows and glass doors. The integration of diverse elements into a cohesive whole, whether functional or theme based, can enhance the ability of spaces to prevent pollution by the indoor environment. Indirectly, outdoor air pollutants enter the indoor environment through open windows and doors, as well as cracks in walls and doors. It is often possible to combine both attributes by linking sequentially and successively spaces and clearly distinguishing boundaries.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature' and P.7 'Connection with natural system': It is acknowledged that occupants need to live in an environment that is comfortable and healthy, however, there are several environmental factors that govern the perception of comfort, making it difficult to find architectural solutions to improve indoor air quality. The process of integrating nature into the design strategies could impact how people perceive comfort in their surroundings. This biophilic design strategy, as a connection to natural elements and natural systems, relies on the perception of the environment as directly attributed to the surroundings. Even so, the body's response to the environment would be indirect, meaning all the environmental factors and conditions, such as indoor air quality, would affect the human body's reaction to its surroundings.

P.4 'Thermal & Airflow Variability' and P.10 'Complexity and order': This pattern is primarily intended to use airflow, either stimulated or natural, to enhance indoor air quality. Different strategies would be used to achieve this goal. A passive cooling design to fetch in natural light and air via skylights, glass walls, atria, and materials that assist in insulating the interior climatic conditions. Living area orientation to improve livability and climate comfort. A thermally zoned building minimizes the need for heating, and having clear stores reduces energy consumption by providing daylight to all living areas. During the design of an underfloor air distribution system, which would keep clean air separate from the dirty air exhausted at the ceiling.

Physical Contributor (Air temperature)

Table 31: Correlating Physical Contributor (Air Temperature) at Design Stage with Biophilic Actions and Solutions

Physical contributor (Air temperature) Design stage	Biophilic actions and solutions		
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Use of cool color	Principle 1	. Att.13	. P.1
. Control temperature . Functioning control system	Principle 5	. Att.2	. P.4
. Passive design . Use of sunlight	Principle 3	. Att.21 . Att.23 . Att.22 . Att.25	. P.10
. Smart/responsive building skin . Ventilation to control indoor temperature	Principle 2	. Att.19	. P.9
. Open and closed-building ventilation	Principle 1	. Att.3 . Att.6 . Att.4 . Att.21	. P.1 . P.7 . P.3 . P.10

Table 32: An overview of framework shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** **PRINCIPLE 2** **Natural shapes and forms** **PRINCIPLE 3** **Natural patterns and processes** PRINCIPLE 4 Light and space **PRINCIPLE 5** **Place-based relationships** PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE Att.1 Light **Att.2 Air** **Att.3 Water** **Att.4 Plants** Att.5 Animals **Att.6 Landscapes** Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** P.2 Non-Visual Connection with Nature **P.3 Non-Rhythmic Sensory Stimuli** **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light **P.7 Connection with Natural Systems**
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture **Att.13 Color** Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air **Att.19 Biomimicry**	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns **P.9 Material Connection with Nature** **P.10 Complexity & Order**
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge **Att.21 Organized complexity** **Att.22 Mobility** **Att.23 Transitional spaces** Att.24 Place **Att.25 Integrating parts to create wholes**	NATURE OF THE SPACE PATTERNS-HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': This principle participates in controlling the indoor air temperature by its three key features, air flow defined by the amount of wind speed inside and outside the building, views and vistas that indicate land cover, and the use of natural materials for walls, roofs and floors that complement the given climate.

Principle 2 'Natural shapes and forms': A design type that uses shapes from the natural world and that plays a role in controlling the internal temperature through its structural design. According to this principle, building forms and elements are selected based on climatic conditions and thermal comfort requirements to create necessary internal comfort.

Principle 3 'Natural patterns and processes': This principle promotes mutual reinforcement, interconnection, and integration of design elements through its associated features of bounded spaces, transitional spaces, and hierarchically organized ratios and scales. Considered a functional strategy to optimize the use of passive design strategies in heating and cooling the living environment.

Principle 5 'Place-based relationships': This principle entails aspects of unique connections to place, indigenous materials, landscape features and orientation as a passive design strategy. The building should be oriented in such a way that its longer sides will not be exposed to the sun due to its orientation along the north-south axis. Buildings should have an orientated north-south axis so that their long sides are not exposed to the sun, and be well ventilated on both sides –vertically and horizontally- to allow heat to escape by air movement and convection in hot and dry climate zones.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.2 'Air': Temperature and airflow have an inverse relationship. When the airflow over the design elements of walls, roofs and floors increases, the cooling/heating systems are forced to either increase their power output to maintain a constant temperature or to lower the temperature of the output air. In drier climates, natural ventilation involves preventing heat accumulation during the day and ventilating at night, whereas in cold climates, natural ventilation means ventilating in the morning.

Att. 3 'Water': Bringing people into contact with water is one of the most effective ways to reduce heat stress. By evaporating, absorbing heat, and transporting heat, open water can lower the air temperature. Cooling is greater for flowing water than for water that is still. Despite this, surface water, whether flowing or stagnant, has only a minimal cooling effect.

Att.4 'Vegetation' and Att.6 'Ecosystem and natural systems': In addition to providing shade, trees and vegetation lower air and surface temperatures through evapotranspiration, a procedure in which soil water is lost both by evaporation from the surface and by transpiration from leaf surfaces.

Att.13 'Color': The absorption of light by colors causes them to absorb heat, thereby affecting the temperature of the air. An explanation is that a dark color absorbs more sunlight, which means it absorbs more heat, whereas a bright color reflects more sunlight, which means it absorbs less energy and heat.

Att. 'Biomimicry': Learn from and emulate nature's forms, processes, and ecosystems to create smarter, more responsive building skin designs that will be integrated into advanced ventilation systems to control indoor air temperatures.

Att.21 'Organized complexity', Att.22 'Mobility', Att.23 'Transitional spaces' and Att.25 'Integrating parts to create wholes': Together, the attributes would work under building forms and layout. Design strategies are based on climate and place, specifically, air temperature and humidity to determine whether a building needs a passive heating strategy in areas with cold winters or a passive cooling strategy in areas with hot summers. Organization of interior spaces in the building to make them work in harmony with the outside organization of the landscape to control the amount of sunlight and the direction, as well as the air temperature and ventilation into the interior spaces. An example is using the courtyard as an atrium by the organization of the building space so that a channel of airflow is created for the interior spaces. In addition, it presents an opportunity for the creation of transitional spaces and mobility between interior spaces and interior-exterior spaces.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': Choosing the color affected not only humans' mood, motivation, and productivity, but also their health, causing what is called 'temperature stress'. Nevertheless, in the visual direct connection with nature, biophilic design elements such as natural/light colors and their hue, saturation, tone, and brightness define the ambiance of a space and its effect on enhancing temperature comfort.

P.4 'Thermal & Airflow Variability': A natural environment can be observed by its relative humidity, its temperature, flow of air over its surface, and its temperature. Although ventilation of the interior using natural solutions results in positive impacts on thermal concerns, seasonal climate variability significantly impacts the relative human thermal comfort in the living environment. Thus, seating that is exposed to variable levels of solar heat gained through operable windows can add value to a space.

P.9 'Materials': In this pattern, natural materials, whose features have a high thermal capacity, are used as design elements, such as walls, floors, or roofs. If a place has cold nights and hot days, for instance, a design element is used so that heat is absorbed during the day and released at night, so that the interior spaces are maintained at a comfortable temperature all through the day.

P.10 'Complexity and Order': As a result of the patterns organized in an articulated pyramid format, visual health, and perception that aid in issues of air temperature and comfort will be created. It can be accomplished by arranging the details, diversity, and richness in a pleasing manner, offering a variety of textures and colors, or arranging plants in a specific way.

Physical Contributor (Humidity)

Table 33: Correlating Physical Contributor (Humidity) at Design and Use Stage with Biophilic Actions and Solutions.

Physical contributor (Humidity)	Biophilic actions and solutions		
Design stage			
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Dehumidifies and air conditioners	- non	- non	- on
. Control mold . Relative humidity 30% - 60%	Principle 1	. Att.1 . Att.4 . Att.2	. P.1 . P.2
. Heat circulation by fans . Furniture organization	- non	- non	. P.4
. Insulation with plywood	Principle 1	- non	. P.9
Use stage			
Solutions/synthesis and actions	Biophilic principles	Biophilic attributes	Biophilic patterns
. Plants to increase humidity . Plants as dehumidifier	Principle 1	. Att.4	. P.1

Table 34: An overview of framework shortcuts

Principles of Biophilic design	**Attributes/Experience of Biophilic design**	**Patterns of Biophilic design**
PRINCIPLE 1 **Environmental features** PRINCIPLE 2 Natural shapes and forms PRINCIPLE 3 Natural patterns and processes PRINCIPLE 4 Light and space PRINCIPLE 5 Place-based relationships PRINCIPLE 6 Evolved human-nature relationships	DIRECT EXPERIENCE OF NATURE **Att.1 Light** **Att.2 Air** Att.3 Water **Att.4 Plants** Att.5 Animals Att.6 Landscapes Att.7 Weather Att.8 Views Att.9 Fire	NATURE IN THE SPACE PATTERNS- DIRECT CONNECTION **P.1 Visual Connection with Nature** **P.2 Non-Visual Connection with Nature** P.3 Non-Rhythmic Sensory Stimuli **P.4 Thermal & Airflow Variability** P.5 Presence of Water P.6 Dynamic & Diffuse Light P.7 Connection with Natural Systems
	INDIRECT EXPERIENCE OF NATURE Att.10 Images Att.11 Materials Att.12 Texture Att.13 Color Att.14 Shapes and forms Att.15 Information richness Att.16 Change, age, the patina of time Att.17 Natural geometries Att.18 Stimulated natural light and air Att.19 Biomimicry	NATURAL ANALOGUES PATTERNS-INDIRECT CONNECTION P.8 Biomorphic Forms & Patterns **P.9 Material Connection with Nature** P.10 Complexity & Order
	EXPERIENCE OF SPACE AND PLACE Att.20 Prospect and refuge Att.21 Organized complexity Att.22 Mobility Att.23 Transitional spaces Att.24 Place Att.25 Integrating parts to create wholes	NATURE OF THE SPACE PATTERNS- HUMAN SPATIAL RESPONSE P.11 Prospect P.12 Refuge P.13 Mystery P.14 Risk/Peril P.15 Awe

Design stage

A. Solutions/synthesis of Biophilic principles

Principle 1 'Environmental features': According to this principle, relative humidity describes how much moisture there is in the air, and would be controlled using air, sunlight, plants, and natural materials. Despite this, it is important to note that a building should have an ideal relative humidity level of 30 to 60 percent.

B. Solutions/synthesis of Biophilic attributes (Experiences)

Att.1 'Light': One of the most effective solutions to controlling moisture and humidity in a building is to use tools that will let in natural light. This can be explained by the fact that a lower temperature usually indicates moist air with considerable amounts of water vapor and vice versa.

Att.2 'Air': It is possible to manage relative humidity through passive ventilation by opening windows. Ventilation in a building is accomplished through pressure differences, which leads to control over the amount of air and moisture contained within the building envelope.

Att.4 'Vegetation': Due to evapotranspiration, plants can act as a dehumidifier by releasing moisture through their leaves into indoor spaces. In addition, they work to manage and decrease indoor humidity by absorbing the water vapor emitted from the leaves into their roots.

C. Solutions/synthesis of Biophilic patterns

P.1 'Visual connection with nature': Direct interaction with plants in and around the built environment would be made possible through a direct connection with nature in design. By maintaining relative humidity values between 30% and 60%, as its being one of the primary environmental variables that influence human thermal comfort in living environments.

P.4 'Thermal & Airflow Variability': The increase of thermal and airflow within the building will promote evaporation of any moisture. Buildings can be reduced in humidity by installing fans to reduce indoor temperatures.

P.9 'Material Connection with Nature': Natural materials can alter the humidity level of indoor spaces. It is best to use natural materials such as wood, bamboo, rock, stone, and clay. Therefore, all finishes in the building are chosen based on their ability to create a healthy living environment.

3.3 Findings

Correlations achieved by the help of SBS evaluative frameworks and the study of different principles, attributes, and patterns of biophilic design, workable solutions have been attained/synthesized. Based on correlating each of the keywords extracted from the given solutions/actions at the end of the SBS section, the findings of this study suggest that positive results can be achieved through implementing the biophilic design in an indoor environment to solve SBS issues. Taking the findings and dividing them into three sections would allow us to determine what actions/solutions can be taken in the design, construction, and use stage. There will be three sub-titles in each stage; beginning with the most used principles/attributes/patterns, then the principles/attributes/patterns that are rarely used to overcome problems created by SBS, and finally those that are not used at all. Figure (41, 42 and 43) depicts graphically the interaction of design, construction, and use stage with biophilic principles, attributes, and patterns.

Design stage

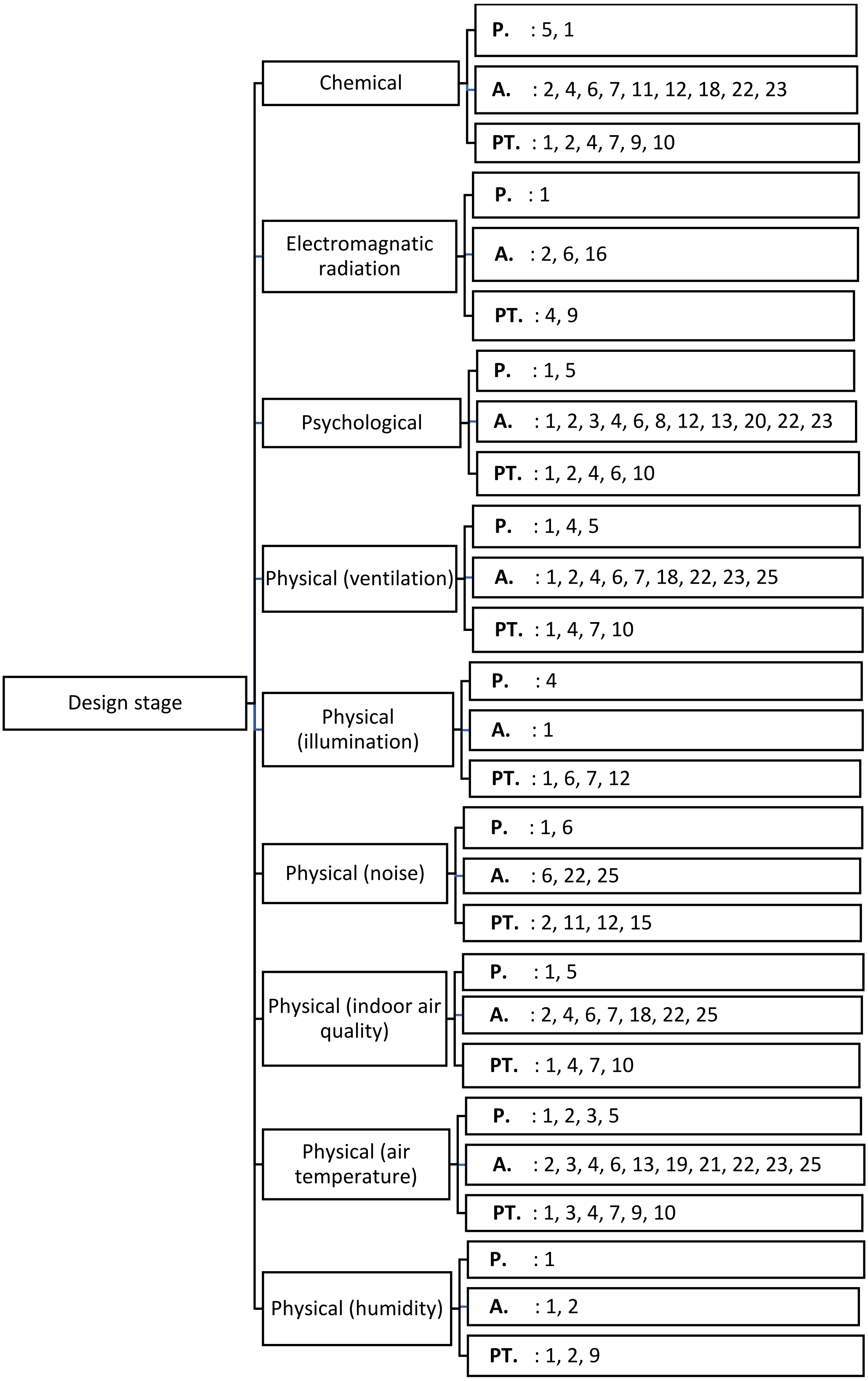


Figure 41: displays graphical interactions between Design Stage with biophilic principles, attributes and patterns (P: Principle, A: Attribute, PT: Pattern)

The most used principles/attributes/patterns

Upon reviewing and examining the use of biophilic strategies for each SBS contributor, it was observed that there are principles, attributes, and patterns that are more frequently seen within the table, allowing a good convergence between actions to solve each SBS contributor. For this part of the evaluation, the principles, attributes, and patterns in the table above which have been mentioned about five times and above would be considered. In the table above, it is obvious that the first principle, 'Environmental features,' is repeated eight times, solving most of the SBS contributors except 'illumination', which is a physical contributor. Also, for principle number five 'Place-based relationships' would be in second place solving several SBS issues except for electromagnetic radiation, illumination, noise, and humidity.

Regarding the use of biophilic attributes, it is evident from the table above that a few elements have been observed to be mentioned more than others for solving SBS contributors. The attribute number 2 'Air' is mentioned in all actions/solutions to the SBS contributors, except for illumination and noise contributors. Come in the same rank, the attribute number 6 'Ecosystems and natural landscapes', which can solve all the SBS issues except for illumination and humidity, in the planning and design stage. On the second spot comes attribute number 22 'Mobility,' which has been mentioned six times in the table above claiming that it can solve most SBS issues except for electromagnetic, illumination, and humidity. As for attribute number 4, 'Vegetation', it has been used quite often to solve many SBS issues, except for chemical, illumination, and noise issues.

In terms of biophilic patterns, we can see that pattern 1 'Visual connection with nature' has the greatest potential for resolving SBS issues, having been mentioned seven times in the table, and lacking in electromagnetic radiation and noise. This is followed by pattern number 4 'Thermal & Airflow Variability' being mentioned six times in the table, with only a shortfall in solving the illumination, and noise issues. The same level of five repetitions mentioned in the table is pattern 7 'Connection with Natural Systems', which is deficient in solving electromagnetic radiation, noise, and humidity issues, and pattern 10 'Complexity and Order', which is deficient in solving electromagnetic radiation, illumination, noise, and humidity issues.

The principles/attributes/patterns that are rarely used in biophilic actions

The purpose of this part is to note the principles, attributes, and patterns that appear less than five times across the table. In this sense, several biophilic principles are mentioned twice or three times to solve SBS issues, including principles no. 2 'Natural shapes and forms', no. 3 'Natural patterns and processes', no. 4 'light and space', and no. 6 'Evolved human-nature relationships'.

As for biophilic attributes, some elements have been mentioned four times, including number 1 'Light', 23 'Transitional spaces', and 25 ' Integrating parts to create wholes '. There were other biophilic attributes discussed between three and once, which were: number 3 'Water', number 7 'Weather', number 8 'View', number 11 'Materials', number 12 'Texture', number 13 'Color', number 16 'Change, age, and patina of time', number 18 'Stimulated natural light and air', number 19 'Biomimicry', number 20 ' Prospect and refuge’, and number 21 ‘Organized complexity’.

Some biophilic patterns have been listed four times, which is the case for pattern 2 'Non-visual connection with nature' and pattern 9 'Material connection with nature'. Other patterns were mentioned between two and once, such as pattern 3 'Non-

Rhythmic sensory stimuli', pattern 6 'Dynamic & diffuse light', pattern 11 'Prospect', pattern 12 'Refuge' and pattern 15 'Awe'.

The principles/attributes/patterns not used at all in biophilic actions

As the name suggests, this aspect focuses on those principles, attributes, and patterns that have not been associated with any of the SBS contributors in the table. In addressing actions/solutions derived from biophilic design to the issues associated with SBS, none of the six biophilic principles have failed at least once. By integrating one or more key elements, one or more SBS issues and various building design standards would be addressed to maintain the health and well-being of occupants.

For biophilic attributes, the study was unable to demonstrate in a few categories its importance in solving SBS issues and being linked to its contributors. These attributes are number 5 'Animals', number 9 'Fire', number 10 'Images', number 14 'Shapes and forms', number 15 'Information richness', and number 17 'Natural geometries'.

In contrast, (Figure 52) shows that patterns number 5 'Prescence of Water', number 8 'Biomorphic Forms and Patterns', number 13 'Mystery', and 14 'Risk/Peril' seem under-represented in biophilic patterns.

Construction stage

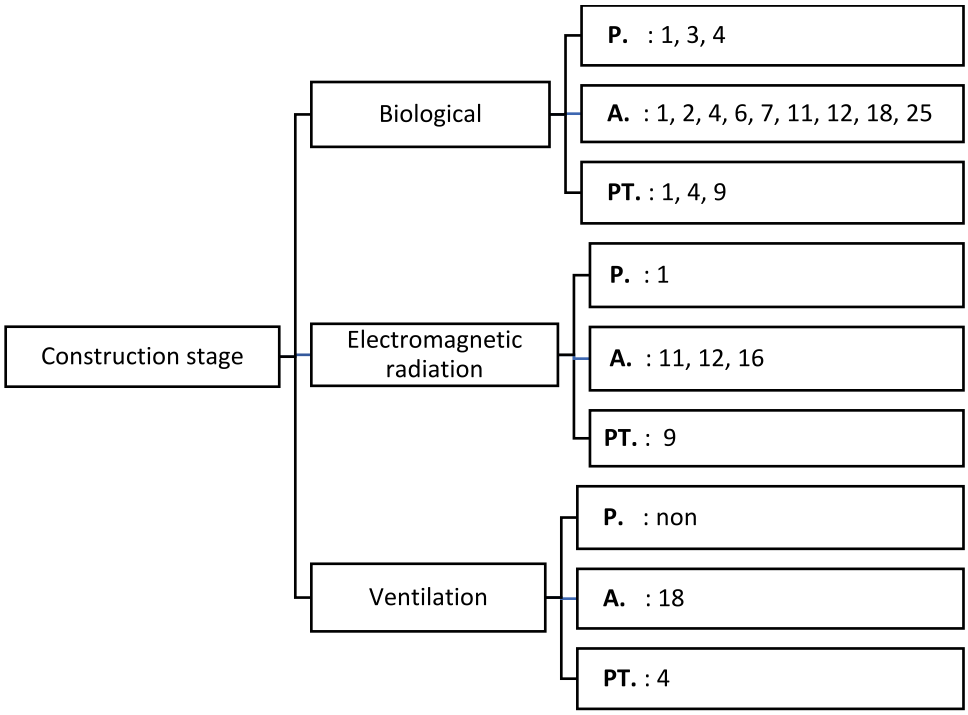


Figure 42: displays graphical interactions between Construction Stage with biophilic principles, attributes, and patterns (P: Principle, A: Attribute, PT: Pattern).

The most used principles/attributes/patterns

Reviewing and examining the table above, it became apparent that the biophilic principles, attributes, and patterns' ability to solve SBS contributors is limited during the construction phase. Accordingly, the calculation of the data in the construction stage has been changed so that the mostly used biophilic design approach would be considered when the principle, attributes, and pattern are mentioned at least once. In the construction process, the most used principle would be principle 2 'Natural shapes and forms', as it was mentioned twice as being beneficial in the case of electromagnetic radiation and biological problems.

As for the biophilic attributes, none are repeated more than twice. While this may seem to be a limitation, there are a few attributes that could be incorporated in the design, including no.1 "Light", no.2 "Air", no.4 "Vegetation", no.6 "Ecosystems and natural landscapes", no.7 "Weather", no.11 "Materials", no.12 "Texture", no.16 "Change, age, and the patina of time", no.18 " Stimulated natural light and air", and no.25 'Integrating parts to create wholes'.

The table mentioned only three patterns as being able to resolve the SBS issues during the construction stage, as follows: pattern 1 'Visual connection with nature' is mentioned only once as having the ability to solve the biological contributor, pattern 4 'Thermal and Airflow Variability' has been mentioned twice, and pattern 9 'Material Connection with Nature' has also been mentioned twice.

The principles/attributes/patterns that are rarely used in biophilic actions

According to the table, biophilic principles, attributes, and patterns in the construction stage cannot solve the SBS issues, which means even if the design elements are mentioned to solve the SBS contributor it would be restricted to only two. As a result, it would be better to mention the principle, attribute, and pattern at least twice to solve SBS issues during the construction stage, and it should be placed in the most used section.

The principles/attributes/patterns not used at all in biophilic actions

According to the table, an extensive number of biophilic characteristics, attributes, and patterns have not been able to solve the problem of the SBS contributor during the construction phase. Biophilic design principles include Principle 2 'Natural shapes and forms', Principle 5 'Place-based relationships', and Principle 6 'Evolved human-nature relationships'. In terms of the biophilic attributes, a few elements have also been omitted. For example, no.3 'Water', no.5 'Animals', no.8 'Views', no.9 'Fire', no.10

‘Images’, no.13 ‘Color’, no.14 ‘Shapes and forms’, no.15 ‘Information richness’, no.17 ‘Natural geometries’, no.19 ‘Biomimicry’, no.20 ‘Prospect and refuge’, no.21 ‘Organized complexity’, no.22 ‘Mobility’, and no.23 ‘Transitional spaces’.

Among the biophilic patterns, many were missing, such as pattern 2 ‘Non-visual connection with nature’, pattern 3 ‘Non-Rhythmic sensory stimuli’, pattern 5 ‘Presence of Water’, pattern 6 ‘Dynamic & diffuse light’, pattern 7 ‘Connection with natural systems’, pattern 8 ‘Biomorphic Forms and Patterns’, pattern 10 ‘Complexity and Order’, pattern 11 ‘Prospect’, pattern 12 ‘Refuge’, pattern 13 ‘Mystery’, pattern 14 ‘Risk/Peril’, and pattern 15 ‘Awe’.

Use stage

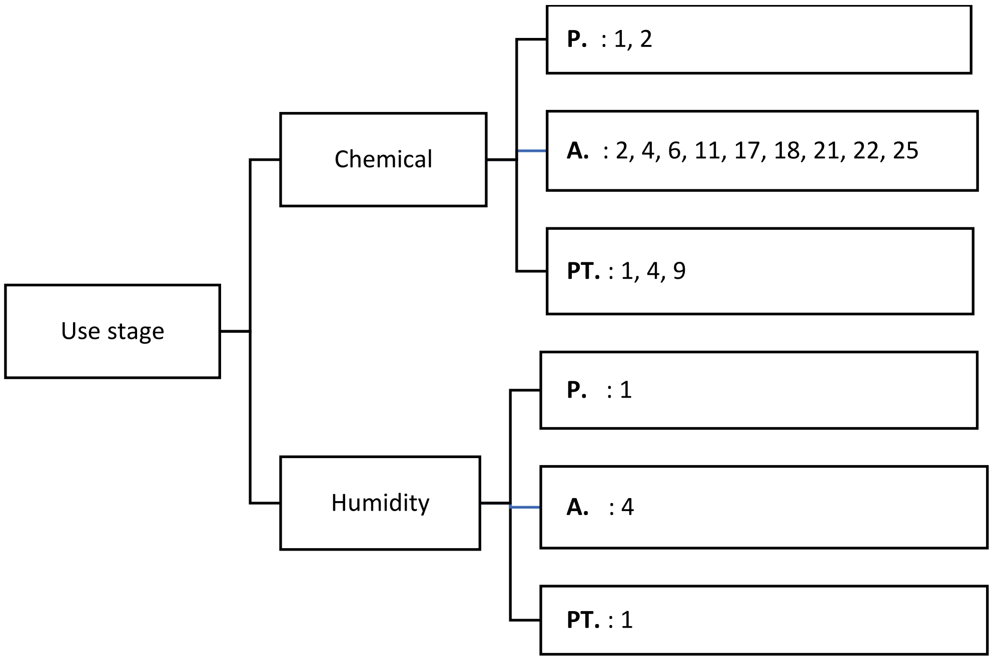


Figure 43: displays graphical interactions between Use Stage with biophilic principles, attributes, and patterns (P: Principle, A: Attribute, PT: Pattern).

The most used principles/attributes/patterns

As seen in the table above, it is evident that biophilic principles, attributes, and patterns cannot solve SBS problems during the use phase, which means it would be more sensible to focus on the used principles, attributes, and patterns when solving SBS contributors, which are just confined to chemical and humidity issues. Hence, in the table, biophilic patterns use the principles of 'Environmental features' and 'Natural shapes and forms'.

According to the biophilic attribute, a variety of elements can solve a chemical contributor, such as number 2 'air', number 4 'vegetation', number 6 'ecosystems and natural landscapes', number 11 'materials', number 17 'natural geometries', number 18 'natural lighting and air', number 21 'organized complexity', number 22 'mobility', and number 25 'integrating parts to create wholes '. Additionally, attribute number 4 'Vegetation' was mentioned to solve the humidity issue.

In terms of biophilic patterns, the table mentioned that pattern “1 'Visual connection with nature' was susceptible to chemical and humidity issues. Meanwhile, pattern 4 'Thermal & Airflow Variability' and pattern 9 'Material Connection with Nature' can address the chemical contributor” as similarly stated by Loftness, (2020).

3.4 Summary of the Chapter

As part of the border discussion that the study considered, it found out that biophilic design may be a way to solve SBS problems. The creation of a framework that discusses the possibilities for developing a healthy building based on the physical dimensions of a biophilic design approach and by examining the subjective and objective aspects of health. The use of biophilic principles, attributes, and patterns has, nevertheless, opened several possibilities in solving SBS contributors. However, these principles, attributes, and patterns have been achieved in varying degrees at each stage, depending on the accessibility of using biophilic design approaches and the levels of possibility.

To develop healthy buildings, it is essential to fulfilling various technical requirements, such as adhering to design, construction, and use principles of buildings, although the satisfactory performance of the biophilic approach will vary from one stage to the other.

Based on the findings of the research, incorporating biophilic approaches to the SBS contributors at each stage, it was found that the design stage is more likely to resolve SBS issues than the construction stage and the use stage. The design stage it requires the implementation of a less complex biophilic design approach to solve the contributor, than in the later stage, in which it becomes more complicated to solve the contributor. Furthermore, the results indicate that the biophilic actions, attributes, and patterns fall short of finding solutions and actions to the electromagnetic radiation, and humidity contributors. However, the findings have revealed that there are various biophilic principles, attributes, and patterns that are more prominent than the others, and that can be considered in future healthy buildings. Accordingly, in the following part several guidelines are developed which would assist/guide interior architects/architects in various stages of the process in order to control SBS before or after the occurrence.

3.5 Guidelines

Design stage

Strategies/actions:

- Guideline 1: utilization of local and indigenous materials, specifically, building materials that are natural and have a high volatility level.
- Guideline 2: utilizing natural ventilation in the indoor environment.
- Guideline 3: design buildings and landscapes that improve airflow into indoor spaces by integrating local habitats and ecosystems.
- Guideline 4: utilizing technological innovations that reduce indoor air pollution and keeping the environment ventilated.
- Guideline 5: create a design with an easy and efficient movement of occupants between areas inside a building and from the interior to the exterior.
- Guideline 6: adding plants and trees to the landscape near buildings to reduce the intake of outdoor pollution and to channel the breezes into the residence space for cooling.
- Guideline 7: utilize green walls, green roofs, and large atriums to connect the interior design to nature.
- Guideline 8: the Use of materials that reflect the local ecology and geology.
- Guideline 9: arrange the spaces in an articulated pyramid format according to their function, to control air flow rates within the building.
- Guideline 10: Proper landscape allocation and orientation that; uses the landscape features, define the building form, and are characterized by a sense of place.
- Guideline 11: provide an access to natural sunlight in the living environment.

- Guideline 12: the use of natural paint colors (green, blue, and yellow) to brighten the space.
- Guideline 13: the use of texture that are reminiscent of nature.
- Guideline 14: provide a passive design strategy focused on cross ventilation (operable windows and skylights, as well as bifold exterior doors).
- Guideline 15: the use of a smart/responsive building skin, integrated with a sophisticated ventilation system, to imitate natural changes in light and air pressure throughout the day.
- Guideline 16: the use of natural light, diffused light, shadows, spatial harmony, and indoor/outdoor space to increase daylight element in indoor environments.
- Guideline 17: for visual comfort, direct sunlight can be diffused through vegetation, curtains, louvers, etc., which will soften the harshness of the light.
- Guideline 18: design a natural barrier to some degree blocks sound waves from directly reaching homes and workspace along a highway.
- Guideline 19: establish an indoor air quality standard that is driven by the space function and activity requirements of a building.
- Guideline 20: Provides a several types of ventilation for the diverse types of buildings (with natural ventilation only; combining both the natural and stimulated ventilation system and buildings with only stimulated ventilation).
- Guideline 21: prevent the indoor air quality pollution by clearly distinguish boundaries between the indoor spaces.
- Guideline 22: The design of natural ventilation depends on the climate; with drier climates preventing heat accumulation during the day and ventilating at night, while cold climates ventilate in the morning.

- Guideline 23: maintain a relative humidity values between 30% and 60% through a direct interaction with plants in and around the built environment.
- Guideline 24: The use of natural materials like wood, bamboo, rock, stone, and clay in indoor spaces, alters the humidity to the comfort level.

Construction stage

Strategies/actions:

- Guideline 1: the use of natural materials for exterior walls, roofing systems, and window construction to reduce the need for maintenance
- Guideline 2: control indoor climate conditions like airflow, barometric pressure, and sunlight to avoid humidity and mold problems; by constructing windows, curtains, and blinds.
- Guideline 3: the use of waterproofing materials in the indoor construction materials to increase their durability.
- Guideline 4: Mix both natural and stimulated air and light in an indoor environment to keep the relative humidity between 30-60%.
- Guideline 5: during the construction stage of exterior walls, a roofing system, and window construction prevent air leaks, maintain continuity and integrity of the insulation, and prevent water penetration.
- Guideline 6: the use of natural materials in building construction that frame the natural environment in indoor spaces.

<u>Use stage</u>

Strategies/actions:

- Guideline 1: make the users aware that opening the windows will provide them with fresh air.
- Guideline 2: add a two "good-sized" plants per 9 square meters are recommended for air purification and clean the air from VOC toxins.
- Guideline 3: the use and reuse of the natural materials in decorating the interior (Floors, paint, and other home furnishings0 and that have a low chemicals imitation.
- Guideline 4: the use of biomorphic curvilinear shapes in decorating, inspired by nature to prevent dust accumulation and the difficulty of maintaining proper hygiene.
- Guideline 5: open more than one window in different sides to benefit from natural cross ventilation.

Chapter 4

CONCLUSION

Even though exposure to unhealthy indoor environments may trigger SBS symptoms, biophilic design strategies are crucial for a healthy indoor environment, because they seek to give humans positive feedback in their interactions with nature. An exploration of the physical impacts of the indoor environment, as well as its elements on the health and well-being of occupants, has been conducted in this study. It has become increasingly important to incorporate natural solutions into indoor spaces as well as to integrate humans with nature. Hence, this study not only explains biophilic design strategies that focus on human interaction with nature, but also emphasizes the critical role of healthy buildings that have a positive impact on occupants' health besides exploring the negative effects of sick buildings on them.

As a result of the literature review, it was critically concluded that sick building syndrome poses a health risk to occupants. In contrast, biophilic design has been discussed by highlighting its major promising principles, attributes, and patterns, such as controlling indoor environmental quality and thermal control, effectively using daylight, assisting occupants with health and well-being, and creating opportunities to enjoy nature. It would, however, be crucial to evaluate the different approaches adopted for the integration of biophilic design in each sick building syndrome contributor. Thus, the thesis investigated qualitative biophilic design strategies and actions against sick buildings, by integrating its principles, attributes, and patterns with the help of the developed theoretical framework.

In sick building syndrome (SBS), people experience acute health symptoms related to their time spent in a building (Raw, 1992). In SBSs, there are two categories; the first is a lack of natural factors such as temperature, air, and view, and the second is the presence of air pollution and dust. In addition, closed buildings with artificial ventilation and electric lighting are more likely to be SBSs. The biophilic design, however, incorporates nature into the interior space to improve the indoor environment and satisfy its occupants' needs. Three interpretations of biophilic design were included in the study since they have been adopted for studies of biophilic design in health and well-being; the first defined the six primary principles and elements of biophilic design by Kellert et al., 2008, the second defined biophilic design as an experience by Kellert, 2018, and the third defined patterns of biophilic design by Browning and Ryan, 2020.

Accordingly, this study has concluded that using the strategies and approaches of biophilic design assists to improve indoor environmental quality as it is stated in the following;

- By integrating an advanced ventilation system and physical modifications, it is possible to control indoor air pollution emissions from buildings. It is possible to reduce SBS symptoms by frequently opening windows, using cross-air ventilation, using greenery in buildings, and regulating the air flow based on place function (open building ventilation) and forced circulation (closed building ventilation).

- It is possible to solve issues of SBS by enacting construction codes that prohibit the use of dangerous materials in living spaces. Since it is a condition that is related to time spent inside buildings and does not have any other defined symptoms.
- Controlling thermal comfort and humidity by balancing ventilation systems. Due to its effect on thermal comfort, air velocity will also reduce moisture accumulation.
- Well-designed spaces with thoughtful space arrangement and connections between indoor spaces and inside-outside spaces may help to prevent SBS symptoms.
- The decline in productivity rates of occupants caused by SBS is a crucial negative effect. With an eye-catching view of an outdoor scene or indoor space, the eye can adjust and refocus, leading to better health, reduced frustration, and increased productivity.
- Indoor spaces that utilize natural daylight and vegetation, or features nature, are more creative and productive.
- By providing windows that provide natural views, air quality will be improved, pollution will be reduced, and psychological well-being will be improved.
- The orientation of spaces and the thermal zoning of the building will help to improve livability and climate comfort, and the need for heating will be reduced. This method consists of designing a passive solar building to allow winter sunlight in while excluding summer sunlight. This maximizes natural resource utilization.
- Establish connections between interiors and exteriors within transitional spaces.

Based on the study's findings, biophilic design strategies could address sick building issues in the indoor environment. Aside from that, the study also considers what stage would lead to the cure of the SBS issues.

It is possible to solve many sick building syndromes by using biophilic design strategies at the design stage. Several SBS contributors can be solved with the principle of 'Environmental features.' When it comes to attributes, attribute number 2 'Air' appears in all actions/solutions to SBS contributors. Based on its many mentions, pattern 1 'Visual connection with nature' is the most promising pattern for resolving SBS issues. Meanwhile, many principles, attributes, and patterns were not assigned to any of the SBS contributors.

In addition, when it comes to the construction and use stages, the percentage of resolving SBS issues using biophilic design strategies would dramatically decrease. The solutions to SBS have been limited to dealing with biological, electromagnetic radiation, and ventilation issues during the construction stage, whereas chemical and humidity issues are the only issues in the use stage that could be solved by the biophilic design strategies.

This thesis addresses the significant research gap, in which little to no research has been conducted on the evaluation of biophilic design strategies to overcome the sick building problem. Meeting the objectives described above confronts the challenge of meeting the physical environment to be more responsible in providing healthier places. It is therefore more effective to review the built environment as a complex mixed strategy to develop a research base for stages that cannot approve its efficacy, such as construction and use. For this goal to be realized, new professionalism like planner, environmental engineer, air quality technician, and environmental energy managers, must be investigated in all fields of the built environment, architecture, engineering, and design. A form of field investigation would also be required for the deliberative practice to capture and integrate implicit and explicit knowledge.

4.1 Remarks and Recommendations for Further Research Stages

Further exploration of the SBS impacts is necessary to enhance the capacity of indoor spaces and contribute to the overall health and well-being of occupants. Further studies should aim to expand the technical studies on building evaluation using biophilic design, and illustrate the shortcomings, challenges, and drawbacks of biophilic design strategies through case studies instead of concentrating primarily on its advantages as well as calling various stakeholders to take part in the research. Additionally, it is important to explore the benefits of nature in space on a larger scale in different disciplines as well as to integrate other fields, such as phytologists, into architectural studies to demonstrate its effectiveness on a scientific basis.

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