Implications of Green Buildings and Climate Change on Human Health in Israel

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In this article the medical and public health aspects of building design and materials are discussed. The literature linking building exposures, including use of building health effects is reviewed. Materials and design specific to the built environment in Israel are outlined. Building design in the Eastern Mediterranean is influenced by regional climate change and in turn can impact the progression of climatic change. The growing fields of green building and green neighborhood design and its implication on human health and climate change are reviewed, specifically as it pertains to the built environment in Israel.

Keywords: *Green building, Indoor air quality, Volatile Organic Compound (VOC), Sick building, Building related symptoms.*

Israel is an increasingly urbanized society, with the majority of its population spending over 70% of the time in indoor environments. The impact of indoor environmental exposures on human health is significant. A growing body of scientific knowledge has elucidated the role building materials and design plays on development of symptoms and disease. Green building design aims to minimize the negative effect that buildings contribute to global warming and its impact on human health. This paper reviews the possible implications of building design on human health and climate change in general with specific attention to the situation in Israel. Future directions worth perusing for further research in this realm are suggested.

BUILDING, ENVIRONMENT AND HEALTH

The way in which buildings are built, the materials used in the construction as well as its design, has a significant effect on the health of the building's inhabitants. The United States Environmental Protection Agency (US EPA) estimates that 20 out of 24 hours in a day are spent indoors (US EPA, 1989), consequently indoor

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built environment exposures plays an influential role on human health. According to the World Health Organization, the indoor environment is responsible for 3% of all morbidity and mortality worldwide, making it the 9th leading contributing cause of disease (WHO, 2004). A growing body of literature assessing the impact of the built environment on human health has elucidated some of these mechanisms by which the indoor environment contributes to disease.

The term "building related symptoms" (BRS) has been used to describe the confluence of symptoms related to time temporarily spent in a specific building. The use of this term as a medical diagnosis is controversial, however the notion that the building environment influences health is increasingly acknowledged. Symptoms commonly associated with poor building environment include itchy or dry eyes, headache, fatigue, and respiratory complaints such as cough and congestion. While the prevalence of BRS is debated, studies undertaken by the US Environmental Protection Agency estimate 45% of the US workforce reports at least one building related symptom, while 20% report at least three (Brightman et al., 2008).

A number of controllable building exposures have been associated with adverse health and productivity outcomes. Studies on various interventions including increased circulation of outside air, greater natural ventilation, decrease in building moisture, increased control of indoor pollutants, and increased natural daylight, have been associated with decreased prevalence of building related symptoms. A meta-analysis of 32 epidemiological studies on office worker symptoms found consistent findings associating increased symptoms frequency with presence of carpets and low ventilation rates (Mendell, 1993). A decrease in ventilation rate from 10 to 5 Liters/sec per person is associated with a 23% increase in the prevalence of building related symptoms, while increasing ventilation rate from 10 to 25 Liters/sec per person decreases the relative prevalence of symptoms by 29% (Fisk et al., 2009). Building climate is also associated with the health of building occupants. Temperatures in excess of 22 degrees Celsius are associated with increased reporting of building related symptoms as is elevated humidity (Reinikainen, 2001).

Volatile Organic Compounds (VOCs) belong to a family of chemicals that share a similar aromatic chemical structure. Due to their high volatility, they off-gas into the indoor environment and are rapidly absorbed by the building inhabitants. VOCs are found in a number of building materials including adhesives, varnishes and paints. Building furnishings with compressed and treated wood will commonly have measurable amounts of VOC emissions. There is some evidence that passive exposure to VOCs from the building environment is associated with increased frequency of BRS (Sunesson et al., 2006; TenBrinke et al., 1998), however some studies failed to show an association between background VOC exposure and BRS. A study of 1700 office workers in Brazil failed to show an association between measured total VOC concentration and reported symptoms (Rios et al., 2009).

Beyond improved health outcomes, worker productivity is associated with specific building exposures. Improved indoor air quality and increased ventilation rate

is associated with an average 3.3% increase in productivity. Improved temperature control resulted in an average 5.5% increase while improved lighting (indirect light fixtures, task lighting, high-performance fixtures and sky lighting) resulted in a median 3.2% increase in productivity (Carnegie Melon University, 2007).

BUILDING MATERIALS AND DESIGN IN ISRAEL

Much of the literature on building health has originated from North America and Europe where the regional climate and building environment is significantly different than in the Eastern Mediterranean. Consequently, much of the literature linking human health to building material and design cannot be directly applied to the Israeli population. To date no published work has identified the prevalence of building related symptoms in Israel or the surrounding Mediterranean region.

Due to the Mediterranean climate and design traditions, Israeli buildings usually offer extensive natural ventilation from large windows and open design[1]. The use of recycled ventilation and sealed building design is primarily utilized as a method to conserve energy in cold climates. In Israel, sealed building design is primarily found in large public and commercial buildings. In comparison to much of Europe and the Eastern United States, sealed building design which limits natural ventilation is rarely used.

Lumber is comparatively more expensive in Israel than in Europe and North America, consequently wood is not commonly used as a building material. The amount of lumber in a structure increases the concentration of bio-allergens in the indoor environment. Additionally wood is more susceptible to water damage and propagation of mold than cement. Consequently the health effects from water damaged building materials in Israel are limited when compared to Europe and the United States.

Concrete is a commonly used building material in Israel (Alweil, 1983). Concrete as a building material introduces the potential for radon emission and exposure. Radon is an odorless, colorless gas which occurs naturally as a decay product of uranium found in soils containing granite. Chronic exposure to radon gas has been associated to lung cancer. The incorporation of uranium containing gravel into building materials has been a concern for indoor exposure to radon. While the World Health Organization sets an action level of 100-400 Bq/m3 global average of indoor radon is estimated at 38Bq/m3 (WHO, 2008). A study on radon exposures in residential, school and hospital buildings in Hebron demonstrate average radon concentrations above the 74 Bq/m3 action level set by the US EPA (Leghrouz, 2006).

One of the contributing factors leading to increased radon exposure in Israeli buildings is the common practice of incorporating fly-ash into cement mixture. Fly-ash has been found to have 3 times the quantity of radon when compared to Portland Cement. Despite the elevated levels of radon from concrete materials used

in Israeli buildings, an epidemiological study on Israeli patients with lung cancer did not find a significant association with residential radon exposure (Biberman et al., 1993).

Another important difference between Israeli building tradition and those of North America and Europe is the different types of paints used in building. The use of wood for a finishing material in those regions as opposed to plaster and gypsum in Israel is responsible to the difference in the type of paints used. Israeli houses are usually painted with water based paints while traditional houses in the USA and Europe are painted in oil based paints.

Studies assessing the relationship between indoor exposure to VOCs and building materials have demonstrated increased VOC concentration with the use of oil based paints, varnishes, sealants, adhesives, and carpet installation (Won et al., 2003). Paints used in Israeli buildings are primarily water based and do not off-gas VOC's to the extent of oil based paints. Due to frequent dust storms and warm climate, carpets which are also associated with increased VOC concentration, are infrequently installed in new buildings. Due to decreased use of the above VOC generating materials and increased ventilation, VOC concentration in Israeli buildings are presumably less than what is observed in the literature, however no published studies have measured average VOC concentration in Israeli buildings.

IMPACT OF REGIONAL CLIMATE CHANGE ON HUMAN HEALTH

Global climate change is projected to have significant effects on human health in the Eastern Mediterranean. Regional climate changes are expected to result in increasing extreme weather events, water scarcity, ozone and air pollution concentrations, and episodic dust storms. The result of these climatic changes are projected to have significant human health effects, including increased incidence of heat related diseases, change in distribution of infectious diseases, and increased prevalence of air pollution related cardiopulmonary disease (Paz et al., 2010).

A warming trend has been noted in the Eastern Mediterranean with increasing frequency and severity of heat waves being reported from 1958-2000 (Kostopoulou and Jones, 2005). This warming trend has been associated with outbreaks of infectious diseases including Vibrio Vulnificus in Israeli commercial inland fish (Paz et al., 2007) and the West Nile outbreak in Israel (Paz, 2006). Increased frequency of heat-related events in the region has also been associated with increased mortality rates (El-Zein et al., 2004) and incidence of heat stroke (Zawahri, 2004).

Saharan dust is a significant contribution to particulate exposure in the Eastern Mediterranean. Dust influx into the region is increasing as a result of soil degradation and desertification processes in combination with changes in wind direction and intensity (Portnov and Paz, 2008). Much of the increase in the frequency of dust and sand storms over the past three years have been explained by changes in

weather and climate (Zhang et al., 2003). Increased dust related particulate matter is associated with increased frequency of respiratory symptoms as well as physician and hospital visits for cardiopulmonary diseases in the region.

GREEN BUILDINGS AND NEIGHBORHOODS

The increasing global awareness of the threat of the greenhouse effect and the concern for the environment has led governments, organizations and individuals to promote actions in various fields. The first multinational discussion on environmental issues was held in 1972[2]. The conference was a result of a process of rising public awareness to environmental damage due to incidents such as the exposure of Japanese fishing vessel to radioactive fallout in 1954, oil spills from tankers in England and the United States in 1967 and 1969, and publications of bestselling books on environmental issues such as the Silent Spring book that drew attention to the connection between environment and chemicals (Carson, 1962). Modern sustainable or green building design movements can be traced back to the seventies to movements such as Energy Conserving Design, American Solar Energy Society and Passive Solar Industries Council (McLennan, 2004). During the 1980's these organizations saw little development due to declining energy prices. A significant breakthrough began in the early 1990's with the establishment of the Building Research Establishment (BRE) Environmental Assessment Method (BREEAM) in 1990[3] and the US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) that was established in 1993[4].

The primary concern in relation to building design has been connected to consumption of natural resource. It has been estimated that building design influences 40% of primary energy use, 72% electricity use and 39% of CO2 emissions and 40% of portable water consumption. Green buildings can potentially reduce 24-50% of energy use (Turner, 2008) (Kats, 2003), 39% of co2 emission (Kats, 2003) and 40% water consumption. The establishment green or sustainable design does not stop at the building scale. Following the successes of the green building codes, the last decade has seen the establishment of a green code for neighborhood or urban planning. The BREEAM Communities scheme was established in 2003 and aimed to "help planners and developers improve, measure and independently certify the sustainability of development proposals at the planning stage". USGBC LEED for neighborhood development (LEED ND) was established in 2006 and aimed for similar targets. The green codes for urban development promote, among other aspects, dense mixed-use development, walkable areas, healthier transportation, and recreation choices and included an inherent demand for green buildings (Rudlin, 1999).

HEALTH AND GREEN BUILDINGS

Although environmental factors were initially the main focus of the discourse on green building, in recent years there has been a growing interest in other important aspects of green building, including the impacts on health, productivity and quality of life. Currently, these aspects do not receive equivalent attention as the environmental realms; health and productivity of a building's inhabitants contributed 15% of the total points possible in the leading international green certification[5]. Energy related points for comparison constitute approximately 35% of total possible points.

Green buildings' influence on human health (in terms of its influence on wellbeing, comfort and circulation), is connected to four main fields: ventilation, building materials, light and design. There are several fundamental differences in terms of ventilation between green and regular buildings. As opposed to traditional buildings, human comfort conditions in green buildings are accurately controlled and monitored both in preoccupancy and in post occupancy state. Green building certification, such as LEED has several requirements including the possibility to open windows in rooms, a limit of number of air change per hour, a smoking policy and monitoring of CO_2 levels. LEED also requires controls on equipment installation and maintenance during construction and proof that the building air has acceptable levels of specific indoor pollutants before occupancy[6].

Building materials in green building are treated in a very straight forward manner. Only materials that comply with specific green codes are allowed to be used in a building. Moreover, as mentioned earlier the level of pollutants in the indoor environment is carefully monitored. Before occupancy the contractor is required to flush out the building air or to prove that the levels of pollutants comply with published standard[7].

Improved air quality in green buildings in North America is responsible for an average of 43% improvement in all the symptoms connected with air quality (Kats, 2009). In terms of indoor lighting, green building codes require proof that the building complies with a higher required level of daylight illumination. Research on the connection between health and daylight has shown that it can reduce symptom frequency by 34% (Kats, 2009).

Green buildings facilitate increased interaction and movement of the occupants by means of visual exposure and emphasizing stairs as a mean of vertical movement instead of the common centrality of the elevator. Traditional building design and layout has been shown to have a significant impact on physical activity of building inhabitants. Building stairwell placement and design influences the likelihood of its use. Buildings that showcase a stairwell in an open layout that is easily accessible to building inhabitant has been shown to increase stair usage and physical activity up to 33 fold (Nicoll and Zimring, 2009). The Harvard Alumni Health study of approximately 11,000 men found that those who climbed at least 20 floors per week had a 20% lower risk of stroke or death from all causes when controlling for a large number of demographic and other risk factors (Paffenbarger et al., 1997).

When it comes to green code it is difficult to measure and control movement and building/urban layout, especially the expected increase in occupant movement in the building/neighborhood. Consequently, as opposed to other aspects of green building such as ventilation and lighting, layout and movement changes are a challenge to assess and regulate. These topics are usually examined within the frame of design innovation credits, which in the LEED certification represents six out of a 100 total points and is shared also to the evaluation of straightforward design issues[8].

Although there are already hundreds of LEED and BEEAM certified buildings and the first certification for neighborhoods/communities have been given in 2008-2009, research comparing traditional and green building/neighborhoods in terms of walkability and its influence on health is still lacking. A considerable amount of research has been done and published on health related issues in the built environment neighborhoods and cities (Jackson, 2003) (Srinivasan et al., 2003)[9]. No research on these issues regarding officially certified green neighborhoods or a comparison between green and normal neighborhoods/communities was found. This is reasonable since green neighborhood certifications started only in the last decade (2003 for BREEAM Communities and 2006 for LEED) and the number of certified neighborhoods is still small.

One of the main differences between green and normal buildings and neighborhoods is the level of control over the design that the green certification demands. As opposed to normal design where empirical pre-occupancy and post-occupancy information is usually missing, green certification demands empirical proof that the building/neighborhood respond to certain demands. This could be a powerful resource both to persuade researchers to develop methods to measure walkability of designs and to influence public and decision makers' opinion regarding the importance of the design in promoting a healthy way of life and health in general.

GREEN BUILDINGS AND NEIGHBORHOODS IN ISRAEL

Israel voluntary green building standard (5281) was approved in 2005 for office and residential buildings. As of its inception only about 7 buildings have been certified until 2010. This is primarily due to lack of awareness, incentives and claims that the standard is outdated and complicated to follow[10]. A new updated code which was prepared with the help of the BRE is expected to be released in 2011[11]. Voluntary standard 5282, which deals with energy rating of buildings and promotes energy conservation, was also released on 2005 parallel to the green building standard. Since both standards are voluntary and did not gain many certifications several municipalities have been promoting in the last 5 years individual obligatory green dossiers primarily for public buildings and urban plans.[12] In 2010 the first city of Raanana announced its acceptance of Israeli building standard 5281 as an obligatory standard for all the new planning and construction in the city[13]. In addition to

the use of Israeli certification, about ten buildings in Israel are currently certified or are in a process of being certified by international LEED certificate.

Although there are numerous studies on low energy buildings in Israel and other aspects that are included within the definitions of green building (Becker, 2000; Shaviv and Capeluto, 1992; Shaviv et al., 2003), studies that examine the impact of certified green building in general in Israel or comparing green and traditional building in Israel has not been found in the literature. Most likely this is due to the small number of green certified buildings by an international certification and the low demands for empirical evaluation in the existing Israeli green 5281 standard that makes it difficult to receive empirical performance related data on buildings.

It terms of green neighborhoods and communities the situation in Israel is even less developed. Research has been done on healthy environments and cities (Donchin et al., 2006), however, there is no government official code or standard for green neighborhoods or communities design and the local dossiers that were mentioned earlier in this article are only in the beginning of its employment. Moreover, international codes are based on strict grading system that employs empirical information on the design. This information has to be supplied by the designers and local authorities and examined by neutral members of the code organization. The fulfillment of the local dossier rules, on the other hand, is supposed to be examined by the local authorities themselves that do not have the resources to thoroughly examine the designs and could not be considered neutral.

Nonetheless, there are several local initiatives to design and promote new "green" neighborhoods [14,15]. Although these neighborhoods will include important aspects of what is considered to be green neighborhoods by the international codes, and will certainly promote public awareness to green design, it would be difficult to examine the influence of these initiatives on health and environment from the same reasons mentioned earlier. Given the nascence of the field in Israel, there are no academic studies on the implications of green neighborhoods or communities in Israel. However, since the first "green" neighborhoods are being built, an initial research agenda should be established in the near future.

EXPECTED IMPLICATIONS FOR GREEN BUILDINGS AND NEIGHBORHOODS ON HEALTH AND CLIMATE CHANGE IN ISRAEL

There is a scientific consensus that energy use and CO2 emission are two of the main causes for climate change. Buildings in the US are responsible for almost half of the energy use and CO_2 output (Kats, 2009); it is clear that in order to avoid severe consequences of climate change the way buildings are built and operated must be reexamined. Research on green building has indicated that application of green building principles is able to considerably reduce both energy consumption and CO_2 emissions in a cost effective manner (Kats, 2009).

Research on the implications of climate change, green building and neighborhoods in Israel, however, is in the very early stages. Similar to the existing research in North America and Europe, green buildings and neighborhoods are expected to have considerable impact on human health also in Israel. The difference in climate, building methods and materials between Israel and North America and Europe is expected to decrease the impact of green building is some cases. This would be the case of symptoms that are connected to the level of external air change which are higher in Israel in relation to northern countries where the climate does not allow windows to be open as much as it does in Israeli Mediterranean climate. Additionally, due to the difference in building materials the concentration of indoor bio-allergens and toxins such as VOCs is expected to be lower. Nevertheless, the extensive use of concrete could introduce increase in other related symptoms.

Climate change in the Eastern Mediterranean has been shown to influence human health in a number of ways including increase in air pollution, decrease in access to potable water and change in distribution of infectious diseases. Green building has the potential to impart a positive effect on health in Israel both through direct remediation of indoor exposures, and by imparting a positive mitigating effect of regional climate change through decreased energy expenditure. There is minimal research published on the concentration of indoor environmental hazards in Israel and the surrounding Eastern Mediterranean region and the influence of climate change on these exposures. Future work should focus on measuring building ventilation rates, and average exposures of VOCs, bio-allergens and radon to building inhabitants. Assessment of the mitigating effect of green building on climate change should be included as a component of green building's overall health benefit.

NOTES

1. Higher level of comfort allows opening more windows for natural ventilation. A comparison between Tel Aviv, London, Boston and San-Francisco psychometric charts (using Adaptive comfort model in ASHRRAE standard 55-2004) shows level of comfort of 21% in Tel-Aviv, 4.6% in London, 4.5% in San-Francisco and 10% in Boston.
2. See the "Declaration of the United Nations Conference on the Human Environment" on http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=97&ArticleID=1503&l=en
3. See http://www.breeam.org/page.jsp?id=13 for more information about the BREEAM grading system
4. See http://www.usgbc.org/ - U.S Green building council for more information about LEED grading system
5. See for example LEED and BREEAM grading system (http://www.usgbc.

org – LEED, http://www.breeam.org/ - BREEAM).

6. See LEED Rating System 2009 - new construction on http://www.usgbc.org/ShowFile.aspx?DocumentID=8868
7. Ibid
8. Ibid
9. See also Physical Activity and Health: A Report of the U.S. Department of Health and Human Services Office of the Assistant Secretary for Planning and Evaluation June 20, 2002 (also available at http://aspe.hhs.gov/health/reports/physicalactivity/)
10. http://www.sviva.gov.il - Ministry of Environmental Protection website (Hebrew).
11. 5281 Israeli Code for Green Building. Ministry of Environmental Protection. Available at: http://www.sviva.gov.il/Enviroment/bin/en.jsp?enPage=BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals^l6657&enZone=green_building_teken_il [Accessed March 4, 2011] (Hebrew).
12. See for example the City of Kfar Saba green dossier at http://www.kfar-saba.muni.il/_Uploads/dbsAttachedFiles/ogdan-yarok.pdf (Hebrew) and Tel Aviv Green agenda http://www.tel-aviv.gov.il/Tolive/Infrastructures/Pages/EcoBuilding.aspx (Hebrew).
13. See http://www.raanana.muni.il (Hebrew).
14. Green neighborhood in the city of Yavne, Israel - http://www.yavnecity.co.il/schunayerukapage.html (Hebrew).
15. Green Neighborhoods in the city of Kfar Saba, Israel - http://www.kfar-saba.muni.il/?CategoryID=677 (Hebrew).

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