Exposure to Indoor Air Pollutants (PM_{10}, CO_2 And CO) and Respiratory Health Effects among Long Distance Express Bus Drivers

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ABSTRACT: Previous studies have consistently found that exposure to indoor air pollutants is higher inside buildings and buses. However, there are very few studies conducted in Malaysia related to indoor air pollutant in long distance express buses. The objective of this study was to determine the exposure of indoor air pollutants (PM_{10}, CO_2 and CO) and respiratory health problem among long distance express bus drivers. This cross sectional study was conducted among 30 long distance express bus drivers and the entire respondents were male. Exposure of PM_{10} was measured using DustTrak Aerosol Monitor, while CO_2 and CO were measured using Q-Trak IAQ Plus. All parameters were measured along the routes where the average duration was four hours. A purposive sampling was used to select respondents based on inclusion and exclusion criteria such as aged 20 to 56 years old, at least one year working experience, no history of chronic lung diseases, and non-smokers. Questionnaire adapted from American Thoracic Society (ATS) was used to collect information on respondents' socio-economic status, working history, and respiratory symptoms. Lung function tests were performed after the participants arrived at their destinations. Data collected showed that the mean concentration of PM_{10} (220.00±120.00µg/m^3), CO_2 (1085.50±460.98ppm), and CO (2.79±0.95ppm) were still below the permissible level according to indoor air guidelines by WHO. The number of passengers on the bus influenced the concentrations of elevated CO_2 inside buses. Chronic respiratory symptoms, which were reported among drivers, were phlegm (23.3%), cough (20.0%), wheezing (13.3%) and chest tightness (10.0%). Lung function result showed that there were 50% respondents who had abnormality of FVC% value and FEV_1% value. Exposure to air pollutants continuously over a long period while driving is potentially causing ill effects to drivers' respiratory health.

Exposure to PM_{10} in air-conditioned buses such as long distance express buses can increase the risk of respiratory illness and the reduction of lung function among bus drivers. Therefore, control measures may be needed to improve these situations.

Keywords: PM_{10}, CO_2, CO, respiratory symptoms, lung function, bus driver

Introduction

Poor Indoor Air Quality (IAQ) that contain air contaminants such as volatile organic compounds (VOCs), particulate matter, metal, toxic gaseous and airborne bacteria can be hazardous to our health. Many electric power plants, automotive industry for transportation, other industrial processes, construction and agriculture (USEPA, 2013; USEPA, 2012) generally contribute to these contaminants. Lately, cities in Malaysia have seen rapid growth for demand in public transit systems including taxis, buses, and trains. Vehicular usage has been increased rapidly in combination with a booming growth in population (Kadiyala and Kumar, 2011).

A vehicle cabin is an important microenvironment which leads to passengers and drivers' exposure to elevated levels of air pollutants, such as VOCs, carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter (PM) (Hsu *et al*., 2009). The bus drivers are exposed to a mixture of air pollutants from the diesel exhaust particles during their daily work time (Ye *et al*., 2000). Chronic respiratory symptoms that were reported among bus drivers in Klang Valley were phlegm (37.3%), breathlessness (31.8%), cough (25.9%) and wheezing (16.4%) (Zainuddin *et al*., 2005). The prevalence of respiratory health for bus drivers showed that 28% of them is having cough and phlegm. Exposure to indoor air pollution led to decrease of lung function and increase complain of respiratory symptoms.

Long distance express bus drivers spend more than 8 hours in commuting inside buses every day, and without them knowing, the concentration of the indoor air pollutants inhaled by the drivers might cause some health effects. Many passengers use public transportation systems in a tightly enclosed space which could cause adverse health effects due to poor IAQ on top of poor ventilation. Jones *et al*. (2006) found that the measured PM_{10} and CO_2 level were significantly higher in air-conditioned buses due to poor ventilation. Due to the nature of the job, bus drivers are among the risk groups being exposed to highly polluted air consisting of a mixture of air pollutants for about eight hours without any personal protective equipment (Kavitha *et al*., 2011).

In the indoor environment, people exhale CO_2, which contributes to CO_2 levels in the indoor air. The level of CO_2 indoors depends upon the number of people present, how long an area has been occupied, the amount of outdoor fresh air entering the area, the size of the room or area, whether combustion by-products are contaminating the indoor air (*e.g.* idling vehicles near air intakes, leaky furnaces, tobacco smoke), or the outdoor concentration (Minnesota Department of Health, 2014). Working in limited spaces of compartments such as inside motor vehicles can contribute to inhalation of PM_{10}, CO_2 and CO. For this reason, the concentration of PM_{10}, CO_2 and CO needs to be measured in order to maintain a good indoor air quality in bus drivers' compartments.

This study assessed the IAQ inside long distance express bus drivers' compartments in Kuala Lumpur. In this study, the air contaminants measured were CO, CO_2 and Particulate Matter 10 (PM_{10}). The data obtained from this study can be used as a reference for further study regarding IAQ for public transportation and to overcome the air quality problems by providing relevant control measures to ensure the safety, health and welfare of the drivers.

Methodology

Study Location/Study Design

This cross-sectional study was carried out inside long distance express buses, which travelled from Kuala Lumpur, which is located in the western region of peninsular Malaysia to other regions in peninsular Malaysia. The bus routes included routes from Kuala Lumpur to the northern, southern and eastern regions of Peninsular Malaysia, back and forth.

Ethical approval

Approval from Faculty of Medicine and Health Sciences, Universiti Putra Malaysia human research committee was obtained before the study started. Informed consent was also received from each respondent before data were collected.

Sampling

Study populations were all male drivers in express buses, worked as long distance express bus drivers for at least one year, aged between 20 to 56 years old, non-smokers and had no history of chronic respiratory diseases. The sampling frame of this study included all the drivers in the name lists that fulfilled the inclusion criteria obtained from the selected long distance express bus company managers. Thirty respondents fulfilled the inclusion criteria and volunteered to participate in this study.

Instruments and Procedures

Pre-tested validated questionnaires of American Thoracic Society for adults (ATS-DLD-78-A) were used to obtain data on socio-demography such as age, gender, ethnicity, years of working experience, smoking habits and history of diseases. Respiratory symptoms experienced by respondents while being exposed to indoor air pollutants were also obtained using the same questionnaires. The concentration of particles with a diameter of 10 µm or less (PM_{10}) was measured using an aerosol monitor, DUSTTRAK^{TM} (model 8520, TSI Inc., Minnesota, USA). The CO_2 and CO levels were measured by using Q-TRAK PLUS IAQ Monitor (model 8554, TSI Inc.). All of the instruments were calibrated before collecting the samples and were placed near to the drivers' seats. The samples were taken when a steady level was achieved after about 5 min. Lung function test was performed after arriving at the destinations.

Data Analysis

Statistical analysis was carried out using SPSS version 20.0. Categorical variables were presented as frequencies and percentages. Shapiro-Wilk test was used to determine the normality of the data. The data for continuous variables were presented as mean and standard deviation (SD). Chi-square test and Fisher's Exact Test were used to make comparison and to determine association between categorical variables. Spearman's rho test and Pearson Correlation Test were used to determine associations between these continuous variables. A two-sided *p*-value less than 0.05 were considered statistically significant.

Results

Socio-demographic data of respondents

Table 1 shows the socio-demographic data of long distance bus drivers. The data for age, height, weight and working experiences were normally distributed. The mean and standard deviation of the respondents' ages were 41.70±7.80 years old and the range was between 27 to 56 years old. The mean and standard deviation of the respondents' height were 166.43±4.45cm and the range was between 157 to 180 cm. The mean and standard deviation of the respondents' weight were 64.73±6.35 kg and the range was between 48 to 80 kg. The mean and standard deviation of the respondents' working experiences were 7.77±6.16years and the range was between 1 to 26 years with the express bus transportation companies.

Table 1: Socio-demographic data (N= 30)

Variables	**Mean ± S.D**	**Range**
Age (year)	41.70 ± 7.80	27 – 56
Height (cm)	166.43 ± 4.45	157 – 180
Weight (kg)	64.73 ± 6.35	48 - 80
Working experience (year)	7.77 ± 6.16	1 - 26

Indoor air pollutants concentration

Table 2 shows the concentration of indoor air pollutants (PM_{10}, CO_2 and CO) in the express buses. From the data obtained, the concentration of particulate matter (PM_{10}) was 220.00±120.00 µg/m^3, CO_2 was 1085.50±460.98 ppm, and CO was 2.79±0.95 ppm.

Table 2: The concentration of indoor air pollutants (PM_{10}, CO_2 and CO) in the express bus

Variables	**Mean±SD**	**Range**
Concentration of PM_{10} (µg/m^3)	220.00±120.00	10.00 – 410.00
Concentration of CO (ppm)	2.79±0.95	1.20 – 4.60
Concentration of CO_2 (ppm)	1085.50±460.98	466.00 – 2147.00

Meanwhile, Table 3 shows the list of indoor air contaminants and the acceptable limits, which are set by several organisations as listed in the table. The mean concentration of indoor PM_{10} inside the express buses (220.00±120.00 µg/m^3) had exceeded the 24-hours annual mean (150 µg/m^3) recommended by United States Environmental Protection Agency (USEPA). The mean concentration of indoor CO_2 inside the express buses (1085.50±460.98ppm) had also exceeded the range (1000 ppm) recommended by National Institute for Occupational Safety and Health (NIOSH) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 700ppm. Meanwhile, the mean concentration of indoor CO inside express buses (2.79±0.95ppm) had not exceeded the 8-hour limit (50 ppm) recommended by Occupational Safety and Health (OSHA), 8-hour limit (35 ppm) by NIOSH, 8-hour limit (9 ppm) by USEPA, ASHRAE and World Health Organisation (WHO), 8-hour limit (25 ppm) by American Conference of Industrial Hygienists (ACGIH).

Table 3: List of indoor air contaminants and the acceptable limits

Indoor Air Pollutants	**Limit/Range**		**References**
Particulate Matter (PM_{10})	50µg/m^3 (annual mean) 150µg/m^3 (24-hours mean)		USEPA
Carbon Dioxide (CO_2)	1000 ppm		NIOSH
	700 ppm		ASHRAE
	5000 (prolonged period) 35000 ppm (for 15 minutes)		OSHA
Carbon Monoxide (CO)	8-hour TWA	1-hour TWA	
	50 ppm	-	OSHA
	35 ppm	-	NIOSH
	9 ppm	35 ppm	USEPA
	9 ppm (peak)	-	ASHRAE
	25 ppm	-	ACGIH
	9 ppm	26 ppm	WHO

Respiratory symptoms

The modified questionnaire from American Thoracic Society-Adult Questionnaire (ATS) was used to identify the prevalence of respiratory symptoms among the respondents. There were eight respiratory symptoms studied in order to find its association with indoor air pollutants level. Table 4 shows the respiratory symptoms that were experienced by the respondents. The most common symptoms experienced by the respondents were sore throat (43.3%), runny nose (33.3%), and blocked nose (26.7%). Table 5 shows the chronic respiratory symptoms that were reported among drivers were phlegm (23.3%), cough (20.0%), wheezing (13.3%) and chest tightness (10.0%).

Table 4: Respiratory symptoms among the respondents (N= 30)

Variables	**Study group n (%)**	
	Yes	**No**
Dry eye	17 (56.7)	13 (43.3)
Watery/itchy eye	12 (40.0)	18 (60.0)
Stuffy nose	8 (26.7)	22 (73.3)
Runny nose	10 (33.3)	20 (66.7)
Sore throat	13 (43.3)	17 (56.7)
Exhausted/ fatigue	23 (76.7)	7 (23.3)
Headache	9 (30.0)	21 (70.0)
Dry/itchy skin	6 (20.0)	24 (80.0)

Table 5: Chronic respiratory symptoms among respondents (N= 30)

Variables	**Study group n (%)**	
	Yes	**No**
Cough	6 (20.0)	24 (80.0)
Phlegm	7 (23.3)	23 (76.7)
Chest tightness	3 (10.0)	27 (90.0)
Wheezing	4 (13.3)	26 (86.7)

Lung function test

Lung function test was done to assess the respiratory health and impairment of bus drivers. By having these data, we can identify the association between indoor air pollutants concentration and respiratory symptoms experienced by respondents. Lung function test was performed after arriving at their destinations to determine the reduction of lung function among respondents. Table 6 shows the FVC%, FEV_1% and FEV_1/FVC% of lung function abnormalities whereas Table 7 shows the prevalence of lung function abnormality.

Table6: Lung function of respondents (N = 30)

Variables	**Median(IQR)**	**Range**
FVC%	85.29(35.91)	17.00-123.00
FEV_1%	99.57(44.10)	6.00-120.00
FEV_1/FVC%	109.09(18.25)	35.00-167.00

Table 7: Prevalence of lung function abnormality

Variables		**Study Group (N = 30)**	
		n	**%**
FVC%	Abnormal	15	50.0
	Normal	15	50.0
FEV_1%	Abnormal	15	50.0
	Normal	15	50.0
FEV_1/FVC%	Abnormal	14	46.7
	Normal	16	53.3

(Note: Abnormal <80%; Normal>80%)

Association between levels of indoor air pollutants concentration (PM_{10}, CO_2 and CO) respiratory symptoms

The result from Table 8 shows that there was a non-significant increase risk of chronic cough (OR = 1.69, 95%CI = 0.26-11.07) for PM_{10} levels of concentration.

Table 8: Association between level of PM_{10} concentration and respiratory symptoms (N = 30)

Variables	Exposure to PM_{10} n(%)		χ^2	p	OR	95% CI
	High	Low				
Chronic Cough						
Yes	4(66.7)	2(33.3)	-	0.672[a]	1.692**	0.259-11.065
No	13(54.2)	11(45.8)				
Chronic Phlegm						
Yes	3(42.9)	4(57.1)	-	0.666[a]	0.482	0.087-2.680
No	14(60.9)	9(39.1)				
Chest tightness						

Yes	0(0)	3(100)	-	0.070[a]	0.370	0.226-0.606
No	17(63.0)	10(37.0)				
Wheezing						
Yes	2(50.0)	2(50.0)	-	1.000[a]	0.733	0.089-6.041
No	15(57.7)	11(42.3)				
Dry eye						
Yes	8(47.1)	9(52.9)	1.475	0.225	-	-
No	9(69.2)	4(30.8)				
Watery/itchy eye						
Yes	6(50.0)	6(50.0)	0.362	0.547	-	-
No	11(61.1)	7(38.9)				
Blocked nose						
Yes	4(50.0)	4(50.0)	-	0.698[a]	0.692	0.136-3.518
No	13(59.1)	9(40.9)				
Runny nose						
Yes	4(40.0)	6(60.0)	-	0.255[a]	0.359	0.075-1.714
No	13(65.0)	7(35.0)				
Sore throat						
Yes	7(53.8)	6(46.2)	0.074	0.785	-	-
No	10(58.8)	7(41.2)				
Exhausted/fatigue						
Yes	13(56.5)	10(43.5)	-	1.000[a]	0.975	0.177-5.358
No	4(57.1)	3(42.9)				
Headache						
Yes	4(44.4)	5(55.6)	-	0.433[a]	0.492	0.101-2.396
No	13(61.9)	8(38.1)				
Dry /itchy skin						
Yes	3(50.0)	3(50.0)	-	1.000[a]	0.714	0.119-4.297
No	14(58.3)	10(41.7)				

(Note: *significant at $p<0.05$, **OR significant >1 at 95% CI, [a] Fisher Exact Test)

Table 9 shows that there were non-significant increase risk of chest tightness (OR = 2.91, 95%CI = 0.23-36.16), wheezing (OR = 1.36, 95%CI = 0.17-11.23), blocked nose (OR = 1.44, 95%CI = 0.28-7.34), and runny nose (OR = 1.50, 95%CI = 0.33-6.92) for CO_2 levels of concentration.

Table 9: Association between level of CO_2 concentration and respiratory symptoms (N= 30)

Respiratory Health Symptom	**Exposure to CO_2 n(%) High**	**Low**	**χ^2**	**p**	**OR**	**95% CI**
Chronic Cough						
Yes	2(33.3)	4(66.7)	-	0.672[a]	0.591	0.090-3.864
No	11(45.8)	13(54.2)				
Chronic Phlegm						
Yes	3(42.9)	4(57.1)	-	1.000[a]	0.975	0.177-5.385
No	10(43.5)	13(56.5)				
Chest tightness						
Yes	2(66.7)	1(33.3)	-	0.565[a]	2.909**	0.234-36.164
No	11(40.7)	16(59.3)				
Wheezing						
Yes	50.0)	2(50.0)	-	1.000[a]	1.364**	0.166-11.233
No	11(42.3)	15(57.7)				
Dry eye						
Yes	7(41.2)	10(58.8)	0.074	0.785	-	-
No	6(46.2)	7(53.8)				
Watery/itchy eye						
Yes	5(41.7)	7(58.3)	0.023	0.880	-	-
No	8(44.4)	10(55.6)				
Blocked nose						
Yes	4(50.0)	4(50.0)	-	0.698[a]	1.444**	0.284-7.341
No	9(40.9)	13(59.1)				
Runny nose						
Yes	5(50.0)	5(50.0)	-	0.705[a]	1.500**	0.325-6.918
No	8(40.0)	12(60.0)				

Sore throat						
Yes	6(46.2)	7(53.8)	0.074	0.785	-	-
No	7(41.2)	10(58.8)				
Exhausted/fatigue						
Yes	9(39.1)	14(60.9)	-	0.666[a]	0.482	0.087-2.680
No	4(57.1)	3(42.9)				
Headache						
Yes	3(33.3)	6(66.7)	-	0.691[a]	0.550	0.108-2.805
No	10(47.6)	11(52.4)				
Dry /itchy skin						0.233-8.421
Yes	3(50.0)	3(50.0)	-	1.000[a]	1.400**	
No	10(41.7)	14(58.3)				

(Note: *significant at $p<0.05$, **OR significant >1 at 95% CI, [a] Fisher Exact Test)

Table 10 shows that there was a non-significant of respiratory symptom for CO levels of concentrations.

Table 10: Association between level of CO concentration and respiratory symptoms (N= 30)

Respiratory Health Symptom	**Exposure to CO n(%)**		**χ^2**	**p**	**OR**	**95% CI**
	High	**Low**				
Chronic Cough						
Yes	3(50.0)	3(50.0)	-	1.000[a]	0.846	0.141-5.070
No	13(54.2)	11(45.8)				
Chronic Phlegm						
Yes	3(42.9)	4(57.1)	-	0.675[a]	0.577	0.104-3.186
No	13(56.5)	10(43.5)				
Chest tightness						
Yes	1(33.3)	2(66.7)	-	0.586[a]	0.400	0.032-4.960
No	15(55.6)	12(44.4)				
Wheezing						
Yes	2(50.0)	2(50.0)	-	1.000[a]	0.857	0.104-7.043
No	14(53.8)	12(46.2)				

Dry eye						
Yes	8(47.1)	9(52.9)	0.621	0.431	-	-
No	8(61.5)	5(38.5)				
Watery/itchy eye						
Yes	5(41.7)	7(58.3)	1.094	0.296	-	-
No	11(61.1)	7(38.9)				
Blocked nose						
Yes	2(25.0)	6(75.0)	-	0.101[a]	0.190	0.031-1.177
No	14(63.6)	8(36.4)				
Runny nose						
Yes	3(30.0)	7(70.0)	-	0.122[a]	0.231	0.045-1.184
No	13(65.0)	7(35.0)				
Sore throat						
Yes	5(38.5)	8(61.5)	2.039	0.153	-	-
No	11(64.7)	6(35.3)				
Exhausted/fatigue						
Yes	12(52.2)	11(47.8)	-	1.000[a]	0.818	0.149-4.505
No	4(57.1)	3(42.9)				
Headache						
Yes	3(33.3)	6(66.7)	-	0.236[a]	0.308	0.060-1.589
No	13(61.9)	8(38.1)				
Dry /itchy skin						
Yes	2(33.3)	4(66.7)	-	0.378[a]	0.357	0.054-2.344
No	14(58.3)	10(41.7)				

(Note: *significant at p<0.05, **OR significant >1 at 95% CI, [a] Fisher Exact Test)

Association between levels of indoor air pollutants concentration (PM_{10}, CO_2 and CO) lung function

The result from Table 11 shows that there is a significant difference between levels of PM_{10} concentration and FVC% value, while results from Table 12 and Table 13 show that there was no significant difference between CO_2 and CO levels of exposure concentration.

Table 11: Comparison between level of PM_{10} concentration and lung function (N= 30)

Variables		Personal Exposure of PM_{10} n(%) High	Low	χ^2	P
FVC%	Abnormal	12(80.0)	3(20.0)	6.652	0.010*
	Normal	9(33.3)	10(66.7)		
FEV_1%	Abnormal	10(66.7)	5(33.3)	1.231	0.269
	Normal	7(46.7)	8(53.3)		
FEV_1/FVC%	Abnormal	8(57.1)	6(42.9)	0.002	0.961
	Normal	9(56.7)	7(43.3)		

(Note: *significant at p<0.05)

Table 12: Comparison between level of CO_2 concentration and lung function (N= 30)

Variables		Personal Exposure of CO_2 n(%) High	Low	χ^2	p
FVC%	Abnormal	6(40.0)	9(60.0)	0.136	0.713
	Normal	7(46.7)	8(53.3)		
FEV_1%	Abnormal	6(40.0)	9(60.0)	0.136	0.713
	Normal	7(46.7)	8(53.3)		
FEV_1/FVC%	Abnormal	6(42.9)	8(57.1)	0.002	0. 961
	Normal	7(43.8)	9(56.2)		

(Note: *significant at I<0.05)

Table 13: Comparison between level of CO concentration and lung function

Variables		Personal Exposure of CO n (%) High	Low	χ^2	p
FVC%	Abnormal	9(60.0)	6(40.0)	0.536	0.464
	Normal	7(46.7)	8(53.3)		
FEV_1%	Abnormal	7(46.7)	8(53.3)	0.536	0.464
	Normal	9(60.0)	6(40.0)		
FEV_1/FVC%	Abnormal	7(50.0)	7(50.0)	0.117	0.732

Normal	9(56.2)	7(43.8)

(Note: *significant at $p<0.05$)

Association between working duration (years) and the lung function parameters

Normality test showed that the data was not normally distributed. Hence, Spearman's rho test was used to determine the correlation between working duration (years) and the lung function parameters among the respondents. Table 14 shows that there were significant correlations between years of working duration with FVC (p = 0.016) and FEV_1 (p = 0.013).

Table 14: Correlation between working duration (years) and the lung function parameters among respondents (N= 30)

Variables	**Working Duration (Years)**	
	r value	**p value**
FVC (litre/s)	-0.434	0.016*
FEV_1 (litre/s)	-0.450	0.013*
FVC %	0.149	0.433
FEV_1 %	0.235	0.212
FEV_1/FVC %	0.266	0.156

(Note: *significant at p<0.05)

Discussions

Socio-demographic data of respondents

This study involved 30 long distance express bus drivers who fulfilled the inclusion criteria from local transportation companies, who were exposed to the indoor air pollutants inside air-conditioned bus such as PM_{10}, CO_2 and CO. Due to limited time of conducting the study, only 30 respondents volunteered to participate and fulfilled the inclusion criteria in this study. From the results, the mean age of the respondents was 41.70±7.795 years old. Age was considered as an important factor in the present study to understand the susceptibility to air pollutant-induced lung diseases. According to Sheldon (2011), age, weight and height are important factors that can influence the lung function parameters among the subjects.

Indoor air pollutants concentrationof particulate matter (PM_{10})

The levels of PM_{10} vary within individual buses over time. Moreover, almost all long distance express buses are operated with conventional fuel, the diesel, which is a source of PM_{10} from the bus itself. Location and age of bus engine, ventilation system of the bus, maintenance of bus and length of bus route may affect the concentration levels of indoor PM_{10} in the buses. The mean concentration of indoor PM_{10} inside the express buses (220.00±120.0 $\mu g/m^3$) had exceeded the 24-hours annual mean (15 $\mu g/m^3$) recommended by USEPA. The concentration levels of PM_{10}done by Huang and Hsu (2009) in the long distance buses were 17$\mu g/m^3$, which was lower compared to transit buses (196.1 $\mu g/m^3$), but there is no standard that has been regulated regarding exposure of indoor air pollutants in motor vehicles such as buses. Long distance buses have lower concentrations of PM_{10} because they do not idle as much as transit buses, which have to fetch and drop passengers here and there frequently. When the bus is idling and waiting for passengers to come in, the build-up of PM_{10} within the bus cabin occurs. Other studies in developing countries have reported the range of PM_{10} values inside cars (65-1401 $\mu g/m^3$), buses (125-18 $\mu g/m^3$) and subways (55-78 $\mu g/m^3$). Table 3 showed the acceptable limits of indoor air pollutions by WHO (2005).

Carbon dioxide (CO_2)

From the data obtained, the concentration of CO_2 (1085.50 ppm) was higher when compared to a study done by Huangand Hsu (2009) in long-distance buses (159 ppm), but lower compared to a study done by Jones *et al.*(2006) in air-conditioned bus in Hong Kong (2113.8 ppm). In addition, the mean concentration of indoor CO_2 inside the express buses (1085.50±460.98 ppm) had exceeded the range (1000 ppm) recommended by NIOSH and ASHRAE (700 ppm). At this high concentration level of CO_2 inside air-conditioned buses, it reflected the insufficient ventilation inside the buses, in part also caused by the number of passengers inside buses. As respiration from occupants in the buses contributed to accumulation ofCO_2inside the buses, CO_2 concentrations were also observed to increase if no door or window was opened. On the other hand, PM_{10} concentration tends to increase when the doors and windows were opened, which allow for circulation of air inside and outside of the buses.

Carbon monoxide (CO)

The CO levels (2.79ppm) in the long-distance buses in this study were lower than those obtained from urban buses in Athens, Greece at 9.6 ppm (Hsu *et al*., 2009). Besides that, the mean concentration of indoor CO inside express buses (2.79±0.95 ppm) had also not exceeded the 8-hour limit (50 ppm) recommended by OSHA, 8-hour limit (35 ppm) by NIOSH, 8-hour limit (9 ppm) by USEPA, ASHRAE and WHO, 8-hour limit (25 ppm) by ACGIH. Source of CO inside the buses was from the incomplete combustion emitted by vehicles. The low CO levels in long-distance buses are due to faster driving speed of the buses and the condition of the roads taken. When the buses were driven on interstate highways with low traffic volumes and moderate speeds, the concentration of CO was found to be low. When compared to intercity buses, long-distance buses do not stop and drive as frequent as intercity buses. When the intercity bus stops, outdoor CO could penetrate inside the bus and get trapped indoors. Intercity buses are exposed to more vehicles and traffic on city roads, whereas long-distance buses are exposed mostly to vehicles on the highways.

Respiratory symptoms

Respiratory symptoms among respondents were obtained using American Thoracic Society Questionnaires (ATS, 1978). Eight respiratory symptoms were studied among the respondents, but not all of them were having the same respiratory symptoms. It is common for people to report one or more of the following symptoms like dryness and irritation of the eyes, nose, throat, and skin, headache, fatigue, shortness of coughing and sneezing, dizziness, etc. Some people may not be sensitive to indoor air quality problems in the early years of exposure, but can become sensitized as exposure continues over time (Canadian Centre for Occupational Health and Safety, 2013). The most common symptoms experienced by respondents were sore throat (43.3%), runny nose (33.3%), and blocked nose (26.7%). Table 5 shows the chronic respiratory symptoms that were reported among drivers, which include phlegm (23.3%), cough (20.0%), wheezing (13.3%) and chest tightness (10.0%). In a study done by Jones *et al*. (2006), long distance express bus drivers experienced sore throat (11.1%), runny nose (8.0%), chronic cough (7.7%) and chest tightness (6.7%). In a local study by Zainuddin*et al.* (2005), they found that transit bus drivers experienced phlegm (37.3%), chest tightness (31.8%), cough (25.9%), and wheezing (16.4%).

Lung function test

Table 6 shows the distribution of lung function among the respondents. From the result, median and IQR of FVC%, FEV_1% and FEV_1/FVC% of lung function were 85.29(35.91), 99.57(44.10) and 109.09(18.25). Table 7 shows the prevalence of lung function abnormality. Normal FVC% value and FEV_1% value were 80%. FVC% value and FEV_1% value below 80% were considered as abnormal. From the result, 50.0% was classified as abnormal for FVC% value and FEV_1% value, while abnormal for FEV_1/FVC% value was 46.7%.

Association between levels of indoor air pollutants concentration (PM_{10}, CO_2 and CO) respiratory symptoms

From the result, it shows that there was non-significant respiratory symptom for CO levels of concentration due to the small number of respondents in this study. Headache, dizziness, fatigue and dyspnea shows the occurrence of CO. Unintentional exposure to CO can be attributed to smoke inhalation from inadequately vented combustion appliances, and from vehicles and tobacco smoke. Acute effects are due to the formation of carboxyhaemoglobin in the blood, which inhibits oxygen intake and caused difficulty of breathing or chest tightness (WHO, 2005). The ventilation system in closed buses may serve to concentrate CO_2 generated by passengers and other pollutants if the exchange of air is not effective enough. Exposure to CO_2 for long duration with high concentration may cause a feeling like unable to breathe (dyspnea), increased pulse rate, headache, and itchy skin. The symptoms experienced by the respondents may due to the long-term exposures with lower concentration level. Zainuddin*et al*., (2005) and Pope and Dockery (1999) found that there was association between lower respiratory symptoms, asthma, cough and reduction of lung function. Even though this study showsthat, there was no significant association but respondents still have the risks of getting respiratory symptoms if exposed for long-term period.

Association between levels of indoor air pollutants concentration (PM_{10}, CO_2 and CO) and lung function

Exposure to low concentration of PM_{10} in long duration can cause impairment of lung function among the respondents. Concentration level of PM_{10} (220.00±120.00µg/m^3) is considered low but it has the potential to cause the development of chronic disease of lung function. Meanwhile, exposure to CO_2 and CO does not have any correlation with lung function problems. The effects of indoor air pollutants to respiratory health depends on many factors such as level of pollutants exposures, duration of exposures, individual susceptibility levels and also their individual features such as age, gender, smoking habits, genetics and eating habits (Zainuddin*et al*., 2005).

Association between working duration (years) and the lung function parameters among respondents

Shapiro-Wilk test indicated that the data was not normally distributed and Spearman's rho test was used to determine the correlation between working duration (years) and the lung function parameters among respondents. Table 14 shows that the result were inversely correlated between working duration with FVC ($p = 0.016$, $r = -0.434$) and FEV_1 ($p = 0.013$, $r = -0.0450$), which indicated that duration of exposure to air pollutants also contributed to decreased in lung function. There was no correlation between working duration with FVC %, FEV_1 % and FEV_1/FVC %. According to Zainuddin*et al.*(2005), lung function depended on health status, eating habits, smoking status and lifestyles. There is a possibility that the respondents were exposed to indoor air pollutants for a long-term, but practiced a healthy lifestyle and did not have lung function decline that is apparent.

Conclusion

Common symptoms experienced by the 30 bus driver respondents were sore throat (43.3%), runny nose (33.3%), and blocked nose (26.7%). Chronic respiratory symptoms that were reported by the drivers were phlegm (23.3%), cough (20.0%), wheezing (13.3%) and chest tightness (10.0%). Exposure to PM_{10} in air-conditioned buses such as long distance express buses can increase the risk of respiratory illnesses and the reduction of lung function among the bus drivers. The risk could be worse for older drivers or drivers with respiratory diseases. The respiratory concentrations of PM_{10}, CO_2 and CO were still below the permissible level according to indoor air guidelines by WHO. However, since there is no standard regulated for indoor air quality inside a motor vehicle, it is better to always keep the exposure level to these indoor air pollutants at the minimum level.

Exposure to air pollutants continuously over a long period while driving has a potential to cause chronic effect to drivers' respiratory health. Therefore, control measures are needed to improve these situations. Regular cleaning and maintenance, as well as good ventilation system will help to reduce accumulation of indoor air pollutants in the long distance express buses. Future studies from the findings of this research can be conducted to observe any connection between exposures to indoor air pollutants in long distance express buses with cognitive function of the bus drivers. Apart from the long distance express bus drivers, the respondents could also be the long distance lorry, trailer or railway train drivers.

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