Original Article

Indoor Air Quality and Sick Building Syndrome among Caretakers in Childcare Centers

Sudkhed Detpetukyon[1,2], Nutta Taneepanichskul[1,3]

[1]College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand, [2]Department of Health,Ministry of Public Health, Nonthaburi, Thailand, [1]College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand, [3]HAUS IAQ Research Unit, Department of Pediatrics, Faculty of Medicine, Chulalongkorn University King Chulalongkorn Memorial Hospital, Bangkok, Thailand.

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Abstract

Sick Building Syndrome (SBS) refers to the health-related symptoms of exposure to an unhealthy microenvironment, especially poor indoor air quality This study investigated the associations of indoor air quality including particulate matter (PM10 and PM2 5), Carbon Dioxide (CO2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOCs), and childcare center environment with SBS symptoms among caretakers. SBS was assessed using a self-reported questionnaire The prevalence of SBS was 77 78% among caretakers PM10 negatively correlated with CO2 (r=0 -558; p<0 01) PM10 levels were associated with any reported symptoms of SBS (OR=7 38; 95%CI 1 98 - 27 53), and upper respiratory symptoms (OR= 12 00; 95%CI 1 46 – 98 08) PM2 5 showed no association with SBS Using air refresher was associated with upper respiratory symptoms (OR=5 10; 95%CI 1 46 – 13 59), lower respiratory symptoms (OR=3 64; ; 95%CI 1.22 - 10.82).

Keywords: Childcare center, Indoor air quality, Sick building syndrome, Caretaker

Introduction

The World Health Organization (WHO) reported that indoor air pollution can cause the deaths of 3.8 million people annually.[1] especially, developing countries which suffered from the largest effect of air pollution. Nonetheless, few studies reported on health impacts of indoor air pollution in Asian developing countries.[2] Approximately, 2.2 million of Asian people have been affected due to air pollution[3], Thailand was reported about 50,000 fatalities caused by air pollution[4].

In many areas of Thailand was reported that the air quality was worse than its standards, especially in urban areas [5]. Not only the particle matters [6, 7] but also Volatile Organic Compounds (VOCs) were considered as air pollution problem in Thailand.[8] Moreover, some studies found that air pollution was related to hospital admission.[9, 10] Furthermore,

Corresponding Author: Sudkhed Detpetukyon, College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand .

E-mail: mr.sudkhed@gmail.com

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numerous studies linked indoor air pollution to Sick Building Syndrome (SBS).[11-13] Up to 88 percent of people reported their illness because of building' air quality.[14] In addition, a study was revealed a prevalence of SBS of about 76.9% among preschool children in Shanghai .[15]

However, there are very little research on sick building syndrome in Thailand. This study investigated the associations of indoor air quality including particulate matter (PM_{10} and $PM_{2.5}$), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOCs), and childcare center environment with SBS symptoms among caretakers. The aim of this study was to investigate the associations of indoor air quality including particulate matter (PM_{10} and $PM_{2.5}$), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOCs), and childcare center environment with SBS symptoms among caretakers.

Materials and methods

Study design

A cross-sectional study was conducted in November – December 2020 to investigate the relationships between indoor air quality and childcare center environment with SBS symptoms among caretakers. 10 public childcare centers in central regions of Thailand were invited to participate in the study. Before collecting the data, an online meeting was held to explain the procedure of data collection and answer to related questions. The dates were scheduled after getting confirmation from the head of public childcare centers. In each childcare center, all caretakers were invited to participate. From 10 centers, 81 caretakers including teachers, health volunteers, and practical nurses were recruited. The data collection was separated into 2 parts : self-reported questionnaire from caretakers, and indoor air quality measurement. This study was conducted in accordance with the Declaration of Helsinki guidelines and approved by The Research Ethics Review Committee for Research Involving Human Research Participants Chulalongkorn University Thailand (COA No. 133/2564). All respondents read and sign the consent form before participating.

Questionnaire

81 caretakers in 10 childcare centers completed the self-reported questionnaire. The questionnaire consists of 3 parts: demographic of caretaker, working environment, and SBS. The demographic of caretakers included age (<40 and >= 40 years), gender (male and female), body mass index (normal and abnormal), smoking (yes and no), underlying disease including asthma (yes and no), and working hour per day (>8 and <=8 hours). Body mass index (BMI) was calculated by a person's weight in kilograms divided by height in meters squared. The normal BMI ranged between 18.5 – 24.9 kg/m2. The working environment was also collected by self-reported from caretakers. Presence of carpet (yes/no), presence of printer (yes/no), presence of xerox machine (yes/no), applying air refresher (yes/no), and applying mosquito repellent (yes/no) were asked.

Sick Building Syndrome (SBS) was reported by caretakers. The definition of SBS was informed before the questionnaire was distributed. The evaluation questions for SBS symptoms were developed from Gary's questionnaire[16] and translated into Thai language. Translate and back-translate were performed. SBS consisted of 4 sub-categories: general symptoms(7 symptoms), upper respiratory symptoms (4 symptoms), lower respiratory symptoms (3 symptoms), and skin symptoms (3 symptoms). General Symptoms consisted Headache, Unusual tiredness, Tension, Difficulty in concentrating or remembering things, Dizziness, Feeling depressed, and Nausea. Upper respiratory symptoms included Sore or dry throat, Sinus congestion, Coughing, and Sneezing. Lower respiratory symptoms were Wheezing, Chest tightness, and Shortness of breath. Skin symptoms were Dryness, Itching, and Irritation of the skin. The analyses of outcomes defined as symptoms experienced in the childcare center and improved when leave the childcare center at least 1 day per week in the last 4 weeks.

Indoor air parameter measurement

Indoor air pollution was analyzed in each childcare center according to indoor air quality guidelines of Bureau of Environmental Health, Thailand[17]. The instruments and methods that used to assess including particulate matter (PM), Carbon

Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOCs), Total Fungal Count, Total Bacteria Count were shown in Table 1.

The assessment of PM_{10},$PM_{2.5}$,CO_2,CO,TVOCs was conducted for eight hours as working duration of caretakers. Two sampling points of Total Fungal Count and Total Bacterial Count Total Fungal Count and Total Bacterial Count were considered the position of respondents (middle of the room) and far from doors or windows. After collection, the samples for Total Fungal Count and Total Bacterial Count were stored in a cooler box at approximately 4 °C before being transported to the laboratory of the College of Public Health Sciences at Chulalongkorn University.

Statistical analysis

The relationship between general characteristics and sick-building syndrome was evaluated using data from 81 childcare takers in 10 childcare centers who self-reported their characteristics. The categorical variables were reported as a percentage of frequency. The continuous variables were presented in the range of data with the standard deviation (SD) for parametric data and the median value for nonparametric data.

All statistical analyses were performed using the Statistical Package for the Social Sciences for Windows (SPSS) version 28. Spearman's correlation was utilized to determine the relationship between two air pollution parameters as the rank values of the variables. The correlation coefficient was classified as 5 levels including negligible correlation, weak correlation, moderate correlation, strong correlation, and very strong correlation. [18,19] The linear regression was determined for each factor associated with SBS. Throughout the statistical analysis, a p-value of 0.05 was used to identify the significance of all tests.

Results

The prevalence of sick-building syndrome among childcare workers in the central region of Thailand was 77.78% of participants as shown in Table 2SBS symptoms were divided into four categories: general symptoms (72.84%), upper respiratory symptoms (45.68%), lower respiratory symptoms (22.22%), and skin symptoms (23.46%). The body mass index (BMI) as demographic characteristic was found significant relationship with SBS symptoms($p < 0.05$)

The relationship between indoor concentrations of two factors was shown in, Table 3. $PM_{2.5}$ was found significantly strong correlated with PM_{10}. TVOC was found moderate significantly correlated with relative humidity and temperature, meanwhile a significant negative correlation with CO_2 and CO. PM_{10} has a strong correlation with TVOC but showed negatively correlated with CO_2, and CO. A strong negative correlation was found between CO_2 with TVOC and Relative Humidity. In addition, CO was showed a weak negative correlation with temperature. While, a moderate correlation between TVOC and temperature was reported, there was a strong correlation between TVOC and relative humidity.

Table 4 shows the association between indoor air pollutions and SBS symptoms among childcare workers. Any Symptoms were associated with PM_{10} levels (OR 7.38, CI 1.98 - 27.53). According to the General Symptoms, PM_{10} was also associated with OR 5.04 (CI 1.398–18.169). While, Upper Respiratory Symptoms were associated to PM_{10} levels(OR 12.00, CI 1.46 - 98.08). On the other hand, CO_2 levels were found to lower the risk of SBS symptoms since the percentage of any symptoms, general symptoms, and upper respiratory symptoms among childcare workers by 87, 81, and 92 percent were lower than the median, respectively workers. Finally, Table 5 showed the association between the workplace environment and SBS. This present study found that room air fresheners could affect upper respiratory symptoms (OR 5.10, CI 1.92 - 13.59), lower respiratory symptoms (OR 3.64 ;95% CI 1.22 - 10.82), and skin symptoms(OR 8.05;CI 2.50 - 25.91).

Table 1 Sampling methods and measuring instruments for indoor air pollution analyzes

Indoor air pollution	Instrument's	Sensor	Accuracy
PM_{10}	Met One Aerocet -531S	Laser Diode	± 10%
$PM_{2.5}$	Met One Aerocet -531S	Laser Diode	± 10%
CO_2	AQ expert	NDIR	±2% Rdg. ±10 ppm
CO	AQ expert	NDIR	±1 ppm Rdg. ±0.2 ppm
TVOCs	AQ expert	PID	10 % Rdg. ± 20 ppb

Table 2: Self-reported Sick-Building Syndrome of childcare takers by demographic characteristic

Variable	Total (n=81)	Any Symptoms (77.78%)		General Symptoms (72.84%)		Upper Respiratory Symptoms (45.68%)		Lower Respiratory Symptoms (22.22%)		Skin Symptoms (23.46%)	
	n=81	n= 63	p-value	n=59	p-value	n=37	p-value	n=18	p-value	n=19	p-value
Age											
< 40 years	36	29	0.591	27	0.696	17	0.803	7	0.591	10	0.412
>= 40 years	45	34		32		20		11		9	
Gender											
Female	79	62	0.339	58	0.462	36	0.901	18	0.603[a]	18	0.370
Male	2	1		1		1		0		1	
Body Mass Index											
Normal	44	29	0.561	27	0.590	25	0.043*	6	0.289	6	0.194
Abnormal	37	34		32		12		12		13	
Smoking											
Yes	1	0	0.222[a]	0	0.272[a]	0	0.543[a]	0	0.778[a]	0	0.765[a]
No	80	63		59		37		18		19	
Underlying Disease											
Yes	64	14	0.610	13	0.770	7	0.675	6	0.190	6	0.195
No	17	49		46		30		12		13	
Working hour per day											
<=8	24	19	0.845	18	0.777	12	0.612	6	0.696	7	0.431
>8	57	44		41		25		12		12	

[a] Fisher's exact test, * Significance level with p-value < 0.05

Table 3: Concentration of indoor air pollution

	Total (N=19)		Spearman Rank Correlation					
	Mean	SD	PM_{10}	CO_2	CO	TVOC	Temperature	Relative Humidity
$PM_{2.5}(ug/m^3)$	13.15	6.06	0.803**	-0.842**	-0.260*	0.871**	0.511**	0.692**
$PM_{10}(ug/m^3)$	99.44	46.72		-0.558**	-0.180	0.741**	0.017	0.574**
CO_2 (ppb)	634.86	269.30			0.102	-.837**	-.543**	-.786**
CO (ppm)	0.28	0.54				0.170	-.293**	0.203
TVOC (ppm)	0.32	0.28					.413**	.726**
Temperature (°C)	26.57	2.27						0.176
Relative Humidity (%)	49.69	8.03						1.000

**Significance level with p-value < 0.01

Table 4 Percentage of indoor air pollution comparing with those medians correlated with SBS symptoms (n=81)

SBS symptom group	n(%) of caretakers reporting symptoms	$PM_{2.5}$			PM_{10}			CO_2		
		<=Median	>Median	OR (95%CI)	<=Median	>Median	OR (95%CI)	<=Median	>Median	OR (95%CI)
		n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Any SBS Symptoms	63 (77.78)	56 (88.89)	7(11.11)	1.00 (0.189-5.295)	5 (7.94)	58 (92.06)	7.38 (1.98 - 27.53) *	58(92.06)	5 (7.94)	0.13 (0.036 - 0505) *
General Symptoms	59 (64.20)	52 (88.14)	7 (11.86)	1.34 (0.258 - 7.037)	5 (8.4)	54 (91.53)	5.04 (1.398 - 18.169) *	54 (91.53)	5(8.47)	0.19 (0.055 - 0.715) *
Upper Respiratory Symptoms	37 (45.68)	32(86.49)	5(13.51)	1.56 (0.387 - 6.302)	1 (2.70)	36 (97.30)	12.00 (1.46 - 98.08) *	36 (97.30)	1 (2.70)	0.08 (0.010 - 0.681) *
Lower Respiratory Symptoms	18(22.22)	15 (83.33)	3 (16.67)	1.90 (0.425 - 8.499)	0	18(100)	N/A	18 (100)	0	N/A
Skin Symptoms	19(23.46)	15(78.95)	4(21.05)	3.04 (0.726 - 12.735)	0	19(100)	N/A	19 (100)	0	N/A

Table 5 Relationship between workplace environment and symptoms of SBS

SBS Symptom Group	n(%) of caretakers reporting symptoms	Carpet		Printer		Xerox machine		Air refresher		Mosquito repellent	
		Yes	OR (95%CI)	Yes	OR (95%CI)	Yes	OR (95%CI)	Yes	OR (95%CI)	Yes	OR (95%CI)
		n (%)		n (%)		n (%)		n (%)		n (%)	
Any Symptoms	63 (77.78)	7 (11.11)	2.12 (0.24-18.50)	39 (61.90)	1.62 (0.57 - 4.67)	35 (55.56)	1.56 (0.54 - 4.48)	38 (60.32)	1.71 (0.53- 5.39)	29 (46.03)	1.71 (0.57 - 5.12)
General Symptoms	59 (72.84)	6 (10.17)	1.13 (0.21 - 6.08)	35 (59.32)	1.01 (0.37 - 2.73)	31 (52.54)	0.92 (0.35 - 2.46)	36 (61.02)	1.37 (0.48 - 3.87)	28 (47.46)	1.94 (0.69 - 5.43)
Upper Respiratory Symptoms	37 (45.68)	5 (13.51)	2.13 (0.47 - 9.61)	21 (56.76)	0.83 (0.34 - 2.01)	20 (54.05)	1.07 (0.45 - 2.58)	21 (56.76)	5.10 (1.92 - 13.59) *	21 (56.76)	2.81 (1.13 - 6.98)
Lower Respiratory Symptoms	18 (22.22)	2 (11.11)	1.19 (0.22 - 6.46)	12 (66.67)	1.50 (0.05 - 4.50)	11 (61.11)	1.52 (0.52 - 4.43)	13 (72.22)	3.64 (1.22 - 10.82) *	8 (44.44)	1.07 (0.37 - 3.06)
Skin Symptoms	19 (23.46)	3 (15.79)	2.14 (0.46 - 9.92)	12 (63.16)	1.24 (0.43 - 3.57)	13 (68.42)	2.31 (0.78 - 6.86)	13 (68.42)	8.05 (2.50 - 25.91) *	10 (53.63)	1.64 (0.58 - 4.62)

Discussion

The present study found a higher prevalence of SBS among caretakers in Central Thailand, at 77.78%, than other studies, which found lower prevalence percentages. In a study that estimated the prevalence of SBS in aboveground and subterranean workplaces among multiethnic Asian employees, the prevalence of SBS was estimated to be 17.9%. In addition, it was discovered that increasing air quality and temperature comfort in workplaces can decrease the incidence of sick building syndrome.[14] In addition, Hong Kong had the highest prevalence of sick building syndrome-specific survey symptoms: 72% had fatigue symptoms, 34% had eye symptoms, and the study found that nasal irritation was the most prevalent home-related SBS symptom, with noise being the most significant. Residents perceive an issue with local environmental quality.[20] This finding is consistent with a study that determined the prevalence of sick building syndrome among healthcare workers to be between 64.7% and 74.1% in hospitals.[21] In the study of general hospitals in Slovenia, the surgical ward had the highest prevalence of Sick Building Syndrome, at 67.6%, while the Anesthesiology and Reanimation Services Department did not report any cases.[22] Furthermore, calibrated sensors were used to measure CO_2, CO, temperature, and humidity levels, and dosimeter tubes were utilized to measure SO_2, H_2S, and NO_2 levels in a study on Sick Building Syndrome among university laboratory workers in Nigeria. The study found that 38.46% of participants reported skin-related symptoms, 28.32% reported general-related symptoms, 19.23% reported mucosal-related symptoms, and 13.99% reported respiratory-related symptoms.[23] In the study that had been conducted before this one, the prevalence of Sick Building Syndrome (SBS) was far lower than it was in this study.

The data show that the prevalence of SBS in Thailand's childcare centers is high, and there is an urgent need to improve indoor air quality to reduce its effects. Studies have emphasized the importance of addressing SBS in childcare centers and the urgent need to improve indoor air quality. This is important.

Furthermore, our study and other studies show a possible relationship between PM and TVOC. The relationship has also been found in other studies. For example, the research utilized a multilevel path model for the purpose of evaluating the association between the levels of PM and TVOC that were observed in a school building, student-reported symptoms, and students' subjective assessments of indoor air quality (IAQ). According to the findings of the study, levels of PM and TVOC are related.[24]

The study evaluated the concentrations of particulate matter and volatile organic compounds in an underground parking garage and evaluated the associated health risks. Furthermore, the impact of ventilation and traffic volume on these pollutants, as well as indoor/outdoor ratios and PM deposition, were investigated. While TVOC concentrations were found to be higher in the summer, there were no significant differences between ventilation types in any of the three parking areas [26]. However, the study found that a room with low CO2 levels was related to elevated levels of PM10 and PM2.5, most likely as a result of outside air going into the room. This finding is related to the study on developing and implementing effective strategies to improve indoor air quality and reduce exposure to harmful pollutants in schools, which found a correlation between CO2 levels and outdoor ventilation.[25] Therefore, it is necessary to purify the air approaching the classroom to help reduce CO2, PM2.5, and PM10 levels.

In addition, our study revealed a correlation between PM10 and CO2 levels and sick building syndrome (SBS) in childcare centers' caretakers., especially PM_{10} levels. Similar to Cuong et al.[26]significantly found the correlation of room temperature, dust, and stale, stale air and SBS symptoms.[27] In addition, a study in Malaysia found indoor relative humidity, visible dampness, mold, and dust in classrooms affected SBS and occupational health[11]. Similarly, reported a positive correlation between the presence of fine dust in the classroom and SBS diseases was reported[28]. A study in China showed an association between SBS symptoms and school dust colony-forming in the units per gram [11]. Apart from PM_{10}, the study in Iran reported that indoor air pollutants (NO_2, PM_{10}, $PM_{2.5}$, and CO) from open fireplaces and gas stoves were associated with SBS symptoms [7]. In addition, the results of an Indonesian study showed that PM_{10}, $PM_{2.5}$, and humidity levels on building floors impacted on SBS

symptoms [29]. Meanwhile, no correlation between $PM_{2.5}$ with the prevalence of SBS symptoms was reported as same as these other studies in China, Thailand and Turkey[12, 30, 31]. In order to reduce the risk from indoor air exposure, a Swedish research recommended that the installation of modern ventilation systems can improve school indoor air quality by increasing individual air flow and air exchange rate. [32]

Conclusion

The prevalence of SBS symptoms among childcare workers in the Central of Thailand was 77.78%, and the correlation between PM_{10} and air fresheners with childcare workers were investigated. In addition, a strong correlation between $PM_{2.5}$ and TVOC was found, while a strong correlation between TVOC and relative humidity was also discovered. Consequently, the decreasing risk of a variety of SBS symptoms should be conducted by using air filtration and dehumidification at the childcare center. Caretakers, including teachers, health volunteers, and practical nurses, can play a crucial role in mitigating SBS in childcare centers. Practical nurses, in particular, can be instrumental by engaging in SBS education, promoting health and wellness, and developing prevention plans.

Ethical Clearance: This study was conducted in accordance with the Declaration of Helsinki guidelines and approved by The Research Ethics Review Committee for Research Involving Human Research Participants Chulalongkorn University Thailand (COA No. 133/2564). All respondents read and sign the consent form before participating.

Conflict of Interest & Source of Funding Statement

The authors declare no conflict of interest.

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