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Poor Indoor Environmental Quality Leading To Sick Building Syndrome

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ABSTRACT: Sick Building Syndrome is an unpleasing mix of health symptoms in poorly designed buildings, and it has a significant negative effect on the inhabitants as occupants cannot control what they are breathing when they are enclosed in a built environment. 80% of people's time is spent indoors when sealed environments are not always the healthiest. This research paper focuses on the relationship between human health and the interior built environment through three case studies in Lebanon: workplace, school, and residential building which was investigated to find the disparities in buildings (problems in humidity, ventilation, human comfort, and materials' radiations) that lead to sick building syndrome. The evaluation of these cases is based on field visits and theoretical information gathered on the subject. The study also aims to identify emission sources and potential indoor air quality problems in order to find solutions on how to sustain occupants' healthy indoor spaces. The results indicated that the concept of sustainability has been applied on the three different selected places to ascertain the health status of buildings and occupants by taking into consideration several steps in order to save water, reduce energy use, reduce indoor air pollution and relying on passive design strategies to achieve natural ventilation and natural lighting, and finally to reduce thermal gain.

KEYWORDS: Occupant well-being; indoor environmental quality; Sick Building Syndrome; air pollution; green building.

I. INTRODUCTION

Buildings are constructed for people to reside, work, study, and perform different activities. Requirements for their tenancy are needed to be achieved as a precondition for their well-being[1]. After year 1960, constructed buildings are emitting more toxic gases, less planned to provide good air quality, and have less breathability than old buildings that were created to adapt to heat and cool by natural phenomena. Also, buildings constructed near industrial areas or heavy traffic will generally need more stringent requirements on ventilation systems to assess safety and civil protection as well as air tight buildings. For that, providing adequate air quality for the occupants is one of the most important functionalities of a building[2]. Basically, to construct a building, the design should reduce emissions that pollute the environment. Town planners, architects, interior designers, and occupants are all responsible to improve life attributes indoors by avoiding health hurdles.

In 1983, the world health organization (WHO) used the term "sick building syndrome" (SBS) to describe situations in which building occupants experience symptoms of discomfort and acute allergies that appear to be linked to time spent in a building, with no identified illness or cause[3]. SBS is a situation in which non-specific symptoms are experienced by more than 30% of the building's occupants. It costs the society tremendous amounts every year[4]. Studies done in the U.S. and Scandinavia have found that SBS is more commonly found in multifamily dwellings and public buildings than in private houses. Formaldehyde has been determined to be a major irritant for humans and can also be one cause of SBS[5]. It is found in the construction materials such as plywood paneling, adhesive for carpets, backings, finishes, carpets, wall coverings, and paint. It is used as insulation in buildings and is commonly found in chemical household products such as cleaning supplies, detergents, perfumes, soaps, etc... So, treated building's envelope can infiltrate contaminated outdoor air if parameters are poor[6]. On the other hand, emissions from synthetic materials, computers, photocopying machines, improper cleaning, fluctuating temperatures, and humidity contributed significantly to SBS. So, if relative air humidity is higher and indoor temperatures exceed 22 centigrade, headaches and allergens start by hypersensitivity resulting in lung problems. Symptoms should disappear within a few hours of leaving a sick building. However, dryness of the skin may take a few days to improve[7]. In addition, it was found that SBS is an important issue at work because it can lead to absenteeism and poor productivity among staff leading to economic consequences[8]. Indoor Environmental Quality (IEQ) encompasses the conditions inside a building in respect to human health like air quality (airborne and chemicals pollutant),

lighting, thermal comfort, humidity, ventilation, acoustic performance, green spaces, fitness, ergonomics, views, materials (formaldehyde), and their impacts (both short term and long term) on the health of occupants. Therefore, exposure of humans to poor IEQ made some occupants to experience headaches, allergies, asthma, dry coughs, throat irritation, and thirst[9]. Seppänen & Fisk[10] show that the risk for indicators is up to three times if a building has air conditioning or is mechanically ventilated, in comparison to naturally ventilated buildings. The Environmental Protection Agency, states that exposure to electromagnetic radiations can have negative impacts on health, ranging from short-term ailments like skin and eye irritation, headaches, and dizziness to long-term effects like respiratory disease, heart disease, and cancer[11][12]. By consequence, inadequate ventilation, indoor combustion emissions, inefficient energy cooking appliances, and leaks are factors that contribute to the decline in the IEQ and the rise of SBS [13]. So, the main question today is how to design, construct and manage buildings economically, and still satisfy indoor air quality needs of building occupants.
The importance of the study stems from the fact that many occupants, while they are in the building, experience some irritating symptoms with unspecified stimuli. Understanding these symptoms and their causes will help the designers and the residents to eliminate these sources and to protect them from harmful contamination.

II. RESEARCH PROBLEM AND OBJECTIVE

The phenomenon of sick residential building symptoms, which occurs in a large part of new or renovated buildings, has become among the well-known symptoms at the global level, and the negative effects of modern residential buildings on the environment in the form of depletion of its resources, the method of energy and water consumption, and the production of waste, in addition to the effects of the poor health of the users of these buildings, cannot be overlooked, especially as they collectively threaten the continuity and sustainability of human settlements. To date, there has been little discussion about SBS in Lebanon. The purpose of this study was to assess the symptoms of SBS and their correlation with personal characteristics in three building typologies considered in Lebanon. It also aims to describe the different steps performed in these buildings in order to improve their environment and to decrease SBS symptoms.

III. MATERIAL AND METHODS

Documentation through Photography: The relation between occupant, environmental factors, and SBS symptoms was evaluated and determined using photographs taken for three building typologies: Central Bank of Lebanon- CLB and M1 Building as offices, International College Elementary School –IC and Caza Batroun as a house.

IV. CASE STUDIES

First case: Central Bank of Lebanon- CLB (Workplace)
Location: Beirut, Lebanon
Type: Landscaping
Area: 720 m²

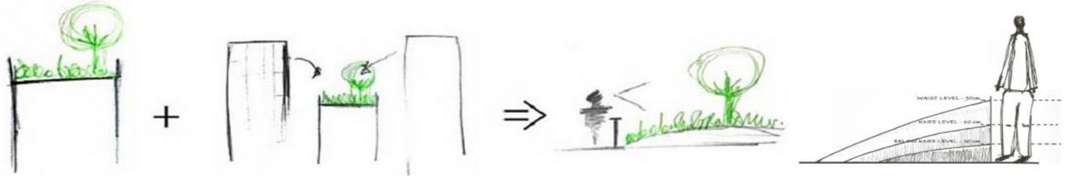

Fig. 1. Different views of the central bank of Lebanon (https://www.architecturelab.net/central-bank-of-lebanon-roof-garden-beirut-green-studios)

Bank of Lebanon (Fig. 1) is located in Beirut-Lebanon. In 2013, Green studios, a Lebanese/American Landscape design & technology start up, launched the first pilot garden on the roof of the bank. With UNDP's team, a series of sensors and vital data were collected to measure insulation, water consumption, rainwater storage capacity, toxins reduction. The roof (800 m^2), overlooked by the surrounding higher buildings, was planted to restrict the hardscape to around 20% for occasional activities in order to integrate more green and sustainable practices and to deliver an aesthetical garden allowing the ecological habitats to be restored, birds and butterflies to belong to in a new home, and also for insulation of the building from extreme temperatures. In addition, this event has economic benefits since it greatly reduces the heating and cooling bills over the years. Finally, it presents a crucial social benefit, since it provides employees with a new space mostly seen from the office windows of the other complex buildings and a dynamic and vibrant plan view. The design concept was developed around movement and color, since the garden was to be mostly seen from the office windows of the other complex buildings. The garden was completed in March 2014, and has become an inspiration to a few neighboring buildings as a prototype to copy to compensate the lost green spaces in the streets below.

First case: M1 Building (Workplace)
Location: Mina al Hosn, Beirut Central District, Lebanon
Type: Landscaping
Area: 33,200 m²

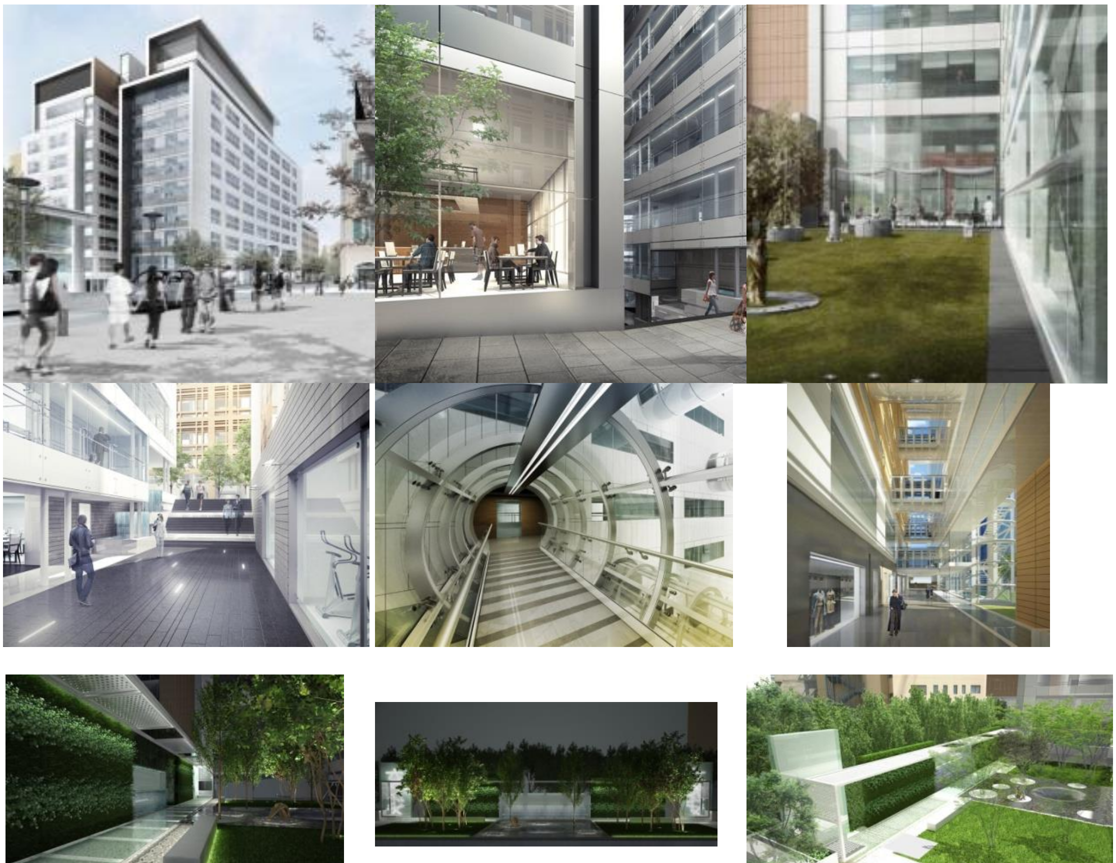

Fig. 2. Different views of the M1 Building
http://www.m1realestate.net/Portfolio/Details/47

The project consists of three new interlinked office buildings of 10-storey each with an additional 5 basement levels, totaling around 33,200m^2. The three buildings are interconnected by bridges as well as the parking area, in addition to a communal retail platform at the base.M1 building officially received the Leadership in Energy and Environmental Design (LEED) PLATINUM certification on July 20th, 2016 after construction completion and commissioning of systems. It is the 1st project in Lebanon to achieve the LEED Platinum rating and the 5th LEED certified project in the country.

By constructing this building some of the sustainability measures have been tackled among them: significantly minimizing water consumption via low-water fixtures, grey-water recycling for WC flushing; reducing energy usage through highly energy-efficient HVAC, lighting systems, low-energy consuming elevators engines; producing on site renewable electricity through arrays of Photovoltaic Panels installed on the roof; improving internal thermal comfort as well as indoor environmental quality by promoting a smoke-free building, and low-toxicity paint and finishes; specifying a large proportion of locally sourced and low-impact materials with recycled content; establishing and adopting a "Green Cleaning Policy" in the office buildings; as well as allocating a permanent sustainability display area to raise public awareness about eco-friendlier buildings.

Second case: International College Elementary School – IC

Location: Ras Beirut, Lebanon

Type: Landscaping

Area: 22,670 m²

Fig. 3. Different views of IC Building

http://www.flansburgh.com/portfolio/international-college-ras-beirut-elementary-school/

The IC elementary school is the first project in Lebanon to be certified according to the US Green Building

Council (USGBC) LEED sustainability scheme, and the 1st LEED for school's certification in the country as well. The LEED "Gold" certificate was awarded in March 2013.To do, dynamic thermal modeling analysis as well as day-lighting simulations of the proposed buildings were carried out in order to lessen the buildings' cooling load and energy consumption, while maintaining comfortable thermal standards. Also, a particular importance was paid for creating a healthy indoor environment for the kids, through the promotion of low-emitting and non-toxic materials, paint, and finishes, as well as proper ventilation levels.

Third case: CAZA BATROUN (Residential Dwellings)
Location: Batroun, Lebanon
Type: Residential
Area: 200 m^2

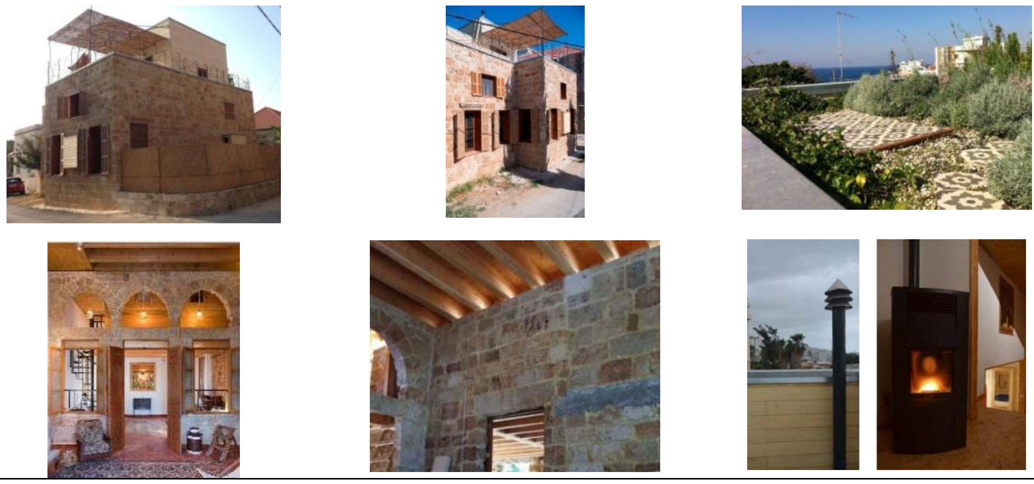

Fig. 4. Different views of the Caza Batroun (http://ecoconsulting.net/www/Casa_Batroun.htm)

Casa Batroun, a small private house in Batroun has been renovated and extended following rigorous eco-friendly criteria, achieves 1st BREEAM International "EXCELLENT" rating in the Middle-East in 2017, and Lebanese Architects Award for Sustainable Architecture. The project incorporated a bio-climatic design enhancing cross-ventilation and energy-efficiency through careful window positioning and openings, shading devices, thermal insulation, zoning of LED lighting, solar water heating and biomass heating via wood pellet stoves. A thermal modeling analysis demonstrated that the house achieves significant reductions in its energy consumption and CO_2 emissions of 50% and 36%, respectively. Water savings are realized via rainwater harvesting and low-water fixtures, as well as a green roof with drip irrigation. The house's envelope, finishing, and furniture integrate almost exclusively natural, low-embodied energy, or recycled materials with very low toxicity levels.

V. DISCUSSION

In 2000, WHO issued a report titled "The Right to Live in a Healthy Indoor Environment". This confirmed that the provision of a healthy internal environment has become a human right[14]. It is achieved only by providing healthy air that guarantees a good condition and which does not pose a risk to the disease. The following should also be put into consideration: prevention of air stagnation and draughts, thermal properties, poor insulation, poor provision for daylight and/or uncontrolled solar gain, sealed windows, large areas of soft furnishing, use of inadequately tested materials, paints, joining mastics and glues, lighting types and glare, services, and areas that are not designed for easy cleaning and maintenance[14]. There is an association between the perception of poor indoor air quality and SBS[15]. A lot of problems occur in offices and in other buildings, particularly schools, hospitals, and care homes. Also, factors such as gross overcrowding, poor cleaning, space management, water damage, and the occupancy of areas of a building which is not designed as workplaces may also lead to SBS. Research indicates that SBS symptoms are 30–200 % more frequent in mechanically ventilated buildings[6]. In addition, SBS leads to an increase in self-reported illness absences and reduced productivity in offices[16][17][18]. In our research, three different types of places have been investigated. The first was the Central Bank of Lebanon considered as a workplace located in the core of Beirut and surrounded by higher buildings. In order to improve the quality of its features and to be environment friendly, 800 m^2 of its roof was planted and becomes probably the first smart green roof in the Arab World. It is equipped with sensors to collect data such as insulation, water consumption, rainwater storage capacity and toxin reduction. Around 20% of the roof area was kept as hard roof for visitors to attend activities held there[19].This step beside its economic benefits resulting from energy cost savings, led to the creation of new medium with green space having a good impact on the psychology and the productivity of workers. Also, CBL assumes visual comfort which defines lighting conditions and the view of one's workspace and plays such a vital role in the overall productivity, comfort and well-being of the occupants[20] as it was reported that insufficient light, especially daylight or glare, reduces the ability to see objects or details clearly[21]. In the second case study, the IC elementary school analyzed the effect of visual comfort on students' performance, productivity, comfort, and satisfaction as windows and its therapeutic impact of natural views are well established in the literature[22]. Architectural design has a direct impact on classroom lighting, personal well-being, and productivity.

A school's indoor environment can have a significant impact on health and learning. Recent studies have reported associations between provision of ventilation (outdoor air) and students' health and academic performance. Low ventilation rates can result in an increased exposure to indoor air pollutants, which are assumed to be the primary reason for adverse effects on occupant's health and performance[23]. Children are often more heavily exposed to toxic substances in the environment than adults because they spend more time on the ground and engage in more hand-to-mouth behavior[24]. Exposures to environmental contaminants can cause adverse health impacts and performance[25]. Furthermore, some children with disabilities face unique challenges that might make them particularly vulnerable to the effects of an unhealthy school environment[26].

The IC elementary school worked on a project to decrease the buildings' cooling load and energy consumption, and to create a healthy indoor environment for the kids through the promotion of low-emitting and non-toxic materials, paint, and finishes at proper ventilation levels. The IC project enhanced thermal insulation. It was demonstrated that temperature and humidity have a strong and significant impact on the perception of indoor air quality[27] and then on the intensity of fatigue, headache, difficulty, and performance[28][29]. In a study done in Switzerland, increased sickness absence in a group moving from a naturally-ventilated to an air-conditioned office was found[30]. Another study indicated that good physical conditions in a school and adequate outdoor air ventilation help to maintain comfortable indoor temperatures to facilitate learning, reduce absenteeism, and improve test scores[31][32]. Children in classrooms with higher outdoor air ventilation rates tend to achieve higher scores on standardized tests in math and reading than children in poorly ventilated classrooms[33]. Also, it was demonstrated that the absence of sickness was also higher in buildings with humidifiers[34].

In the third place, the project incorporated a bio-climatic design enhancing cross-ventilation and energy-efficiency through careful window positioning and openings, shading devices, thermal insulation, zoning of LED lighting, solar water heating and biomass heating via wood pellet stoves in order to have a high-quality indoor environment. Acceptable indoor air quality is defined as air where no known contaminants are found in hazardous concentrations, and where a majority of the exposed occupants do not express dissatisfaction[35]. In fact, exposure to pollutants in indoor air can cause respiratory diseases, allergies and respiratory tract irritation. Particulate matter and noise degrade the quality of the various environments that people frequent during their daily activities[36][37]. Also, Persily & Dols[38] present measurements of air exchange rates, ventilation effectiveness and CO_2 concentrations in an office/library building with mechanical ventilation in Washington, DC. Analyzing some characteristics inside the building, such as thermal conditioning in summer and in winter times, will help to assess whether the building is healthy or sick. Several technologies in the market are useful to variable degrees in the purification of air and the maintenance of IEQ.

Manufacturers often don't know the full list of chemical compounds in their products, the way they are made, or what harm they pose. These unregulated chemicals may pose health hazards alongside ecological problems. Also, no one has asked manufacturers to prove the safety of their products – neither to people, nor to the environment. Product manufacturing is continuously exposed to these health hazards. IEQ assessment in buildings has taken different dimensions based on building type and environmental setting. Alternative materials free from 'red list' chemicals should be used as this will protect occupants from chemical hazards. Manufacturing should be discouraged to limit their release into the natural environment. Also, green building rating systems such as LEED, BREEAM, and Australian Green Star (GBCA) have made some significant contributions towards promoting sustainable healthcare facilities planning, design, and construction[39].

Integrating energy efficiency and IEQ improvements entails getting involved in the building structure, equipment or ongoing maintenance and operations, insuring occupant health-protection goals, focusing primarily on opportunities to protect and improve IAQ during building upgrades, preventing and controlling exposure of occupants to contaminants that may be disturbed or introduced during upgrade projects, controlling moisture, and ensuring that occupants are provided with adequate ventilation to promote health and comfort. Components responsible for an environment appear to be psychosocially healthy for its inhabitants. Improving the health of people and communities in the built environment through innovative design strategies do not necessarily cost more if it is integrated and implemented at the right point in the design process. When designing the buildings and developing services strategies, engineers need to engage the participation of experts in toxicology, industrial hygiene, environmental health, building science, lighting design, environmental management and building systems engineering, which understand the relationship between the built environment and human health. The interface of individuals with the sky views should be enhanced, if available, using green panorama. The walls, being painted with light hued shades, improve visual contentment.

VI. CONCLUSION

Various health outcomes mostly SBS are related to unhealthy built environments. It is a consequence of exposure to numerous health risk factors and their parameters. The identification of these risks is an important step in the process of effective control and prevention. In order to prevent SBS, the architectural and interior designer must provide the sustainable performance of the building after the completion of its implementation and operation through various points (design process, planning and designing the site, using the building's energy, the internal environment, choosing materials and the product, water management, implementation management, surrender or follow-up walls, operation and maintenance).In our study, the concept of sustainability has been applied on three different kinds of places to ascertain the health status of buildings and occupants. For that, several steps have been tackled to save water, reduce energy use, reduce indoor air pollution and relying on passive design strategies to achieve natural ventilation and natural lighting, reduce thermal gain. The benefits of a healthy building are in abundance, e.g., natural daylight, human thermal comfort, air purity, and health payback. Finally, care must be taken when coordinating the interior spaces in a way that they are compatible with human activities inside, by selecting the appropriate place and climate for its performance.

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