Enhance Indoor Environment in Buildings and Its Effect on Improving Occu...
II. RESEARCH AIM AND OBJECTIVES

The aim of this research is to present an overview of the connection between the indoor environment and occupant's health and well-being. In addition, it will show that a good design and construction practices will minimize the indoor hazards and provide a healthier living for its occupants.

III. RESEARCH PROBLEM

As people became more aware about the effects of poor indoor environment on occupants' health, the main problem of this paper is how to measure the effects of the indoor environment and how sustainable design can help improve the indoor environment.

IV. RESEARCH METHODS

The descriptive qualitative method will be used to gain an accurate and detailed knowledge depending on relevant papers. In addition, this research will evaluate different approaches in terms of their impact on the indoor and outdoor environment. Also, present guidelines for designers, contractors and owners to turn buildings to become sustainable.

V. LITERATURE REVIEW

The literature shows an increasing state of awareness concerning indoor air quality. In fact, minimizing the effects of indoor pollutants is a priority in building design, since a high percentage of peoples' time in indoor. The climate changes as a result of increasing greenhouse gas emissions resulted from increasing in building construction which is the main sector in energy consumption; therefore, governments should encourage the building sector to move towards sustainability and an implementation of green specifications [8].

Building performance and its effect on occupant's health and comfort with respect to sustainable design got more attention in the last decade. The government's main concern around the world seeks to improve building performance to ensure reducing building's hazards to health and well-being. Several studies investigated the factors that affect indoor occupants' health, satisfaction and consequently their performance [9], [16]. Health will be improved significantly by improving IEQ, he added improvements in lighting and thermal conditions increase productivity [10], [17]. As a result, LEED organizes these different IEQ (Fig. 4). These studies indicate that IEQ affects health and productivity. Therefore, architects and designers have to be aware about IEQ in their design to minimize health hazards.

A. Sustainable Buildings

Sustainable buildings aim to meet human needs while preserving the environment [7]. Thus, sustainability should minimize environmental negative impacts, conserve natural sources, enhance and protect the nature environment, decrease global warming, heat island effects, pollutions and ozone depletion, while providing a comfortable, healthy and productive environment for its occupants (Fig. 5). Nowadays, recent interest about buildings in general is creating more sustainable and healthy buildings [11], [18]. The need for buildings to consume less natural resources, contribute a smaller carbon emission, and provide better and healthier indoor environments. The resulting changes in the approach to architectural design have a number of consequences which should be considered. The most significant aspect to consider regards the use of natural lighting as approximately 25% of energy consumption in buildings on artificial lighting; in addition, artificial lighting is also a source of heat in indoor spaces. Using natural light needs to change in the plan layout from deep floor plans to more strategically oriented buildings with narrow floor plan and glazing strategically allowing for day lighting of placing openings on the north side of the
building to minimize both the potential for glare and direct solar radiation [11].

![LEED - IEQ credits](image1)

**Fig. 4 LEED - IEQ occupant well-being and productivity structure (Source: [16, p. 753])**

![Integrative Approach: Benefits](image2)

**Fig. 5 Benefits of Sustainable building design (Source: [17, p. 100, 105])**

**B. Pollutant Source Identification**

There are so many sources of contaminants contribute in increasing health hazards in buildings. The knowledge of these sources contributes in putting a proper criteria and guidelines to mitigate their effects. These can be as Fig. 6.
1. Materials and Inhabitant's Activities
The quality of indoor air is affected by the indoor materials used; therefore, occupant’s health is influenced by the materials used. The materials used in buildings and furniture are main sources of indoor volatile organic compounds (VOCs) [12]. On the other hand, some of the indoor pollutants results from inhabitants’ activities and can be very harmful. Among these pollutants are: cleaning products, pets, tobacco smoking, etc.

2. Electricity, Heating and Cooling
The indoor environment in general and the indoor air in particular are affected by heating and cooling system as they depend mostly on gas, which pollute the environment when consumed.

3. HVAC Systems
As HVAC is depending on its work on the air taken from outdoor environment, which is polluted from vehicles, parking lot, factories, garbage, producing a poor indoor air quality include carbon monoxide and bacteria. In addition, HVAC noise causes discomfort and headache [13].
TABLE I
INDOOR AIR POLLUTION

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Source</th>
<th>Health Effects</th>
<th>Steps to Reduce</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Radon</td>
<td>Earth, Rock, building materials</td>
<td>Lung cancer</td>
<td>Seal cracks in floor</td>
</tr>
<tr>
<td>2 Tobacco smoke</td>
<td>Cigarette, pipe, cigar smoke</td>
<td>Eye, nose, throat irritation, headache</td>
<td>Stop smoking</td>
</tr>
<tr>
<td>3 Biological</td>
<td>Wet walls, ceiling, carpet</td>
<td>Eye, nose, throat irritation, fever, asthma</td>
<td>Vents kitchens and bathrooms, clean and dry wet carpet.</td>
</tr>
<tr>
<td>4 Carbon Monoxide</td>
<td>Un-vented kerosene and gas heaters, furnaces</td>
<td>Fatigue, impaired vision, headaches, nausea</td>
<td>Ventilate over stove</td>
</tr>
<tr>
<td>5 Nitrogen Dioxide</td>
<td>Kerosene heaters, tobacco smoke</td>
<td>Eye, nose, throat irritation, impaired lung function</td>
<td>Ventilate over stove</td>
</tr>
<tr>
<td>6 Organic gases</td>
<td>Paints, stains, and strippers</td>
<td>Headaches, dunes to liver and kidneys</td>
<td>Ventilate area</td>
</tr>
<tr>
<td>7 Formaldehyde</td>
<td>Plywood, furniture, particle board</td>
<td>Eye, nose, throat irritation, wheezing, coughing, fatigue, skin rash</td>
<td>Increase ventilation</td>
</tr>
<tr>
<td>8 Respirable</td>
<td>Fireplaces, wood stoves, kerosene heaters, tobacco smoke</td>
<td>Eye, nose, throat irritation, lung cancer</td>
<td>Vent furnaces</td>
</tr>
</tbody>
</table>

Source: Modified by the Author from [18 p. 40]

VI. DESIGN CONCEPT FOR HEALTHY INDOOR ENVIRONMENT
There are many possibilities for achieving healthy and comfortable indoor environment; these can be summarized as follows:

A. Site Planning
A proper building sitting help to maximize natural resources such as light, heat, ventilation, plants, shade, and maximize the use of natural resources on the site. For example, using deciduous and evergreen plants have a big role in modifying the microclimate in the site. Site planning includes the followings:

1. Urban Solar Radiation
The aim of solar responsive design is to maximize the access of solar radiation to building’s indoor spaces in winter and protecting buildings from unwanted solar radiation in summer with enhancing the usages of nature day lighting and ventilating indoor buildings. This design can be achieved by good urban planning, orienting, designing of buildings, choosing suitable building materials and good using of vegetation.

2. Wind Control
Tall buildings which are separated by open spaces can create a pressure difference which creates local ventilation that continues flowing to building’s indoor spaces, while landscape vegetation block and control the wind and give shade to exterior walls and therefore reduce indoor heat gain.

3. Air Quality
Vegetation plays a vital role in improving the air quality. In addition, vegetation can block dust and odors from entering indoor buildings (Fig. 7).

4. Landscape
Landscape has more benefits by creating more green spaces with more trees and greener views and other benefits such as:
- Filtering outdoor air and reducing dust.
- Reducing air pollutants, noise and other negative impacts.
- Enhancing local temperature.
- Reducing unwanted wind speed.
- Reducing unwanted solar gain.

B. Controlling Solar Gain
Controlling solar gain in buildings by planting shade trees in front of west and south elevations of the buildings are a very effective way to protect buildings from unwanted solar gain and then reduce cooling loads, energy consumption, production of pollutions, noise and other negative impacts (Fig. 8).

C. Landscape and Natural Ventilation
Enhancing natural ventilation and cooling by influencing wind flowing to reduce mechanical HVAC systems, then reducing the consumption of energy and enhancing the quality of the indoor environment is one of the required processes to achieve sustainability in buildings, this is require designing landscape elements to controlling the wind direction (Fig. 9).

Fig. 7 Using landscape elements for decreasing urban pollutions (source: [19, p. 30])
D. Roof Garden Systems

The roof garden is very important in controlling indoor temperature, conserving flat roofs from unwanted direct solar gain, reducing pressure on mechanical HVAC systems and enhancing outdoor environment quality.

E. Indoor Landscape

Indoor plants influenced the wellbeing of building occupants as plants enhance the indoor environment and air quality [14], [19]. Plants have the following benefits: reducing carbon dioxide, reducing airborne dust, and keeping air temperatures down.

F. Insulation

The two critical elements in buildings are windows and walls as they can facilitate the intrusion of outdoor polluted air, dust, and heat. Therefore, protecting an indoor environment from polluted outdoor environment will help reduce heat gain, minimizing dependencies on HVAC as a result reducing mechanical noise and creating healthier and comfortable environment.

G. Natural Ventilation

Mechanical ventilation systems are using big amount of energy and considered one of the noisiest and air pollutants sources indoor buildings. Natural ventilation can easily solve those problems by good designing of building by improving the natural ventilation to flow in building’s interior spaces to achieve many benefits such as: improving indoor air quality and replacing indoor air which contain CO2 by new fresh air with O2, removing moisture, smells and indoor air pollutants [6]. Therefore, suitable orientation of buildings, good designing of building architecture form and articulated walls to make a pressure difference between outdoor and indoor to dragging air flowing into building’s indoor spaces.

H. Indoor Acoustical Comfort

A good planning of building control both indoor and outdoor noise from its source or decreasing its effects in indoor spaces [20].

I. Materials Conservation

Construction of any building needs building materials, these building materials should be green materials which have low consumption of energy, low or no chemical emissions or toxic compounds in the environment.

J. Natural Day Lighting

Natural day lighting has an impact on occupant’s health, comfort, performance and satisfaction; it is also influenced buildings energy usages. The design of buildings which depend on natural day lighting concept is very complex because it should be integrated with: designing of artificial lighting, building architecture form, orientation, and elevation details, many benefits of natural day lighting such as reducing pollutions which is resulted from artificial lighting and enhancing the visual quality of building’s indoor spaces by connecting to outdoor views [21], [22]. Buildings architecture form has major impacts on improving natural day lighting usages in building’s indoor spaces by considering it in designing roofs and openings elements such as: windows, skylights, roofs and others to improve natural day lighting usages.

VII. CONCLUSIONS

Green building design should have more attention from architects, designers and policy makers. In addition, the community must become more aware of the benefits of green and sustainable design which reflects on improving occupant’s health and wellbeing. Besides, encouraging universities and schools to include sustainable and green design in their curriculum will have a generation of architects and designers aware of the benefits of green design. Different campaigns for communities to enhance their awareness of green buildings and its benefits and to adapt their behavior with green design.

Finally, for indoor environment to perform effectively and healthy for its occupants, a shift is required from occupants to play a more active role to adjust their behavior inside their buildings as inhabitants’ activities can be very harmful [15]. It is essential to increase peoples’ awareness for sustainable building design and building uses.
REFERENCES


[2] Report to Congress on Indoor Air Quality, Section 404 (e), Title IV, ACT (SARA), 1986, p. 43.


