Original Article

Factors Associated Respiratory Health of Occupants in Air-Conditioned Offices in Bangkok, Thailand

Srimarut T, MSc[1], Somrongthong R, PhD[1], Taneepanichskul S, MD[1]

[1] College of Public Health Science, Chulalongkorn University, Bangkok, Thailand

Background: Indoor air pollution contains several substances and can emanate from a range of sources. Of particular importance are volatile organic compounds (VOCs) and respirable particulates. The exposure to indoor air pollution can induce a wide range of acute and chronic respiratory health effects.

Objective: To investigate respiratory health effects of occupants in air-conditioned offices and to determine factors influencing their respiratory health.

Materials and Methods: Fourteen air-conditioned offices in Bangkok were measured for volume and concentration of PM2.5 and VOC. The 212 occupants in these offices were surveyed and their lung function were tested. The subjective respiratory symptoms were cough, phlegm, wheezing, and short breathing.

Results: The logistic regression analysis showed the concentration of VOC was significantly associated with forced vital capacity (FVC) and wheeze symptoms ($p<0.05$). Concentration of PM2.5 was significantly associated with the forced expiratory volume in the first second (FEV1) over the FVC ($p<0.05$). Smoking was significantly associated with cough ($p<0.05$). The significant association between history in gas or VOC job, and phlegm, current work experience, and FEV1 over the FVC ratio were found.

Conclusion: Indoor air pollution exposure was associated with respiratory health effects. Smoking and work experience also affect the respiratory health.

Keywords: Lung function, Respiratory health symptoms, Air-conditioned office

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An increasing number of health effects are seen, especially respiratory health, related to time spent in buildings due to physical and chemical exposures in the office environment. In the past, most buildings used natural ventilation by air movement from indoor to outdoor air pressure difference. Now, most office buildings use mechanical ventilation systems to exchange indoor and outdoor air and circulate air within the buildings. A higher prevalence of work-related upper respiratory symptoms and tiredness has been observed in the air-conditioned building as compared to the building with natural ventilation[1]. Indoor air pollutants can emanate from a range of sources and cause various respiratory health effects. In particular importance might be substances known as volatile organic compounds (VOCs) and respirable particulates. Chemical reactions can occur indoors, and there is indirect evidence that they are associated with eye and airway irritation[2]. The VOC (1, 4-dichlorobenzene) exposure may result in reduced pulmonary function[3]. The indoor PM2.5 levels were sometimes higher than the outdoor levels[4] and the mean PM2.5 concentrations in the big office were more than in small quiet office[5]. In addition to air pollutants, smoking leads to increased respiratory symptoms and reduction of pulmonary function tests (PFTs) values[6]. However, determination of factors influencing the respiratory health of occupants in air-conditioned offices was hardly been documented. The aims of the present study were to investigate the respiratory health effects of occupants in air-

Correspondence to:

Srimarut T.

Faculty of Industrial Technology, Suan Sunandha Rajabhat University, 1 U-Thong Nok Road, Dusit, Bangkok 10300, Thailand.

Phone: +66-81-8808034, **Fax**: +66-2-1601440

Email: thammarak.sr@ssru.ac.th, thsrimarut@yahoo.com

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conditioned offices and to determine the factors that influenced on their respiratory health.

Materials and Methods

Study site and population

The present cross-sectional study was conducted at Suan Sunandha Rajabhat University located in Bangkok, Thailand. Two hundred twelve occupants from fourteen offices were involved in this study and gave consent prior to data collection. Ethics approval was obtained from the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (COA No.710/2559).

Air sampling

The ppb RAE 3000 VOC monitor was used to measure VOC concentration at ppb level (1 ppb resolution in range 1 ppb to 10,000 ppm) by using photo-ionization detector (PID). The DustTrak DRX Desktop Aerosol Monitor Model 8533 was used to measure area PM2.5 concentration in mg per cubic meter (in range 0.001 to 150 mg/m^3) with 90° light scattering and resolution of 0.1% of reading or 0.001 mg per m^3, whichever is greater. The VOC and PM2.5 concentrations were measured at 1.20 meter above the ground (breathing zone when sitting) in three locations in each office. Each location is monitored for eight hours on any weekday.

Questionnaire

The questionnaire was classified into five parts, including socio-demographic characteristics, health related characteristics, workplace characteristics, occupational history characteristics, and respiratory symptoms. The part of the health-related characteristics contained "yes/no" questions about smoking and medical records of nine illness. The part of respiratory symptoms was adapted from the American Thoracic Society Questionnaire and contained "yes/no" questions about cough, phlegm, wheezing, and short breathing. The questionnaires were distributed to participants at the end of their work shift. The validity of the questionnaire was examined by four experts in environmental health, occupational health, and public health.

Spirometry test

The FUTUREMED Discovery-2 Diagnostic spirometer, calibrated every year by a certified body and calibration checked before use by a 3-L calibrated syringe, which had an accuracy of ±0.5%, was used to measure the participants' lung function in each office. The acceptable spirogram was obtained and interpreted in "normal/abnormal". The abnormal lung function classified in restrictive (forced vital capacity [FVC] less than eighty percent), obstructive (forced expiratory volume in the first second [FEV1]/FVC less than seventy percent), and combined.

Statistical analysis

The sample size calculation was based on the mean of FEV1, which was 2.56 liters in high dust exposure and 2.88 liters in low dust exposure[7] at confidence level of 95 percent and power of 80 percent. The 196 samples were received and whole population were enrolled. Data was analyzed by SPSS version 16.0. The factors associated with lung function and respiratory symptoms were determined by binary logistic regression. The univariate analysis and the multivariate analysis were done, respectively, with statistical significance set at 0.05 level.

Results

Study PM2.5 and VOC concentration

Fourteen air-conditioned offices that had volume of 120 to 938 cubic meters were included in the present study. The concentration of PM2.5, measured in each office was between 0.015 and 0.039 milligram per cubic meter and the concentration of VOC, measured in each office, was between 45.33 and 260.67 part per billion. The results are shown in Table 1.

Study population characteristics

The participants were 65 males (30.7%) and 147 females (69.3%). More than half of them were between 31 and 40 years old (57.6%). Eighty-four-point-four percent of them were non-smokers and 80.2% them never had illness. Most of them never experienced a dusty job environment (84.0%), gas or VOC job (90.1%), or fume job (96.2%). A quarter of them work in their current job for more than ten years (25.9%) and one third of them work eight hours per day. The characteristics of the occupants of the air-conditioned offices are shown in Table 2.

Study lung function and respiratory symptoms

Twenty-three-point-six percent of the participants had restrictive result from lung function test with FVC at less than 80%, both obstructive result with FEV1/FVC at less than 70%, and combined at the same proportion, which was 2.8%. Three quarter of them reported no cough symptoms (74.5%) and most

Table 1. Concentration of PM2.5 and VOC in each office

Office	No. of occupants (n=212)	Room volume (m^3)	Concentration of PM2.5 (mg/m^3)	Concentration of VOC (ppb)
Faculty of Education	6	260	0.031	45.33
Faculty of Science and Technology	16	300	0.028	78.00
Faculty of Humanities and Social Sciences	12	245	0.024	135.67
Faculty of Industrial Technology	10	120	0.036	123.33
Faculty of Management Science	10	324	0.027	243.67
Faculty of Fine and Applied Arts	11	430	0.032	150.67
General Affairs Division	20	714	0.023	162.33
Academic Services Division	25	938	0.028	260.67
Financial Division	15	600	0.024	247.00
Policy and Planning Division	22	307	0.028	122.00
Personnel Division	16	655	0.030	127.67
Student Affairs Division	15	615	0.015	156.00
Institute for Research and Development	10	330	0.039	135.00
The Office of General Education and Innovative Electronic Learning	24	400	0.015	116.33

VOC=volatile organic compound

of them reported no phlegm symptoms (84.0%), no wheezing (81.6%), and no short breathing (84.4%). Lung function and respiratory symptoms of occupants are shown in Table 3.

Factors influencing lung function

The results of logistic regression analysis showed that the concentration of VOC was significantly associated with FVC (p=0.001) and the office room volume was also significantly associated with FVC (p=0.001). The odds of restrictive abnormal lung function were 9.289 times higher in the high VOC concentration exposure than the low one; whereas, the odds of restrictive abnormal lung function were 0.110 times lower in the large office than the small one. The concentration of PM2.5 was significantly associated with FEV1/FVC (p=0.037), and current working experience was also significantly associated with FEV1/FVC (p=0.046). The odds of obstructive abnormal lung function were 3.588 times higher in the high PM2.5 concentration exposure than the low one and the odds of obstructive abnormal lung function were 3.407 times higher in the group of more than ten year experience in current job than the group of within ten year experience. Factors associated with FVC and FEV1/FVC of occupants in air-conditioned offices are reported in Table 4.

Factors influencing respiratory symptoms

The results of logistic regression analysis showed that smoking was significantly associated with cough (p=0.030); whereas, the working hour per day and office room volume were marginally associated. The odds of cough were 2.438 times higher in smoker than non-smoker. History in gas or VOC job was significantly associated with phlegm (p=0.004), while office room volume was marginally associated with phlegm. The odds of phlegm were 4.184 times higher in the group of ever experience in gas or VOC job than the never group. The concentration of VOC was significantly associated with wheezing (p=0.043); whereas, the current working experience and office room volume were marginally associated with wheezing. The odds of wheezing were 3.196 times higher in the high VOC concentration exposure than the low one. Gender was significantly associated with short breathing (p=0.043), while history in dusty job was marginally associated. The odds of short breathing were 2.791 times higher in female than male. Factors associated with respiratory symptoms of occupants in air-conditioned offices are reported in Table 5 and 6.

Discussion

In the present study, the range of PM2.5 concentration in university offices is between 0.015

Table 2. Characteristics of occupants in air conditioned offices (n=212)

Characteristic	n (%)
Personal characteristic	
Age (years)	
• ≤30	59 (27.8)
• 31 to 40	122 (57.6)
• 41 to 50	20 (9.4)
• >50	11 (5.2)
Sex	
• Male	65 (30.7)
• Female	147 (69.3)
Health related characteristic	
Smoking	
• Non-smoking	179 (84.4)
• Smoking	33 (15.6)
Previous medical records*	
• Never have illness	170 (80.2)
• Illness	42 (19.8)
Work related characteristic	
History in dusty job	
• Never	178 (84.0)
• Ever	34 (16.0)
History in gas/volatile job	
• Never	191 (90.1)
• Ever	21 (9.9)
History in fume job	
• Never	204 (96.2)
• Ever	8 (3.8)
Working experience (years)	
• ≤10	157 (74.1)
• >10	55 (25.9)
Working hour per day (hours)	
• ≤8	70 (33.0)
• >8	142 (67.0)

* Illness records about asthma, chronic lung disease, emphysema, chronic bronchitis, pneumonia, hay fever (allergic rhinitis), heart disease, high blood pressure, and diabetes

Table 3. Lung function and respiratory symptoms of occupants (n=212)

Respiratory health	n (%)
Lung function	
Normal	150 (70.8)
Restrictive (FVC <80%)	50 (23.6)
Obstructive (FEV1/FVC <70%)	6 (2.8)
Combined (restrictive and obstructive)	6 (2.8)
Respiratory symptoms	
Cough	
• No symptoms	158 (74.5)
• Have symptoms	54 (25.5)
Phlegm	
• No symptoms	178 (84.0)
• Have symptoms	34 (16.0)
Wheezing	
• No symptoms	173 (81.6)
• Have symptoms	39 (18.4)
Short breathing	
• No symptoms	179 (84.4)
• Have symptoms	33 (15.6)

FEV1=forced expiratory volume in the first second; FVC= forced vital capacity

and 0.039 mg per m^3 (15 to 39 µg per m^3) and resemble the concentration of PM2.5 in university classrooms, which is between 26 and 37 µg/m^3[8]. The PM2.5 concentration in office buildings in United States is between 1.3 and 24.8 µg/m^3[9], which is lower than in Bangkok. The VOC concentration in university offices is between 45.33 and 260.67 ppb, which is similar to VOC concentration in Australian buildings[10] and apartments[11]. These are higher than roadside resident[12] but lower than non-industrial sector in building[13]. The prevalence of abnormal lung function of occupants in university offices is 29.2 percent more than the prevalence of abnormal lung function of office workers, which is 13.5 percent[14]. The only respiratory health effect that concentration of PM2.5 significantly associated with was FEV1/FVC. Exposure to PM2.5 may result in reduced FEV1/FVC. Low FEV1/FVC indicated the obstructive result of abnormal lung function owing to airway obstruction. The respirable particulates inhaled through the airways, may cause the obstruction, so that the volume of air exhaled during the performance of a FEV1 will decrease. Exposure to VOC appear to significantly associate with FVC and wheezing. In addition, history in gas or VOC job was significantly

Table 4. Factors associated with FVC and FEV1/FVC of occupants

Factors	Univariate		Multivariate	
	OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
FVC (normal value ≥80%)				
Age ≤30				
• 31 to 40	1.827 (0.853 to 3.914)	0.121		
• 41 to 50	2.350 (0.760 to 7.263)	0.138		
• >50	0.970 (0.183 to 5.133)	0.971		
Sex	1.289 (0.653 to 2.546)	0.464		
Smoking	0.714 (0.291 to 1.751)	0.462		
Previous medical records	1.145 (0.540 to 2.431)	0.723		
History in dusty job	0.833 (0.353 to 1.967)	0.677		
History in gas/volatile job	0.629 (0.202 to 1.956)	0.423		
History in fume job	0.926 (0.181 to 4.727)	0.926		
Working experience	1.712 (0.879 to 3.335)	0.114		
Working hour per day	1.342 (0.679 to 2.579)	0.410		
Concentration of PM2.5[1]	0.663 (0.314 to 1.402)	0.283		
Concentration of VOC[2]	1.573 (0.852 to 2.907)	0.148	9.289 (2.501 to 34.499)	0.001*
Room volume	0.662 (0.357 to 1.228)	0.191	0.110 (0.029 to 0.410)	0.001*
FEV1/FVC (normal value ≥70%)				
Age ≤30				
• 31 to 40	1.735 (0.349 to 8.620)	0.501		
• 41 to 50	3.167 (0.416 to 24.119)	0.266		
• >50	2.850 (0.236 to 34.469)	0.410		
Sex	0.600 (0.183 to 1.966)	0.399		
Smoking	1.090 (0.228 to 5.218)	0.914		
Previous medical records	2.132 (0.610 to 7.448)	0.236		
History in dusty job	1.050 (0.220 to 5.020)	0.951		
History in gas/volatile job	-	-		
History in fume job	-	-		
Working experience	3.082 (0.950 to 9.994)	0.061	3.407 (1.024 to 11.340)	0.046*
Working hour per day	0.985 (0.286 to 3.390)	0.981		
Concentration of PM2.5[1]	3.255 (1.002 to 10.571)	0.050*	3.588 (1.078 to 11.943)	0.037*
Concentration of VOC[2]	0.587 (0.171 to 2.012)	0.397		
Room volume	0.510 (0.149 to 1.748)	0.284		

FEV1=forced expiratory volume in the first second; FVC=forced vital capacity; VOC=volatile organic compound; CI=confidence interval

[1] Median cut point 0.028 mg/m^3, [2] Median cut point 135.67 ppb, * p<0.05 indicates statistical significance

associated with phlegm. Low FVC indicated the restrictive result of abnormal lung function because of lung flexibility loss. VOC exposure may cause FVC reduction. Expose to VOC (1, 4-dichlorobenzene) may result in reduced pulmonary function[3]. A significant association between smoking and cough was found.

Table 5. Factors associated with cough and phlegm of occupants

Factors	Univariate		Multivariate	
	OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Cough				
Age ≤30				
• 31 to 40	0.678 (0.338 to 1.362)	0.275		
• 41 to 50	0.569 (0.167 to 1.944)	0.369		
• >50	1.302 (0.338 to 5.009)	0.701		
Sex	0.757 (0.393 to 1.457)	0.404		
Smoking	2.188 (1.002 to 4.775)	0.049*	2.438 (1.091 to 5.447)	0.030*
Previous medical records	0.758 (0.336 to 1.706)	0.503		
History in dusty job	1.502 (0.677 to 3.329)	0.317		
History in gas/volatile job	2.433 (0.963 to 6.147)	0.060		
History in fume job	0.974 (0.191 to 4.978)	0.975		
Working experience	0.764 (0.368 to 1.587)	0.471		
Working hour per day	1.780 (0.881 to 3.596)	0.108	2.015 (0.979 to 4.148)	0.057
Concentration of PM2.5[1]	0.935 (0.455 to 1.921)	0.856		
Concentration of VOC[2]	0.864 (0.463 to 1.612)	0.646		
Room volume	0.654 (0.349 to 1.222)	0.183	0.580 (0.305 to 1.106)	0.098
Phlegm				
Age ≤30				
• 31 to 40	0.755 (0.331 to 1.722)	0.505		
• 41 to 50	0.770 (0.192 to 3.096)	0.713		
• >50	0.970 (0.183 to 5.133)	0.971		
Sex	0.777 (0.359 to 1.684)	0.523		
Smoking	1.516 (0.598 to 3.840)	0.381		
Previous medical records	1.059 (0.426 to 2.631)	0.901		
History in dusty job	3.223 (1.389 to 7.477)	0.006*		
History in gas/volatile job	4.980 (1.905 to 13.021)	0.001*	4.184 (1.567 to 11.170)	0.004*
History in fume job	1.792 (0.346 to 9.275)	0.487		
Working experience	0.702 (0.287 to 1.718)	0.439		
Working hour per day	1.448 (0.636 to 3.296)	0.377		
Concentration of PM2.5[1]	1.308 (0.580 to 2.951)	0.518		
Concentration of VOC[2]	0.446 (0.201 to 0.986)	0.046*		
Room volume	0.381 (0.172 to 0.843)	0.017*	0.447 (0.197 to 1.010)	0.053

FEV1=forced expiratory volume in the first second; FVC=forced vital capacity; VOC=volatile organic compound; CI=confidence interval

[1] Median cut point 0.028 mg/m^3, [2] Median cut point 135.67 ppb, * p<0.05 indicates statistical significance

There was more prevalence of cough in smokers than non-smokers. Smoking leads to increased respiratory symptoms and reduction of PFTs values[6]. Gender was significantly associated with short breathing. Women reported more short breathing than men. It is not clear if the gender influences the individual hypersensitivity

Table 6. Factors associated with wheezing and short breathing of occupants

Factors	Univariate		Multivariate	
	OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Wheezing				
Age ≤30				
• 31 to 40	0.722 (0.324 to 1.609)	0.426		
• 41 to 50	1.679 (0.533 to 5.287)	0.376		
• >50	0.870 (0.166 to 4.569)	0.870		
Sex	1.352 (0.615 to 2.969)	0.453		
Smoking	0.397 (0.115 to 1.375)	0.145		
Previous medical records	1.055 (0.445 to 2.501)	0.903		
History in dusty job	0.730 (0.263 to 2.025)	0.546		
History in gas/volatile job	0.718 (0.201 to 2.568)	0.610		
History in fume job	0.624 (0.075 to 5.224)	0.664		
Working experience	2.078 (0.996 to 4.336)	0.051	2.019 (0.954 to 4.272)	0.066
Working hour per day	1.317 (0.613 to 2.831)	0.480		
Concentration of PM2.5[1]	0.734 (0.314 to 1.714)	0.475		
Concentration of VOC[2]	1.524 (0.759 to 3.063)	0.236	3.196 (1.040 to 9.820)	0.043*
Room volume	0.887 (0.442 to 1.781)	0.737	0.351 (0.114 to 1.078)	0.067
Short breathing				
Age ≤30				
• 31 to 40	1.457 (0.579 to 3.667)	0.425		
• 41 to 50	1.857 (0.481 to 7.165)	0.369		
• >50	1.651 (0.295 to 9.251)	0.569		
Sex	2.212 (0.866 to 5.652)	0.097	2.791 (1.035 to 7.530)	0.043*
Smoking	0.713 (0.233 to 2.183)	0.554		
Previous medical records	0.883 (0.339 to 2.299)	0.798		
History in dusty job	1.883 (0.767 to 4.623)	0.167	2.558 (0.979 to 6.685)	0.055
History in gas/volatile job	1.314 (0.413 to 4.187)	0.644		
History in fume job	-	-		
Working experience	1.534 (0.689 to 3.413)	0.294		
Working hour per day	0.983 (0.447 to 2.162)	0.967		
Concentration of PM2.5*	1.151 (0.498 to 2.660)	0.743		
Concentration of VOC**	0.553 (0.253 to 1.207)	0.137		
Room volume	0.553 (0.257 to 1.190)	0.130		

FEV1=forced expiratory volume in the first second; FVC=forced vital capacity; VOC=volatile organic compound; CI=confidence interval

[1] Median cut point 0.028 mg/m^3, [2] Median cut point 135.67 ppb, * p<0.05 indicates statistical significance

to pollutants.

In conclusion the risk of occupational respiratory health may decrease if indoor air pollution is lowered. Several factors including concentration of VOC, concentration of PM2.5, working experience in current job, and size of office room were associated

with lung function of occupants. Smoking behavior, history in VOC job and concentration of VOC were also associated with respiratory symptoms.

What is already known on this topic?

Several studies have reported the PM2.5 concentration in office buildings and university classroom, the VOC concentration in buildings and apartments, the prevalence of abnormal lung function and respiratory symptoms. However, the association between working environment and behavior factors and respiratory health problems of occupants in university offices were not well clarified.

What this study adds?

This study results showed that the concentration of VOC, PM2.5, working experience in current job, and size of office room were associated with lung function of occupants. Moreover, smoking behavior, history in VOC job, and concentration of VOC were also associated with respiratory symptoms.

In summary, several factors including concentration of VOC, concentration of PM2.5, working experience in current job, and size of office room were associated with lung function of occupants. Smoking behavior, history in VOC job, and concentration of VOC were also associated with respiratory symptoms.

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Conflicts of interest

The authors declare no conflict of interest.

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