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Indoor Air Quality and Adverse Health Effects

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Abstract: The association between Indoor Air Quality (IAQ) and adverse health effects was studied. Sick Building Syndrome (SBS) phenomenon is a collection of health problems caused by indoor pollution.The indoor concentrations of PM_{10} in the living rooms were measured at two multistory residential buildings during summer 2010 in the Damietta City, Egypt. Information on possible particle sources and SBS outcomes were obtained from questionnaires. The concentrations of PM_{10} varied significantly. The concentrations of PM_{10} may be affected by the surrounded traffic density. In addition to tobacco smoking, household cleaning was the predominant indoor activity associated with increased concentrations of PM_{10} within a home. The main SBS symptoms prevailed on different floors of the study sites based on occupant's response in the questionnaire were tiredness, fatigue, or drowsiness; followed by headache; and runny nose, or sinus congestion.The linear relationship between PM_{10} concentration and SBS score showed that PM_{10} might be categorized as an 'indicator' of IAQ, indicating likely presence of indoor air pollutants. Mean SBS symptoms per person ranged between 1.2 and 4.7 for occupants in the age groups of < 10 and ≥ 60 respectively. Females showed more SBS symptoms (2.5) as compared to males (2.0) on all the floors. Questionnaire was also incorporating questions to evaluate the awareness of occupants towards indoor environmental conditions. In all 35% of the occupants were aware of indoor air pollution, 60% were not but they showed concern to know about it and 5% was completely ignorant to it, indicating the need for awareness programmes by concerned authorities as human spend most of their daily life indoors.

Key words: IAQ · SBS · PM_{10} · Questionnaire · Age · Gender · Awareness

INTRODUCTION

The association between indoor air quality (IAQ) and adverse health effects is now well established. Sick building syndrome (SBS) was first recognized by the World Health Organization as a medical condition [1]. It is a collection of health problems caused by indoor chemical and biological pollution, uncomfortable temperature and humidity, or other factors in buildings [2]. SBS is characterized by a variety of nonspecific subjective symptoms, including irritation of the eyes, blocked nose and throat, headache, dry skin, fatigue, sinus congestion, skin rash, irritation and nausea [3-5].

Many studies have shown the association between indoor air pollution and adverse health effects in developed and developing countries [6, 7]. A number of epidemiologic studies have been attributed symptoms characteristic of SBS to the physical indoor environment, especially poor indoor air quality [4, 8]. The association between questionnaire-based responses to SBS symptoms and measured indoor exposures in homes has been investigated [9-14].

Indoor air pollution may pose greater exposure than outdoor air pollution as people spend the majority of their time indoors where dispersion of pollutants may be poor [15, 16]. Certain population groups such as seniors, elderly and children are most susceptible to particle pollution. Generally, women report more SBS than men [17-21]. However, it has not been clear whether this is due to biological differences, or work and life-style differences. In a study in England, it was suggested that women reported more symptoms than men did because they typically work in less favorable physical and psychosocial conditions [22]. However, a German study

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demonstrated that the gender difference in SBS-prevalence cannot be explained by different working conditions, different job characteristics and the indicated demographic and psycho-social factors in general [18].

Many studies have found that the concentrations of suspended particulate matter are higher indoors than outdoors [23, 24]. Cooking [25, 26], smoking [26, 27] and indoor combustion sources [28] are the predominant activities associated with elevated concentrations of the indoor particulate levels. In addition to cooking and smoking, indoor particle concentrations also depend on housekeeping activities such as sweeping and vacuuming [26, 29].

This study attempted to provide more information about the association between IAQ and the health effects. The indoor PM_{10} concentrations were measured and possible particle sources and SBS outcomes were obtained from questionnaires.

MATERIALS AND METHODS

Study Area: The study was conducted at Damietta City, the capital of Damietta governorate, which is located northeast of Cairo on the eastern branch of the Nile and is surrounded by The Mediterranean Sea to the North. Two multistory residential buildings, building (A) and building (B) were recruited for the study. Each ofthem has four floors and therefore has four sampling sites. The building (A) is located at high traffic density area and their sampling sites were designated as A1-A4, while the building (B) is located at relatively low traffic density area and their sampling sites were designated as B1-B4.

Study Design: The indoor concentrations of PM_{10} in the living rooms were measured at each floor of the two multistory residential buildings during summer 2010. Since most households had young children, homes were typically occupied throughout the sampling period. Inlets for the indoor samplers were placed at breathing level for a typical adult. The residents have been instructed to keep the windows closed two hours before the measurements. The doors were opened only for entering or leaving the room. Nobody was present during the measurements and the door of the room was kept close.

Information on possible particle sources and SBS outcomes were obtained from questionnaires. The questionnaire also included queries about age, gender, number of persons living in the home, time spent in cooking place, smoking and the occurrence of dust inside the home. If the participants were too young or old to read or write, another family member answered the questionnaires on their behalf. Participation in the study was voluntary.

Environmental Sampling of PM_{10}: Indoor sampling of PM_{10} was carried out for 8-h duration. Indoor samplers were placed in the middle of the living room approximately 1.5m above the floor. The sampling equipment was housed such that it was as compact as possible and positioned indoors to cause minimal intrusion to the occupants. PM_{10} concentrations were measured using the filtration method [30]. Particles were collected on Whitmann 47 mm Teflon filters with 2µm pores size. Filters were weighed in temperature and relative humidity control. Weighing methods are detailed elsewhere [31]. All samples were collected in duplicate. Field blanks were used and analyzed simultaneously with the exposed samples for quality control during the study.

Particle Sources: Information on possible particle sources was derived from questionnaires. Data from completed questionnaires comprised information on smoking behavior of the parents and housing conditions. Indoor PM_{10} sources were mainly cooking, smoking and cleaning activities.

The SBS Score: Questionnaire data were used to assess the occurrence of SBS outcomes. The SBS score is an integrated index which indicated directly the number of different types of SBS symptoms that were analyzed on a scale of 0-6 [5]. It was also used by Gupta *et al*. [14] and Seppanen and Jaakkola [32]. The six main symptoms of the SBS driven from questionnaire are itching or irritated eyes; headache; sore or dry throat; unusual tiredness, fatigue, or drowsiness; stuffy or runny nose, or sinus congestion; and dry or itchy skin. The answers might be always, sometimes, or never. They were assigned the scores of 1.0, 0.5 and 0, respectively. Always symptoms were defined as occurring 3 times or more per week and sometimes symptoms as occurring once or twice per week [14].

Statistical Analysis: All analyses were performed using SPSS, v. 17.0 (SPSS, Inc., Chicago, IL).The descriptive statistics (i.e. arithmetic means, standard deviations, maxima and minima) were used to present the data. Linear regression was performed to determine the relationships between PM_{10} concentration and SBS score. In analysing the SBS symptoms, chi square test and student's t test were used.

RESULTS AND DISCUSSION

The Study Population: The study population comprised 37 participants. The basic description of the study population including interviewer information and particle sources was given in table 1. The average age of participants was 25.6 years (range 2-80). More than half of the participants (54%) were aged less than 19 years. Overall, they comprised 62.2% females and 37.8% males. About 37.5% of homes occupied by number of persons between 1 and 4 persons whilst a 62.5% of them have 5 or more occupants. Approximately 37.5% of the subjects smoked.

Questionnaire Derived PM_{10} Sources: Table 1 listed the potential sources of indoor particles according to questionnaire evaluation. Almost 37.5% of subjects were exposed to smoke inside. Half of the women spent between 1 and 2 h in the cooking place whilst 37.5% of them spent 3 hours and 12.5% spent 4 hours or more in this location, although cooking was not always taking place. Approximately half of the women reported a lot of dust inside. Gas was the fuel used at building (A), while LPG was the fuel used at building (B). The homes of building (A) were located in a street with traffic density higher than that of building (B). Therefore, traffic may affect the indoor sources of PM_{10}.

Table 1: The basic description of the study population

Factor	Category	% N
Age	< 10	37.8
	10- 19	16.2
	20-29	5.4
	30-39	13.5
	40-49	10.8
	50-59	8.1
	≥ 60	8.1
Gender	Female	62.2
	Male	37.8
Persons number in a home	≤ 2	12.5
	3	12.5
	4	12.5
	≥ 5	62.5
Time spent in cooking place	1 hr	25.0
	2 hrs	25.0
	3 hrs	37.5
	4 hrs	12.5
Smoking	Yes Daily	37.5
	No or rarely	62.5
Dust inside a home	Always	50
	Sometimes	37.5
	Never a lot	12.5

Table 2: The descriptive statistics of the measured indoor concentrations of PM_{10}

Mean	SD	Max	Min	Median
793.0	131.0	992.3	605.6	801.9

Indoor Measurements of PM_{10}: The descriptive statistics of the measured indoor concentrations of PM_{10} were shown in table 2. The median concentration of PM_{10} was 801.9 µg/m^3 whereas the mean concentration of PM_{10} was 793.0 µg/m^3. The maximum concentration of PM_{10} was 992.3 µg/m^3 measured at A2 while the minimum concentration of PM_{10} was 605.6 µg/m^3 measured at B1. The standard deviation was 131.0 µg/m^3.

The indoor concentrations of PM_{10} measured in the living rooms at each floor of the two multistory residential buildings were presented in Fig. 1. The concentrations of PM_{10} varied significantly. As shown in Fig. 1, the indoor concentrations of PM_{10} at building (A) were slightly higher than that at building (B). The concentrations of PM_{10} may be affected by the surrounded traffic density. El-Batrawy [31] reported that the concentrations of PM_{10} are higher in areas with higher traffic density.

In homes where people smoke as A2, B2 and B3, the mean indoor levels of PM_{10} recorded were higher than those measured in homes with no smokers. In addition to tobacco smoking, household cleaning was the predominant indoor activity associated with increased concentrations of PM_{10} within a home. It was found that higher levels of PM_{10} recorded in the living areas of homes were probably associated with the infrequent housekeeping. Lee *et al*. [33] reported thatthe average indoor levels of homes with and without smokers were 155 and 148 µg/m^3, respectively.

The Sick Building Syndrome: Fig. 1 presented the SBS score at each floor of the two multistory residential buildings based on occupant's response in the questionnaire. The B1 was having maximum SBS score (4.75) while A2 and B3 were having minimum (1.90). It implied that occupants of the first floor of the building (B) were having, on an average, four SBS symptoms out of six that creating an unhealthy indoor environment. Gupta *et al*. [14] studied the SBS at a multistory building in India and found maximum SBS score of 3.01 as compared to the control tower (0.97).

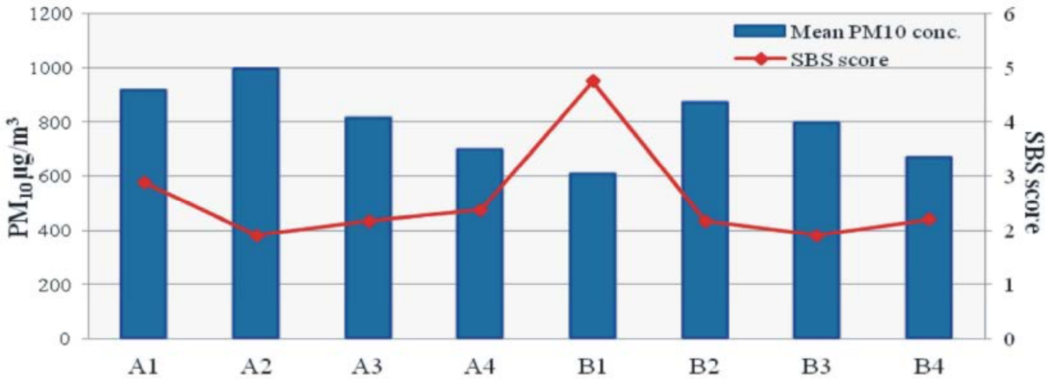

Fig. 1: The measured indoor PM_{10} concentration and corresponding SBS score at each floor of the two multistory residential buildings based on occupant's response in the questionnaire.

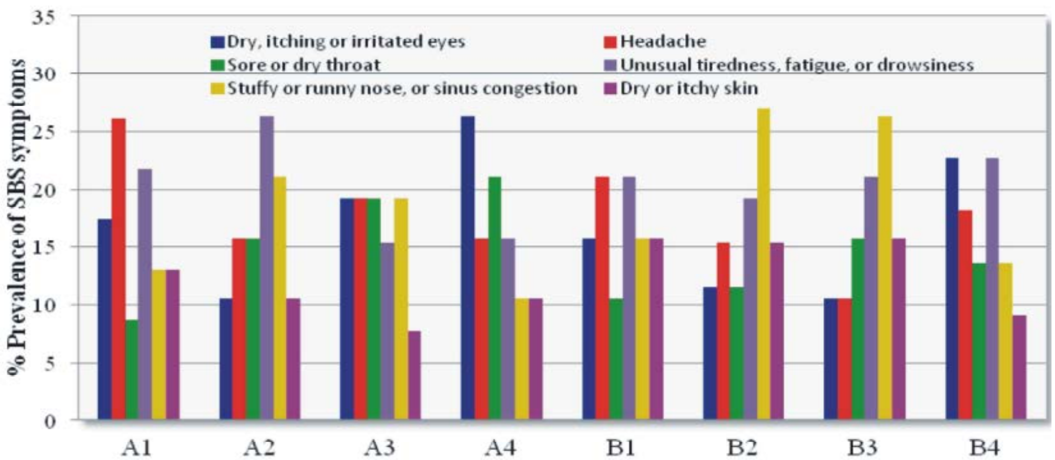

Fig. 2: The prevalence of SBS symptoms at each floor of the two multistory residential buildings.

The prevalence of various SBS symptoms on different floors of the study sites based on occupant's response in the questionnaire was presented at Fig. 2. The main SBS symptoms prevailed were tiredness, fatigue, or drowsiness; followed by headache; and runny nose, or sinus congestion. Dry, itching or irritated eyes symptom was prevailed at A4 and B4. Headache was prevailed at A1 and B1. Unusual tiredness, fatigue, or drowsiness was prevailed at A2, B1 and B4. Stuffy or runny nose, or sinus congestion was prevailed at B2 and B3. Both sore or dry throat and dry or itchy skin symptoms were not common at any sampling sites. Gupta *et al*. [14] concluded that the main symptoms prevailing at a multistory building in India were headache (51%) and tiredness (50%).

Sun *et al*. [17] carried out a study of dorm environment and college students' health in China and found that one out of three students reported general SBS symptoms and one out of four reported mucosal or skin problems. Takigawa *et al*. [9] reported the prevalence of SBS to be about 15% of the studied population. Bachmann and Myers [34] investigated the influences of SBS symptoms and reported that eye symptoms, dry skin and sneezing are relatively common in all buildings, whereas lower respiratory tract symptoms, facial and hand rashes, dizziness and nausea are all relatively uncommon.

The prevalence's of specific symptoms were compared using student's t test and chi square test. The results of t test (Sig. (2-tailed) = 0.737) indicated that there is no differences of IAQ of the both studied buildings. The results of chi square test (x^2= 8.222) showed that the prevalence of specific symptoms are not similar in each of the two buildings. Therefore, this may indicate that there is no direct influence of PM_{10} sources on the presence of SBS symptoms in both buildings.

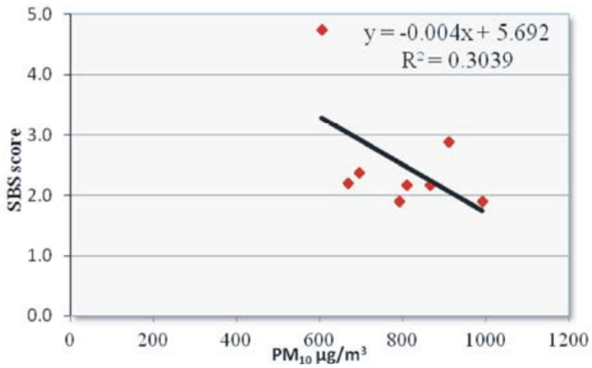

Fig. 3: The correlations between indoor concentrations of PM_{10} and SBS score.

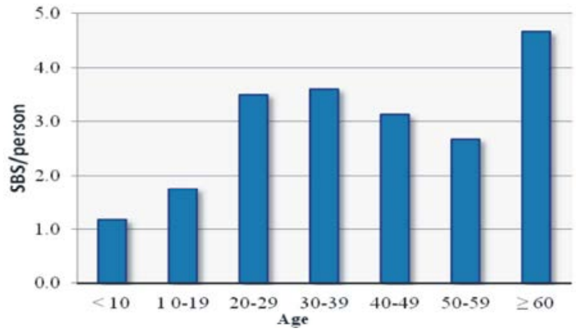

Fig. 4: Association between age and mean SBS per person.

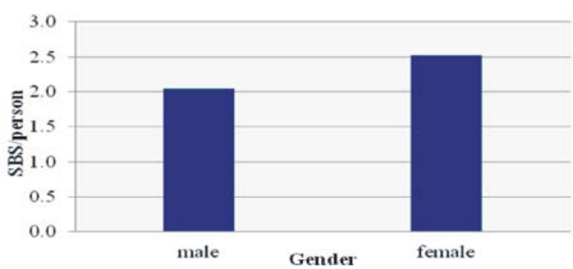

Fig. 5: Association between gender and mean SBS per person.

Correlation between PM_{10} Concentration and Corresponding SBS Score: Fig. 3 showed a linear relationship between PM_{10} concentration and SBS score (R^2 = 0.3039), which showed less correlation between them. This implied that PM_{10} was not the only influencing parameter affecting the SBS score in the studied buildings. However, the linear relationship between PM_{10} concentration and SBS score showed that PM_{10} might be categorized as an 'indicator' of IAQ, indicating likely p resence of indoor air pollutants. Gupta *et al*. [14] found good correlation between PM_{10} concentration and SBS score (R^2 = 0.9499); the higher the PM_{10} concentration, the more the SBS score.

Association between Age and Mean SBS Symptoms per Person: The distribution of mean SBS symptoms per person over age groups on the two buildings was described in Fig. 4. Mean SBS symptoms per person ranged between 1.2 and 4.7 for occupants in the age groups of < 10 and ≥ 60 respectively. It was maximum for occupants in the age groups of ≥ 60 indicated that they might be having chronic health problems. Occupants in the age groups of 20-49 were more susceptible to SBS symptoms as compared to the occupants in the age group of and 50-59. Gupta *et al.* [14] found that occupants in the age group of 20-29 were more susceptible to SBS symptoms as compared to the occupants in the age group of 50-59.

Association between Gender and Mean SBS Symptoms per Person: Females were more susceptible to SBS symptoms than males (Fig. 5). Females showed more SBS symptoms (2.5) as compared to males (2.0) on all the floors. It showed that female gender is more sensitive to SBS symptoms than male, thus needing a lesser dose of pollutants to response to the sick building symptoms.

Previous investigations carried out in different countries reported that females are more susceptible to SBS symptoms than males. In China, Sun *et al*. [17] found that female students reported 1.12-1.31 times more SBS than male students. Zhang *et al*. [35] found the relative risk for SBS symptoms is 0.85-1.02 for girls compared to boys. Gupta *et al.* [14] found that females are showing 50% more SBS symptoms as compared to males on all the floors. In European studies, women have reported 2-3 times more SBS symptoms than men [18, 20, 36].

The Awareness of Occupants Towards IAQ: Questionnaire was also incorporating questions to evaluate the awareness of occupants towards indoor air quality. In all 35% of the occupants were aware of indoor air pollution whereas 60% were not but they showed concern to know about it and a small portion i.e. of 5% was completely ignorant to it, indicating the need for awareness programmes by concerned authorities as human spend most of their daily life indoors.

CONCULSION

The association between IAQ and the Sick Building Syndrome (SBS) phenomenon was investigated. The main SBS symptoms prevailing were tiredness, fatigue, or drowsiness followed by headache and runny nose, or sinus congestion.There are no differences of IAQ of both studied urban and suburban areas. Therefore, this may indicate that there is no direct influence of PM_{10} sources on the presence of SBS symptoms in both buildings. Less correlation between PM_{10} concentrations and SBS score implies that PM_{10} is not the only influencing parameter affecting the SBS score in a building. SBS score was maximum for occupants in the age groups of ≥ 60 indicated that they might be having chronic health problems. Females showed more SBS symptoms as compared to males on all the floors.There is a need for awareness programmes of indoor air quality as human spend most of their daily life indoors.

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