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EXPOSURE TO INDOOR AIR POLLUTANTS (FORMALDEHYDE, VOCs, ULTRAFINE PARTICLES) AND RESPIRATORY HEALTH SYMPTOMS AMONG OFFICE WORKERS IN OLD AND NEW BUILDINGS IN UNIVERSITI PUTRA MALAYSIA

JALALUDIN J, NORDIYANA M. S & SUHAIMI N. F

Department of Environmental and Occupational Health, University Putra Malaysia, Serdang, Selangor, Malaysia

ABSTRACT

This study was done to investigate the association between exposure to indoor air pollutants (formaldehyde, VOCs and ultrafine particles) and respiratory health in two different buildings (old and new). A hundred and five office workers were purposely selected where 55 workers were from an old administrative building and another 50 workers were from the new Faculty of Engineering and Faculty of Medicine and Health Sciences buildings. Questionnaire adapted based on NIOSH Indoor Environment Quality Survey (1991) and American Thoracic Society (1982) was used to record prevalence of respiratory health symptoms. Measurement of indoor air pollutants was performed according to IAQ Code of Practice, Department of Occupational Safety and Health, (DOSH, 2005) Malaysia. Level of ultrafine particles was significantly higher in old building compared to new buildings ($z = -2.72$, $p < 0.05$). There were no significant associations between old and new office buildings and the prevalence of respiratory health symptoms among office workers (OR = 0.47, 95% CI = 0.21 – 1.05). In the old building, ultrafine particles level had a significant association with the prevalence of respiratory health symptoms which was ($p < 0.05$) and (OR = 4.57, 95% CI =1.36-15.40). Moreover, respiratory health symptoms were significantly higher for stuffy, runny nose or sinus congestion and dry or itchy skin ($p < 0.05$). The level of indoor air pollutants in the buildings may influence the prevalence of respiratory health symptoms among office workers. Exposure to high ultrafine particles had a significant association with respiratory health symptoms in the old building.

KEYWORDS: Indoor Air Pollutants, New Building, Office Workers, Old Building, Respiratory Health Symptoms

INTRODUCTION

In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized city (Khalil and Husin, 2009). People spend approximately 90% of their time in indoor environments such as residences, public buildings and offices where concentrations of many pollutants are frequently higher than in outdoor urban air. Generally, office workers would occupy their offices or other buildings for about 8 hours per day and for 5 days per week. Therefore, the quality of the indoor air they breathe is critical for their health and well-being.

Indoor air pollutants, either infiltrating from the outside or produced by indoor sources, have been linked to a wide range of health effects, including asthma and allergy symptoms, airway irritation, decreased lung function and other respiratory symptoms (Mitchell *et al.*, 2007). Some of the common causes of indoor air problems giving rise to poor air quality are the presence of indoor sources of pollution such as poorly designed, maintained or operated air-conditioning and mechanical ventilation systems, and uses of buildings that are unplanned for what the buildings were designed or renovated for (Cheong and Chong, 2001). Indoor air quality has an important issue that affects the comfort, health and productivity of office workers (Graudenz *et al.*, 2005). Due to this matter and an increased awareness regarding poor indoor air quality, it is not surprising that the number of reported employee complaints of discomforts and illnesses in non-industrial workplaces are increasing (Mui *et al.,* 2008).

There are symptoms associated with pollutants emitted from building materials. Studies have linked such symptoms with materials in the offices, office equipment and heating, ventilation and air conditioning (HVAC) systems that can contribute to indoor air pollution (Myers and Maynard, 2005). Moreover, office equipment has been found to be a source of ozone, particulate matters, volatile organic compounds (VOCs) and particles. These can also be emitted by the papers processed during printing and copying (Destaillats *et al.,* 2008). Formaldehyde at normal room temperature is a colourless gas with pungent odor and is a reactive indoor pollutant that may induce airway irritation at low concentrations (Jones, 1999). Besides that, occupants that are exposed to even low levels of formaldehyde might experience irritating effects such as an increased sensitization and asthma (Ongwandee *et al.,* 2009). A significant increase in formaldehyde concentration is also observed in dwellings with newly painted indoor surfaces (Wieslander *et al.* 1997).

Volatile organic compounds (VOCs) are present in indoors from outdoors and are emitted from buildings, furnishings and consumer products (Crump *et al.,* 1997). In renovated or completely new buildings, levels of indoor air pollutants, especially volatile organic compounds (VOCs)–resulting from emissions from constructions and building materials are often several orders of magnitude higher than the VOC levels in buildings with normal use (Brown *et al.,* 1994). The volatile organic compounds (VOCs) concentration in indoor air is typically ten times higher than outdoors (Crump *et al.,* 1997). Ultrafine particles have been defined as those, which are smaller than 0.1 micrometre (µm). Toner and paper dust from printing devices might become airborne that can generate respirable particles, which include ultrafine aerosols (Lee *et al.,* 2001; Kagi *et al.,* 2007). Ultrafine particles formation is also reported during operation of laser printers and copiers (Lee and Hsu, 2007).

Nowadays modern offices are surrounded by high technology equipment, artificial lightings, synthetic carpeting, wall coverings and air conditioning, which have influenced the indoor air quality in the buildings (Vitel, 2001). Based on a study by Menzres *et al.,* (1996), old buildings have been classified as buildings that are more than 10 years old. Meanwhile, new buildings are buildings that are less than 10 years old. They also reported that about 50% of workers in the old buildings reported at least one symptom each week compared with 40% of workers in the new buildings. A study by Skyberg *et al.,* (2003) indicated that office employees in modern buildings frequently report general, mucous membrane and skin symptoms. Furthermore, complaints of draught are less common in newer buildings, which is probably a result of better thermal insulation and tighter construction (Nordström *et al.,* 1995). In addition, new office blocks or schools are modern in design and have a lighter structure compared to old buildings. Besides that, construction and finishing materials used for the buildings are major sources of these compounds in the indoor air (Crump *et al.,* 1997).

This study aims to determine relationship between indoor air pollutants specifically volatile organic compounds (VOCs), formaldehyde and ultrafine particles related with respiratory health symptoms among office workers in UPM, Serdang. It compares the respondents between old and new buildings in UPM, Serdang. This comparison would determine the magnitude of exposure among respondents to develop respiratory diseases.

METHODOLOGY

Study Background

This cross-sectional comparative study was performed among 50 office workers from two new buildings and 55 office workers from an old building. Respondents had fulfilled the inclusion criteria such as Malaysian nationality, fulltime male and female office workers and aged between 20 to 55 years old. Respondents should also have worked in the same buildings for at least 4 months and above. Office workers who did not stay in the office 80% of their working duration (per day) were excluded from this study. Study location was University Putra Malaysia, Selangor. The old building which is an administrative building of University Putra Malaysia was built and used for more than 20 years ago. Meanwhile, two new buildings were Faculty of Medicine and Health Sciences and Faculty of Engineering which were built and have been used for 6 years. Both old and new buildings use centralized air-conditioning system.

Measurement of Formaldehyde, VOCS & Ultrafine Particles

Indoor air measurements were performed to obtain level of indoor air pollutants in both types of buildings. Exposures to indoor air pollutants were sampled by using Formal demeter, P-TRAK Ultrafine Particle Counter and Portable Handheld VOC Monitor ppbRAE 300. All instruments were calibrated upon used. Instruments were placed at 1 meter above floor level at workers' workstation. The instruments were also placed away from the direct sources of indoor air pollutants such as photocopy machines, printers and fax machines. The measuring point was decided based on the total floor area of the office (Department of Occupational Safety and Health, 2010). For each respondent, the exposure level of air pollutants was measured during working hours and the average of total measurements were calculated as the concentration in the specified offices.

Respiratory Health Symptoms Data

Self-administered questionnaire adapted based on NIOSH Indoor Environment Quality Survey (1991) and American Thoracic Society (1982) was used to record prevalence of respiratory health symptoms among respondents. The questionnaire was divided into 4 sections, which were personal information, working history, health, and well-being information and description of workplace conditions.

Statistical Analysis

Data were analyzed by using Statistical Packages for Social Sciences (SPSS version 18). Descriptive analysis was used to obtain frequency and percentage of all data. Mann-Whitney U Test was used to determine the relationship between variables using z-score. Meanwhile, Chi-Square or Fisher's Exact Test was used to make comparison. Population characteristics according to the exposure to indoor air pollutants were also analyzed by using Chi-Square Tests. A two-sided p-value less than 0.05 were considered statistically significant.

RESULTS

Table 1 shows the socio-demographic information for both workers in old and new buildings. Basically, no significant differences were observed between workers in old and new buildings in term of age, gender, race, marital status and education level. The mean age of respondent was 33.14 ± 9.20 years old.

Table 1: Distribution of Gender, Race, Marital Status, Education Level and Age of the Respondents (N = 105)

Variables	Study Groups n (%)		X^2	P
	Old Building (n=55)	New Buildings (n=50)		
Gender			2.58	0.108
Male	12 (21.8)	18 (36)		
Female	43 (78.2)	32 (64)		
Race			1.11	0.476
Malay	55 (100)	49 (98)		
Indian	-	1 (2)		

Table 1: Contd.,

Marital Status			2.75	0.172
Single	16 (29.1)	11 (22)		
Married	39 (70.9)	37 (74)		
Divorced	-	2 (4)		
Education Level			4.46	0.374
Lower Secondary Assessment	1 (1.8)	4 (8)		
Malaysian Certificate of Education	17 (30.9)	14 (28)		
Malaysian Higher School Certificate/	20 (36.4)	19 (38)		
Diploma/Sijil				
Degree	16 (29.1)	12 (24)		
Master	1 (1.8)	-		
Other	-	1 (2)		
Age Group (Year) 20-29 30-39 40-49 50-55	20 (36.4) 25 (45.5) 9 (16.4) 1 (1.8)	25 (50) 11 (22) 6 (12) 8 (16)		

*Significant at $p < 0.05$

Mann Whitney-U test was used to make comparison of concentration of indoor air pollutant between old and new buildings and the results were shown in Table 2. Only ultrafine particles have shown a significant difference with $p < 0.05$ for the old building compared to the new buildings, while other indoor air pollutants (Formaldehyde and VOCs) did not significantly differ in old building compared to new buildings. However, the level of VOCs was still higher in the old building compared to the new buildings.

Table 2: Comparison of Indoor Air Pollutants in Old and New Buildings

Variables	**Median (IQR)**			
	Old Building (n Office=4)	**New Buildings (n Office=8)**	**z**	**p**
Formaldehyde (ppm)	0.01 (0.01- 0.11)	0.01 (0.01 – 0.02)	-0.10	0.919
Total Volatile Organic Compound (ppb)	405.50 (224.50-727.50)	330.50 (262.75-447.50)	-0.17	0.865
Ultrafine Particles (pt/cm^3)	12189.50 (11381.25-12728.50)	5018.75 (4292.50-6668.50)	-2.72	0.007*

*Significant at $p < 0.05$

Table 3 shows the prevalence of respiratory health symptoms recorded based on the modified questionnaire from NIOSH Indoor Environment Quality Survey (1991) and American Thoracic Society (ATS) 1982. Relevant symptoms and exposure levels were recorded based on the questionnaire and measurement of indoor air pollutants. The prevalence of respiratory health symptoms in old and new buildings were compared by using Chi-Square Test. Result shows that there was no significant difference of the prevalence of respiratory health symptoms in old and new buildings.

Table 3: Comparison of the Prevalence of Respiratory Health Symptoms in Old and New Buildings (N=105)

Respondents	Prevalence of Respiratory Health Symptoms N=105 (100%)		χ^2	p	OR	95%CI
	Yes	No				
New buildings (n= 50)	14 (28)	36 (72)	3.42	0.065	0.47	0.21 – 1.05
Old Building (n= 55)	25 (45.5)	30 (54.5)				

***** Significant at $p < 0.05$

Table 4 shows the comparison of respiratory health symptoms among respondents in old and new buildings. Respondents in old building reported the highest percentage on stuffy nose/runny nose/sinus congestion, sore/dry throat and dry/itchy skin. The percentage of symptoms for stuffy nose/runny nose/sinus congestion was 29.1% followed by sore or dry throat, which was 25.5% and dry or itchy skin, which was 20%. Meanwhile, respondents in new buildings reported the highest percentage of sore or dry throat with percentage of 24%. There was a significant difference in two symptoms which were stuffy nose/runny nose/sinus and dry/itchy skin with p value < 0.05 between old and new buildings.

Table 4: Comparison of Respiratory Health Symptoms among Respondents in Old and New Buildings (N = 105)

Respiratory Health Symptoms	Old Building (n=55) n (%)		New Buildings (n=50) n (%)		χ^2	p
	Yes	No	Yes	No		
Coughing	10 (18.2)	45 (81.8)	9 (18)	41 (82)	0.00	0.981
Wheezing	2 (3.6)	53 (96.4)	5 (10)	45 (90)	1.71	0.361
Phlegm	1 (1.8)	54 (98.2)	1 (2)	49 (98)	0.01	1.000
Chest tightness	9 (16.4)	46 (83.6)	8 (16)	42 (84)	0.00	0.960
Sore or dry throat	14 (25.5)	41 (74.5)	12 (24)	38 (76)	0.03	0.863
Stuffy or runny nose or sinus congestion	16 (29.1)	39 (70.9)	5 (10)	45 (90)	5.97	0.015*
Dry or itchy skin	11 (20)	44 (80)	2 (4)	48 (96)	6.18	0.013*
Dry, itchy, or irritated eyes	5 (9.1)	50 (90.9)	2 (4)	48 (96)	1.09	0.441

* Significant at $p < 0.05$

Table 5 and Table 6 show the association between indoor air pollutants exposure level and the prevalence of respiratory health symptoms in old and new buildings in UPM. As in Table 5**,** there was no significant association between level of indoor air pollutants and prevalence of respiratory health symptoms in old building for the parameter; Formaldehyde (OR = 1.24, 95%CI = 0.28 - 5.55), VOCs (OR = 1.57, 95%CI = 0.53 - 4.70), while there was a significant association between ultrafine particles concentration and prevalence of respiratory symptoms with $p < 0.05$ (OR = 4.57, 95%CI =1.36 - 15.40).

This indicated that office workers who worked in the old building with high level of ultrafine particles; above 12189.50 pt/cm^3 were 4 times more likely to develop respiratory health symptoms than those who worked in the office environment with exposure level below 12189.50 pt/cm^3. Table 6 shows that there were no significant association between level of indoor air pollutants and prevalence of respiratory health symptoms in new buildings for all parameter; Formaldehyde (OR = 2.27, 95%CI = 0.64 - 8.05), VOCs (OR = 3.50, 95%CI = 0.92 - 13.31), UFP (OR =1.12, 95%CI = 0.33 - 3.84).

Table 5: Association of the Prevalence of Respiratory Health Symptoms with the Level of Indoor Air Pollutants in the Old Building

Indoor Air Pollutants	Parameter Category	Prevalence of Respiratory Health Symptoms N=55 (100%)		χ^2	p	OR	95%CI
		Yes n= 25	No n = 30				
Formaldehyde (ppm)	High	4	4	0.08	1.000	1.24	0.28-5.55
	Low	21	26				
Ultrafine particles (pt/cm^3)	High	20	14	6.42	0.011*	4.57	1.36-15.40**
	Low	5	16				
Total volatile organic compound (ppb)	High	11	10	0.66	0.418	1.57	0.53-4.70
	Low	14	20				

* Significant at $p < 0.05$
**OR significant at 95%CI >1
N = 55

Table 6: Association of the Prevalence of Respiratory Health Symptoms with the Level of Indoor Air Pollutants in New Buildings

Indoor Air Pollutants	Parameter Category	Prevalence of Respiratory Health Symptoms N=55 (100%)		χ^2	p	OR	95%CI
		Yes n=14	No n=36				
Formaldehyde (ppm)	High	7	11	1.65	0.198	2.27	0.64-8.05
	Low	7	25				
Ultrafine particles (pt/cm^3)	High	7	17	0.03	0.860	1.12	0.33-3.84
	Low	7	19				
Total volatile organic compound (ppb)	High	10	15	3.57	0.059	3.50	0.92-13.31
	Low	4	21				

* Significant at $p < 0.05$
**OR significant at 95%CI >1
N = 50

DISCUSSIONS

Socio-Demographic Information

Total respondents involved were 105 office workers with inclusion criteria of Malaysian, registered as fulltime staff, aged 20-55 years old and have been working in the buildings for at least 4 months and above. Majority of the respondents involved in this study were Malay in the range of 20-40 years old.

Comparison of Indoor Air Pollutants in Old and New Buildings

Table 2 shows the comparison of indoor air pollutants in old and new buildings. Exposure levels of indoor air pollutants in both buildings were different. Based on the results, ultrafine particles were significantly higher in the old building than the new buildings. Various types of printers and photocopy machines used in office environments were known to be potential sources of gaseous and particulate impurities and directly increased evidence of the influence of printer emissions on indoor air quality (Koivisto *et al.,* 2010). From the observation of both buildings, the location of photocopy machines in the old building were in the middle of the office compared to the new buildings where the machines were located in separate rooms.

Therefore, the factor that can lead to the sources of ultrafine particles was the photocopy machines, which were placed in the middle of the office and not in the separate rooms. Besides that, most of the workers had their own printers nearby their workstations. Concentration of ultrafine particles varies depends on the different mechanisms during the photocopying process and the ventilation (Lee and Hsu, 2007). Level of ultrafine particles would be greater in the old building as the pollutants cannot be expelled out of the building if the building does not have proper ventilation system. Also from the observation, carpeted floor was mainly used in the old building compared to the new buildings, which have uncarpeted floor. This is supported by a study from Graudenz *et al.* (2005) who reported that carpeted covering would influence indoor air pollutants in office as they are also sources of the ultrafine particles.

Volatile organic compounds (VOCs) were another parameter that had showed no significant difference between old and new buildings. Level of VOCs was higher in the old building compared to the new buildings. It was higher in the old building, but by referring to Code of Practice Indoor Air Quality by DOSH (2010), the maximum limit of VOCs that can be exposed by the occupants for eight hours is 3 ppm. A study by Hodgson and Levin, (2003) stated that there were many consumer products used in residences and offices, which contain and emit numerous VOCs, and such products include cleaners, air fresheners, insect repellents and combustion processes, in particular smoking.

These are also indoor sources of complex mixtures of VOCs. Based on Jones (1999), he stated that VOCs concentrations may be higher than typical ambient levels in newly constructed buildings or those in which building works or decoration had recently taken place. This was also supported by the study from Crump *et al.*, (1997) where they mentioned that volatile organic compounds concentration in indoor air was typically 10 times higher than outdoors in the newly built building because of the exposure from the painted walls.

Concentration level of formaldehyde was equal and low in both buildings. Formaldehyde was associated with common building materials and furnishings (Mui *et al.*, 2008). Based on the study from Ongwandee *et al.*, (2009), the extensive use of plywood and particle boards in the office could contribute to high level of indoor formaldehyde. However, in this study both office buildings did not use materials such as plywood and particle boards that can influence the presence of formaldehyde in indoor air. Besides that, the rate of emission of formaldehyde varies according to conditions of temperature and humidity (Jones, 1999). Formaldehyde in both buildings was low and within acceptable limits which was 0.1 ppm for eight hours by referring to the Code of Practice Indoor Air Quality by DOSH (2010).

Comparison of the Prevalence of Respiratory Health Symptoms

Table 3 shows the comparison of the prevalence of respiratory health symptoms in old and new buildings. The result shows that there was no significant difference of the prevalence of respiratory health symptoms in old and new buildings. From the result, the percentage of respondents having respiratory health symptoms was 28% from the new buildings and 45.5% from the old building. From the total of 105 respondents, there were 14 respondents from new buildings and 25 respondents old building who had positive score of respiratory health symptoms. Hence, the prevalence of respiratory health symptoms for both buildings was 37.14%. A study by Men dell and Smith (1990) stated that the prevalence of the respiratory health symptoms is striking in even the least problematic office building.

Based on a study by Graudenz *et al.*, (2005), there was an increase in prevalence of indoor air related symptoms from 30% to 200% in buildings with air-conditioning as upper airway could be more sensitive to air-conditioning related conditions. A study conducted by Sky berg *et al.*, (2003) stated that the respiratory health symptoms were influenced due to the building features and indoor air quality in the buildings.

Meanwhile, Graudenz *et al.*, (2005) stated that sealed buildings with air-conditioning are associated with a higher prevalence of work-related upper respiratory symptoms. Therefore, the prevalence of respiratory health symptoms was not higher in both buildings because from the observation made, the buildings were not fully sealed with air-conditioning system.

Comparison of Respiratory Health Symptoms among Respondents

Table 4 shows the comparison of respiratory health symptoms among respondents in old and new buildings. There was a significant difference in two symptoms which were stuffy nose/runny nose/sinus and dry/itchy skin with p value < 0.05 between old and new buildings. The highest prevalence of respiratory health symptoms in old building were stuffy nose/runny nose/sinus congestion, sore/dry throat and dry/itchy skin. Meanwhile, the highest symptoms reported in the new buildings were sore/ dry throat, coughing and chest tightness. As defined by World Health Organization, the perception of a poor indoor air environment particularly air dryness, odor and stuffy air can cause the syndrome comprises irritative symptoms from eyes, skin and upper airways (Nordström *et al.,* 1995).

Coughing could reflect irritation or inflammation either from upper or lower airways, but it is associated with building occupancy as an important marker of poor indoor air quality (Graudenz *et al.,* 2005). Data based on the study from Mendel and Smith (1990) stated that skin-related symptoms suggested a higher prevalence in air-conditioned buildings. A study conducted by Bourbeau *et al.,* (1996) showed that workers who frequently used office equipment and were located less than five meters from a photocopier had a higher prevalence of symptoms of the nose, throat, respiratory tract–and headache. The classification of upper airway symptoms typically reported as dry, itchy, sore, and burning or irritated eyes, nose, sinus or throat (Levin, 1989). Lower respiratory symptoms such as wheezing, shortness of breath and tight chest symptoms can be related to the indoor air quality problems (Graudenz *et al.,* 2005).

Association of the Prevalence of Respiratory Health Symptoms with the Level of Indoor Air Pollutants in Old and New Buildings

Table 5 and 6 are showing the association of the prevalence of respiratory health symptoms with the level of indoor air pollutants in old and new buildings. From the result, there was a significant association between exposure level of ultrafine particles and prevalence of respiratory health symptoms in the old building. Meanwhile, there was no significant association of the prevalence of respiratory health symptoms with the level of indoor air pollutants in the new buildings. Based on Table 6**,** the ultrafine particles have a significant p value (p= 0.011) with OR = 4.57, 95%CI =1.36 - 15.40. These are showing that office workers who work in the old building with high level of ultrafine particles; above 12189.50 pt/cm^3 are 4 times more likely to develop the respiratory health symptoms than those who work~~ed~~ in the office environment with the level below than 12189.50 pt/cm^3.

Ultrafine particles (UFP) are particles less than 0.1 μm in aerodynamic diameter, which may contribute to health effects to human. UFPs are classified as having high number concentration, low mass concentration and big surface area compared with larger particles (Francesca *et al.,* 2006). A study conducted by Koivisto *et al.,* (2010) stated that there were a number of studies that addressed the role of modern printers as a significant emission source of ultrafine particles indoors. Distillates *et al*. (2008) found that significant levels of particulate matter were generally found during operation of printers, copiers and multi-functional devices in the office environment. Toner and paper dust from printing devices may become airborne; generating respirable particles included ultrafine aerosols (Kagi *et al.,* 2007). In addition, based on a study by Francesca *et al.,* (2006), ultrafine particles were able to penetrate deeply into respiratory tract because when compared with larger particles, they had a higher deposition rate in the lung.

Formaldehyde which is associated with common building materials and furnishing is also one of indoor air pollutants that present a risk as a long term health hazard to the building occupants (Mui *et al.,* 2008). In addition, based on a study by Koeck *et al.,* (1997), they found that exposure to formaldehyde with concentrations of less than 1 ppm might result~~s~~ in sneezing, coughing and minor eye irritation. A study by Hodgson *et al.* (1991) found that VOC concentrations in the breathing zone of the building occupants are good predictors of mucous membrane irritation and central nervous system complaints. Besides that, exposure to VOC can also lead to irritation of the eyes and respiratory tract, and cause sensitization reactions involving the eyes, skin, and lungs. Because of the similarity of these symptoms, exposure to VOCs has frequently been attributed as a cause of sick building syndrome among office workers.

Exposure to indoor air pollutants can produce a variety of respiratory health symptoms depending on the mode, duration and concentration of exposure. The development of respiratory health symptoms are also influenced by the health status, age, smoking status and work related activities in the office. A study by Skyberg *et al*., (2003) had found that older employees reported more mucosal symptoms than younger employees and smoking status was also seemed to influence the risk to generate symptoms. Furthermore, Jones (1999) said that exposure to cigarette smoke has been associated with a wide range of acute and chronic health impacts. Office workers are also exposed to the printers and photocopy machines while doing their work related activities in the office, which can also expose them to the related indoor air pollutants. Other ways to reduce occupants' exposure to indoor pollutants include controlling source of emission and improving ventilation effectiveness (Rim and Novoselac, 2010). Reduction of source of emission is an effective way to reduce the exposure of ultrafine particles to workers. Besides that, ventilation can be improved by effectively removing contaminants before they spread to another space.

CONCLUSIONS

In overall, the level of ultrafine particles was significantly higher in the old building compared to the new buildings. High level of indoor air pollutants in the buildings may influence the prevalence of respiratory health symptoms among office workers. In this study, two symptoms which were stuffy or runny nose or sinus congestion and dry or itchy skin showed a significant difference between old and new buildings. The level of ultrafine particles and formaldehyde were higher in the old building although the level of formaldehyde was not significantly higher in the old building compared to the new buildings. From this study, a recommendation is made to improve air quality in the old building by constructing a separated and ventilated room for the photocopiers and printer machines. This will help to reduce emission of particulate matter to working areas. As a consequence, it would help to reduce the prevalence of respiratory health symptoms among workers.

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