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Sick Building Syndrome in Apartment Buildings in Jordan

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ABSTRACT

The present study was conducted to investigate the concept of sick building syndrome which has recently been receiving attention to improve the indoor environmental quality in housing projects in Jordan. Apartment buildings were selected in three locations in Jordan; Amman, Irbid and Zarqa to represent different climatic regions in Jordan.

The methods of enquiries were based on observation(physical architectural and detailed analysis of the buildings),calculations of the environmental factors which affect indoor air quality and healthy environment and questionnaires designed and distributed to investigate occupants' perception in terms of health and building conditions.

The findings revealed that there were significant differences among geographical locations of apartment buildings in Jordan. Zarqa had the most severe condition because of the crowdness in the urban setting and the extreme weather conditions. Moreover, building physical configuration and attributes such as window sizes and types, envelope design, location of the apartment in the building, orientation and building layout had significant effects on the concept of the sick building syndrome.

KEYWORDS: Sick building syndrome, Indoor air quality, Apartment buildings, Jordan.

INTRODUCTION

Sick building syndrome can be defined as an illness from something in buildings; a group of symptoms typically including headaches and respiratory problems that affect occupants in usually new or remodeled buildings and are attributed to toxic building materials or poor ventilation.

There are many different terms which have been used to describe the phenomenon of reporting high incidence of illness or un-wellness; with more than twenty percent; suffered by occupants without any appearance reason. These include "building sickness", "tight building syndrome" and "building related illness". In 1982, the WHO agreed upon the term sick building syndrome to describe this phenomenon. Recently, symptoms similar to SBS in Japan have appeared in homes so that the term Sick House Syndrome (SHS) has been introduced (Ishibashi, 2007).

Sick building syndrome describes a medical condition where the people in a building suffer from symptoms of illness or feel unwell for no apparent reason or cause, another characteristic of SBS is that the symptoms are relived upon exit from the building (Hattori, 2003). It may occur in most types of buildings; offices, apartments, schools… etc. The symptoms can cause substantial disruptions to occupants' productivity, performance and personal relationships. The symptoms tend to increase

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with the time people spend in the building and disappear when leaving the building (Burg, 2004; Burton, 1993).

Building Related Illness (BRI) is defined as illness arising from exposure to indoor contaminants that cause a specific clinical syndrome (Samet and Spangler, 1991). The nature of the illness depends on the contaminant present within the building. This kind of symptoms does not disappear by exiting from the building. The most effective mitigation strategy for building related illness is to trace illness and remove the sources from the building (Lee, 1996).

Identifying Sick Building Syndrome (SBS) and Building Related Illness (BRI) caused by indoor air quality can sometimes be confusing (Arnold, 2001). Sometimes, both illnesses have been present in the same building; in other times (BRI) may be mistaken by (SBS) or *vice versa*. Building occupants complain of symptom indicators such as humidifier fear (high incidence, mild flue), sinusitis, rhinitis, asthma…. Symptoms can be clinically defined and have clearly identifiable causes. Complaints may require a long time to disappear after leaving the building (Menzies, 1997).

Environmental Protection Agency (EPA) indicated that about 10-30% of all American buildings are affected by sick building syndrome. Six out of ten houses and buildings all over the world are characterized as "sick", this means that they are hazardous to human health. The symptom of sick building syndrome is prevalent on about 20% or more of building occupants (Samet and Spengler, 1991: 308).

World Health Organization (WHO) listed the following symptoms as most commonly attributed to sick building syndrome: eye, nose and throat irritation, sensation of skin, eye problems, headache, high frequency of cough, nausea and dizziness. Several of these symptoms are experienced simultaneously. Sources of indoor contaminants can be restricted due to site, building system, materials and building occupants. In an European study the cause of SBS was limited due to design, construction, materials and operation.

Recently, health problems are associated with indoor environments because of the increase of dependence on artificial products and the increase of time spent in indoor environments (Dockery and Spengler, 1981). This increase in time is due to a number of factors like shifting from rural to urban life style, shifting activities to being indoor functions and increase in dependence on automobiles. This means that if the space is unwell, occupants will suffer symptoms and discomfort indoor.

The architectural design process is about creation beautiful and functional spaces. Beauty in architecture is determined by design aesthetics, aside of issues of functionality, practicality, occupant comfort, safety and health.

The problem of providing adequate health housing of citizens is one of the most everyday worries experienced by a large sector of Jordanian society, following the substantial rise in the prices of rent or purchase of housing as a natural result of increasing demand on housing due to the influx of hundreds of thousands of Arabs coming to Jordan as a result of events taking place in the region. In addition to this comes the substantial rise in the index of world oil prices.

Expected annual needs of the Kingdom of units and apartments reach more than 55 thousand housing units, to meet the growing demand on housing, in addition to population growth and rising rates of families in the Kingdom. Amman city ranked first by 20 thousand housing units, followed by Zarqa Governorate with 10 thousand housing units annually. In light of that, there is a need to develop schemes to define and regulate buildings in the Kingdom as an integrated developmental perspective and to set building programs (Department of Statistics, 2006).

Health in the built environment is a complex subject that should be associated with other issues during the design and construction of the building. The architect as a part of design professionals has a main role in easing the transition toward healthy and clean indoor environments, he should advance the quality of indoor environment through selection of building materials, finishes and furniture, ventilation systems, building maintenance, energy efficiency and sustainability as well as the design of the building itself.

Occupants claimed that they have health problems associated with their house conditions, this was based on the observation of the current house conditions in Jordan and on similar case studies and analyses in different locations in the world. Accordingly, this research is about studying and investigating apartment buildings in Jordan and their association with sick building syndrome. Moreover, the study diagnoses the health symptoms caused by bad housing conditions and characterizes the illnesses related to sick building syndrome.

To achieve the aim of this research, the following objectives were targeted; 1. Identifying the term sick building syndrome. 2. Studying apartment conditions. 3. Defining symptoms related to sick building syndrome. To fulfill these objectives, the study used the following methods of inquiry; building attributes and physical analysis, environmental factors and questionnaires. This research was beneficial for decision makers, architects, educators and engineers to create healthy indoor environments and efficient building designs.

LITERATURE REVIEW

Several studies were conducted to investigate the effects of building on occupants' health and indoor environment quality. World Health Organization (WHO) did not provide a standardized method for diagnosing Sick Building Syndrome (SBS), but it summarized common symptoms of sick building syndrome and suggested that the diagnosis of SBS would require a definition of symptom prevalence associated with a particular building.

In the majority of SBS studies, an underlying hypothesis is that SBS has building–related causes. We believe that this hypothesis may prove to be true if it reflects a too simple research model; namely the conventional “dose–response model”. More complex research for SBS was proposed by Jakkola (1998) in his model, which included three conceptual ideas relevant for the cause of IAQ: the physical, physiological/ psychological and social; “mixed cause model” (Hedge, 1992; Erickson, 1995; Rubin, 1996). This research assumed that SBS complaints were influenced by various environmental and non-environmental variables.

To investigate sick building syndrome, a study was conducted between 1971 and 1988 in the United States covering about 446 buildings by The National Institute of Occupational Safety and Health. It concluded that more than half of the problems in the sick buildings were due to inadequate ventilation. In a Danish study, sick building syndrome was defined as one that occurs daily (Burton, 1993). In this study, 2369 office workers in 14 buildings, where indoor climate measurements were made, filled out a questionnaire. Results showed that the concentration of macromolecular organic floor dust, floor covering, number of workplaces in the office, age of the building, type of ventilation and two easily recognizable factors; the shelf factor and the fleece factor, were associated with the prevalence of symptoms (Skov et al., 1990).

In a study held by the Ministry of Environment in Korea on 75 newly built apartments in Seoul, the level of indoor air pollution of all the examined homes exceeded the recommended levels, for example the average density of formaldehyde (used in construction materials) exceeded the standard of 100 microgram by about 360 microgram (Top News on Environment in Asia, Korea Times, 7th of Nov. 2004).

For most indoor air pollution problems in new houses, source control is considered to be the most effective solution. It is usually recommended as the top priority by many indoor air quality management manuals and guidelines .However, the application of source control may not be possible for buildings at the pre-occupancy stage when building materials are already installed. Only limited solutions, such as increasing air changes by natural or mechanical ventilation and cleaning indoor air can be applied (Lee, 1996).

Certain finishing materials act as storage for pollutants like furniture made of foams, acoustical panels and petroleum-based carpets. The offices of the Environmental Protection Agency headquarters in Washington, DC were remodeled in 1987, complaints of eye and nasal irritations, nausea, headaches and skin rashes broadened between occupants. They had to remove 27000 square yards of carpeting. The problem the absolute lowest area in the world (408m below MSL). Figure 1 shows the mean monthly air temperature of Amman, Irbid and Zarqa (Jordan Meteorological Department, 2003).

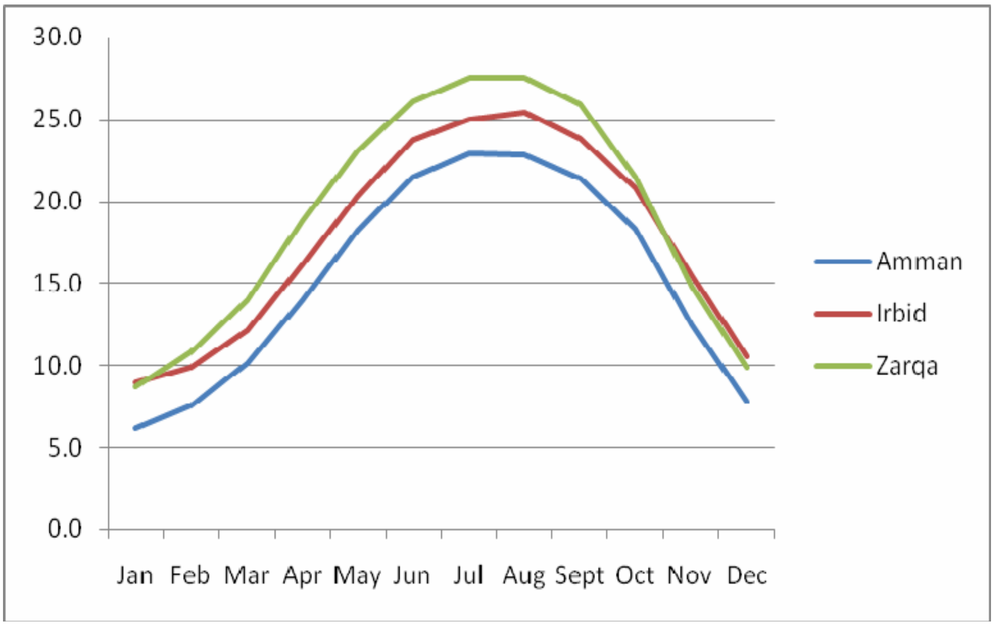


Figure (1): Mean monthly air temperature in Amman, Irbid and Zarqa.

Climate in Jordan is predominantly of the Mediterranean type; hot and dry summer and cool and wet winter with two short transitional periods in autumn and spring. Temperature in summer is about mid- 30ºC and in winter around the 0°C. The rainy season is between October and May. Eighty percent of the annual rainfall occurs through December to March (with an average from 600mm/year in north to less than 50mm/year in south). Rainfall decreases from north to south, west to east and from higher elevations to lower ones (Jordan Meteorological Department, 2003). The gap between maximum actual temperatures and maximum comfortable range (20-23ºC) should be reduced.

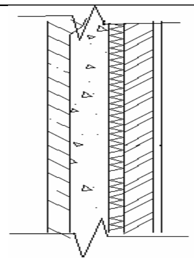
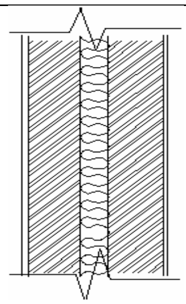
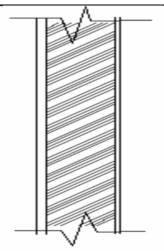
Housing Conditions in Jordan

In Jordan, the annual growth of population is 2.8%. Apartment building has become the most prevalent housing type to meet new demands on housing with rapid urbanization and high population density. A high percent of population lives in apartment buildings especially in high density cities like Amman, Irbid and Zarqa. The records indicated about 118,976 residential apartments with around 6.690 thousand m^2, with a cost of about 755.139 thousand JD. There is a need to 40 thousand apartments every year to cover the residential needs. There are about 112,241 residential apartments in the urban areas to serve about 82.6% of the total population. Number of residential apartment buildings in Amman city is about 65,557 units, 11,065 units exist in Irbid city and 19,678 units exist in Zarqa city (Department of Statistics, 2006).

The average areas of these apartments range from $90m^2$ to $150m^2$, and the personal space (occupation rate) in these apartments is 0.23 person/m^2, depending on the fact that the average household size in Jordan is 2.8 person.

Construction Materials that used in apartment buildings are brick, stone, concrete and insulation with external or internal plaster as shown in Table 1. The properties of materials which affect the rate of heat transfer in and out of a building, and consequently the indoor conditions and comfort of the occupants, are: thermal conductivity, resistance and transmittance, surface characteristics with respect to radiation, absorbability, reflectivity, surface convection coefficient and heat capacity (Giovani, 1981:103).

Table (1): Envelope construction materials used in apartment buildings.

U- Value (W/m^2 C)	Thermal Conductance (W/m.C)	Density (kg/m^3)	Materials	Envelope section	
1.62	1.70	2250	1- Stone		Section type (A)
	1.75	2300	2- Concrete		
	0.04	140	3-Insulation		
	0.90	1400	4- Brick		
1.33	0.90	1400	1- Brick		Section type (B)
	0.28	1.25	2- Insulation		
	0.90	1400	3- Brick		
	1.20	2000	4- plaster		
2.25	0.90	1400	1- Brick		Section type (C)
	1.20	2000	2- Plaster		

DATA COLLECTION

According to the research theme and context, multi methods of data collection were used. These methods were physical analysis, questionnaires and calculations. The sampled apartments were located in Amman, Irbid and Zarqa. These locations represented different climatic regions and urban settings. Fourty apartments were randomly selected in different cities.

Building Attributes and Physical Analysis

The interiors of the apartments were sketched to establish room relationships, ensure some variables (fungal areas, flooring, ceiling situation), investigate whether the design of the building promotes or hinders the occupants' health and provide information to assist us in order to formulate the hypothesis.

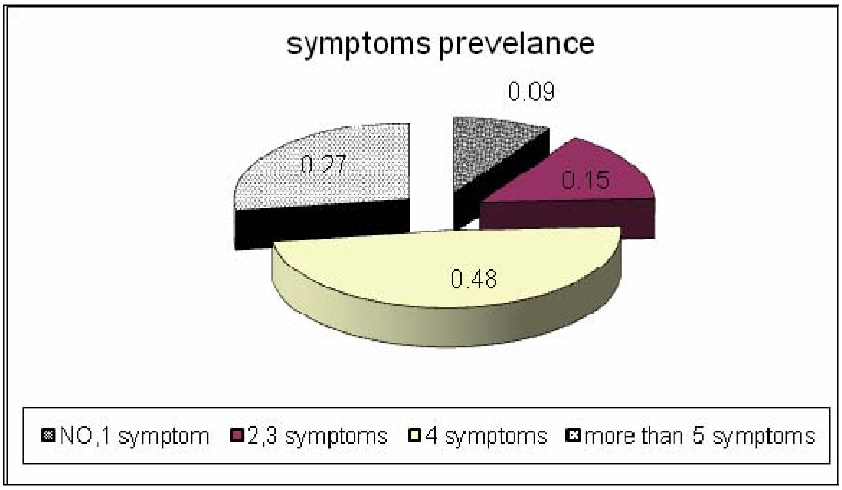


Figure (3): Symptom prevalence among occupants.

Building shape and orientation play a main role in the humidity and temperature values, since they define the high and low pressure areas in the building and its surrounding. Natural forces play an important role in the air movement between exteriors and interiors. In the residential apartments, air moves from lower to upper levels and outdoor air is drawn into the lower levels to replace the air that scrapped.

All natural ventilation methods depend on the movement of air through spaces to equalize pressure and so maintain air quality by dilution or displacement. There are two methods to provide natural ventilation; stack ventilation effect and wind effect. Stack effect depends on the difference between indoor and outdoor temperatures in multi-stories buildings. Air moves from lower levels to replace air that rises up through stairs and elevators. It utilizes the difference in air density and pressure. To equalize outdoor pressure, air enters the building through openings at the wind-ward side and is exhausted through the lee-ward side. Figure 2 shows the plans and photos of selected buildings in Amman, Irbid and Zarqa.

Air exchange (ventilation) can be accommodated through strategically placed windows, doors, roof hatches...etc., so that the space layout, furniture arrangement, and the position of occupants do not block the ventilation system or disrupt the flow of air. There is an inverse relationship between ventilation rate and pollution. Therefore, there is a need to increase wind inlets to provide more air. Windows ratio didn't exceed 20% of the whole apartment's facade. Window size, orientation and type of glass had a major effect on sick building syndrome .Opening rates of the windows during the day had decreased with bad building conditions, like traffic, nearby polluted sources or dusty air; therefore, ventilation of the building in winter times is very important to reduce the risk of sick building syndrome.

Orientation of the building had a major effect on the ventilation air flow inside the unit; moreover, it is associated with direct solar gain into the apartment. Direct sun rays into the building have a major effect in reducing the vapor contents inside the dwellings caused by moisture transmission through the building envelope and/or by the occupants' activities inside the unit, like cooking, water heating, bathing and cleaning.

Questionnaires

The problem of sick building syndrome was first recognized through occupants' complaints that provided information about the way occupants understand the problem. Therefore, the study began with discussions with occupants documenting their complaints to provide a basis for the problem. Each participant was asked to assess his house environmental quality. Some questions used open ended answers while others ended with specific answers to choose from.

The questionnaires held in Irbid, Zarqa and Amman involved questions about environmental risk factors, building information; age, materials, site location, demographic characteristics of occupants; occupancy rate, health symptoms, when and where symptoms prevail and expected reasons for the symptoms.

The initial design of the questionnaire was based on literature by ASHRAE, NIOSH, WHO and Burton questionnaires. It was mainly divided into main sectors that deal with defining problems, when and where complaints occur in addition to demographic data about both buildings and occupants.

Table (2): Symptoms and their possible causes and parameters.

Possible environmental parameters	Possible pollutant	Symptom complex
	HEADACHES, FATIGUE	
Ventilation problems; insufficient fresh air	Carbon dioxide (CO_2)	Drowsiness, shortness of breath
	Carbon monoxide (CO)	Nausea, impaired vision
	VOCs	Respiratory irritation
	SKIN PROBLEMS	
Low relative humidity, warm temperatures, air movement	Glass fibers	Dryness, irritation
	EYE, NOSE AND THROAT IRRITATIONS	
Artificial lights	Nitrogen oxides, formaldehyde	Burning, dry, gritty eye
	Ozone, sulphur dioxide	Coughs
	Formaldehyde	Bleeding nose

To find out if there was building syndrome problems, the frequency of complaints or symptoms of illness was defined. Standards determine the acceptable indoor air quality where there are no known complaints at harmful levels (with which 80% or more of occupants don't express dissatisfaction).

The study included symptoms that could occur like upper respiratory symptoms (sneezing, eye irritation, dry throat, stuffy nose), lower respiratory trace symptoms (cough, wheezing), systemic symptoms (headache, fever, fatigue, nausea). All these symptoms are common in the general population, but the distinguishing feature which makes them part of the sick building syndrome is there temporal relation with a particular building. Table (2) shows the symptoms and their possible pollutants and parameters.

The first target was to estimate the building symptom index (the average number of symptoms per occupant) and the frequency of symptom of illness. As shown in Figure 3, 93% of the occupants suffer from two or more symptoms without knowing the cause. This result existed in all apartments and it was among more than 80% of the occupants. When occupants experienced two or more symptoms of discomfort they perceived a reduction in their performance. This reduction increased as the number of symptoms increased. Seventy five percent suffered from three symptoms or more, and 27% suffered from five symptoms or more.

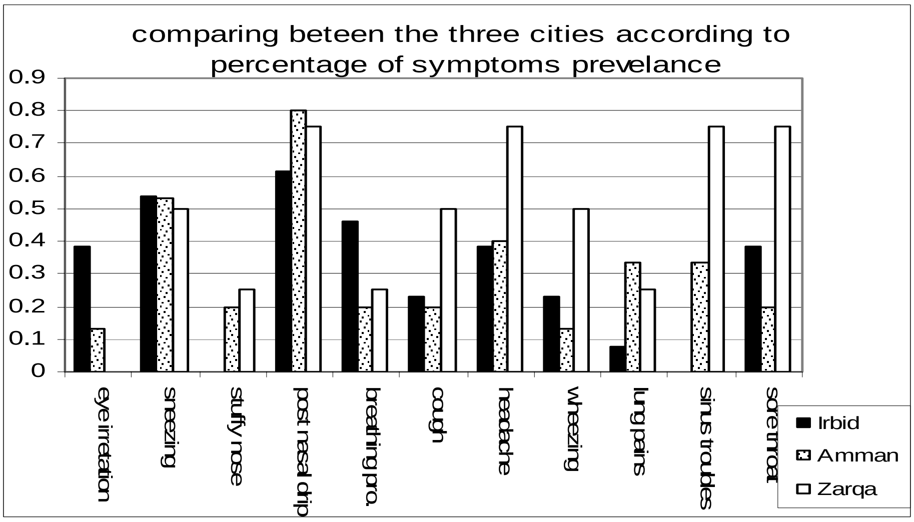


Figure (4): Comparison analysis among the three cities according to type of symptoms.

Table (3): Building products and pollutants.

Possible pollutants	**Building material**
INSULATION	
Resins, polystyrene, hydrocarbons, polyurethane.	Rigid board
VOCs, urea, formaldehyde, asbestos, benzene, acetaldehyde, cresol, phenol	Foamed in place
PAINTS	
Lead, aromatic hydrocarbons, aliphatic hydrocarbon, VOCs	Solvent based
Styrene, vinyl, acrylics	Water based
Urea- and phenol- formaldehyde	Wood products
Formaldehyde, VOC, synthetic fibers, nylon, latex rubber, polyester, micro organism, odor and particulates	Carpeting
Particulate, radon	Concrete
Particulate, radon	Gypsum boards
Radon	Brick
Octane, benzene hexane	Caulking and silicon

A comparative analysis was made in three categories of apartments (Amman, Zarqa and Irbid). The situation in Zarqa was considered the worst case, since about 92% of the occupants suffer from two or more symptoms. This exceeds the comfortable level in all health symptoms. In the second level was the case of Irbid that exceeded 77% of the total sampled occupants.

As shown in Figure 4, headache and postnasal drip were the most prevalent symptoms that about 72% and 43% suffer from, then came sneezing, sinus troubles and sorn throat. As mentioned in literature, the reasons of headache and nasal drip were ventilation problems, insufficient fresh air, temperature and formaldehyde. Symptoms were worse at the beginning of the day because of bad ventilation since windows were shut-off overnight or because of cleaning and maintenance or pollution sources in the bedrooms.

Furniture and finishing used in the apartments are bed-room beds, lockers, chairs, tables… made of wood that produces formaldehyde as a polluting gas, oil-based wall paintings produce VOCs and hydrocarbons, water-based paints, concrete, brick and casual materials produce radon as shown in Table 3.

Fungi appeared in internal building corners because the internal parts of the walls near the corners lose heat through two outside walls, but certain points away from corners lose heat to outside through a single interface, so the temperature of the internal surface is the lowest at the internal corner lines.

Environmental Factors' Calculations

Water coming from the inside of the building reduces fungi, maintains the integrity of construction, decreases heating cost and prevents the creation of unhealthy atmosphere. Water vapor arises from rain, soil, human activities, impeded humidity and sanitation. Impeded humidity arise during the construction stage so that concrete stores humidity inside (within a building with $100m^2$ total area and 20 cm concrete slab, the impeded humidity can reach 5,000 liter of water).

Moisture was affected by the number of occupants using space, so that one person produced an average of about 50 gm/hour because of breathing. The average weight of water vapor in an apartment with 6 occupants (5.6; average household size in Jordan in 2004) can reach 31010 gm/day, due to activities including breathing, heating, cooking, bathing and cleaning (Abu Diieh, 1991).

The national Jordanian code for thermal insulation approved that the internal gained humidity in residential apartments should be 3.4 gm per kilogram of dry air. So the air volume which needs to be thrown away from the apartment and replaced with exterior air reaches $380m^3$/hour ((31010/3.4)/24 hour). In an apartment of (100 m^2 area, 3m height) internal air needs at least one change every hour (($380m^3$/hour)/$300m^3$=1.27 time) to avoid increasing the internal humidity and so fungi areas.

To calculate flow rate through a building due to wind velocity:

$$Q=C4CvAV \qquad (1)$$

where

Cv = effectiveness of openings (assumed to be 0.5-0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds).

A = free area of inlet openings; sq. ft.

V = wind speed, mph(mile per hour).

C4 = unit conversion factor = 88.0.

The worst flow rate was in Zarqa city. Flow rate reached 222.7_{cfm}, in Irbid city the rate was 202.5 $_{cfm}$ and in Amman it was about 192.4 $_{cfm}$. It's important to know that air exchange reduces pollutants' level by replacing the indoor air by outdoor air. But it just works well when the outside air is clean. In an urban area like Irbid, Zarqa and Amman down towns for example it would be an impossible or unbeneficial method.

Source reduction is the ideal method of controlling indoor contaminants, this method is applied where the source is known and a substitute is not required (Issac,1985). But because of cost issues and construction budgets "detail approaches" could be the norm solution rather than "re-design processes". The most effective detail approaches in reducing pollutant sources within a building are through source reduction (selection of materials, finishes and furniture and construction techniques), ventilation and air cleaning. If using cleaning materials is not possible, encapsulation is recommended as a construction technique which eliminates the out-gasing of pollutants into spaces like coating materials with a non -toxic one (Lee, 1996).

Backing out the new materials is a method used to accelerate the material aging process and so reduce the out-gases when the building is occupied. This process involves raising ambient air temperatures while increasing ventilation rates for several days before the building is occupied.

Although it is widely known that using low-emission building materials, finishes and furnishings is the most effective solution for improving indoor air quality, it may not be the possible strategy. Therefore, ventilation and air cleaning seem to be more applicable solutions.

Problems caused by type of ground, climate or polluted area should be avoided. When site conditions permit buildings and major windows should face either north or south direction, so that light and air can be introduced from the two sides to change air several times a day to prevent building up of pollution by open windows, especially in bathrooms and kitchens where humidity is very high (70%). The presence of a plant near the location of the apartment is likely to affect the indoor air quality and so could be a risk factor affecting sick building syndrome. Cleaning habits should be practised in suitable forms to prevent the emission from dust.

Jordan does not have its own standards for acceptable levels in apartment buildings or any type of buildings according to SBS topics, except some numbers which describe contaminant levels, and these numbers didn't take the Jordan specifications into consideration.

CONCLUSIONS AND RECOMMENDATIONS

Indoor environment is a crucial part of the design process; therefore, designers need to change their thinking about this physical environment and increase their awareness of health impact on occupants. Building factors that affect sick building syndrome are high indoor temperatures which enhances fungi, low fresh ventilation which enhances producing biological contaminants, poor individual control of temperatures, poor building service maintenance and poor cleaning or cleaning ability.

When it is impossible to satisfy one hundred percent of a building's occupants, it is possible to alleviate the problem to the satisfaction of the vast majority of users by correctly identifying the cause of the problem instead of focusing on the symptoms. Symptoms, which mostly appear in the morning, are materialized in all study buildings with a ratio greater than 80%. Headache and postnasal drip were the most prevalent symptoms that about 72% and 43% suffer from. Buildings in Zarqa are the worst among buildings that have been considered in the study, about 27% of the occupants in the study describe the ventilation rate in their apartments as very bad. Even the calculation gives that the flow rate reached 222.7_{cfm}.

The term sick building syndrome is used to describe a condition where the cause and mechanism of action are still not completely known. So, sick building syndrome should be part of our scientific cultural vocabulary, further researches and investigations are needed in Jordan to demonstrate the causes of SBS and its risk factors like individual differences, tobacco smoking and psychological factors.

The findings revealed that there was a significant difference among geographical locations of apartment buildings in Jordan. Zarqa has the most severe condition because of the crowdness in the urban settings and the extreme weather conditions. Moreover, building physical configurations and attributes such as window size and type, envelope design, location of the apartment in the building, orientation and building layout have a significant effect on the concept of the sick building syndrome. Just about 25% of the sampled apartments in Zarq city considered the ratio of openings to be enough, and no one was satisfied with the ventilation rate. The ratio of occupants who considered the ratio of openings as enough in Irbid city was about 38%, but even just about 15% of the occupants were satisfied with the ventilation rate.

Apartments which were used rarely achieved appropriate human health or comfort needs. It is recommended that building materials, design and construction, in addition to the way of living should be improved. Although we may be at higher risk in relation to environmental conditions than ever before, much can be done in the design and management of our homes. Effective maintenance should be ensured by standards and codes.

Symptoms tend to appear at the beginning of the day. 81% of the occupants connect the symptom appearance with weather changes. It was found that sick building syndrome was a major cause of a series of diseases such as upper, lower, skin and systematic symptoms. These symptoms go quickly as leaving the building. They result from the way in which the building is designed and constructed or from the way it is operated, maintained and used or because of insufficient ventilation strategies or wrong material selection which directly affect residents' health and comfort. This factor should be considered in the early phase of design to improve the health conditions in residential buildings in Jordan and multi-family housings (apartments) in particular.

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