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Evaluation of In-Vehicle Pollutants Exposure during Movement Control Order (MCO) and Respiratory Symptoms among Bus Drivers in Kota Bahru, Malaysia

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Abstract. Exposure to in-vehicle air pollutants has been recognized as a risk factor for respiratory diseases. The present study therefore investigates the factors, including duration of employment and in-vehicle concentrations of fine particulate matter ($PM_{2.5}$), carbon dioxide (CO_2) and nitrogen dioxide (NO_2) that can influence the prevalence of respiratory symptoms in commercial bus drivers. A total of 34 bus drivers and 51 administrative staff (comparative group) from the bus operator in Kota Bahru, Malaysia were randomly enrolled in this cross-sectional study. The personal characteristics and respiratory symptoms were reported using a validated questionnaire from the American Thoracic Society (ATS-DLD-78-A). In-vehicle concentrations of $PM_{2.5}$, CO_2 and NO_2 were continuously measured over eight hours on each bus driver. The prevalence of self-reported cough, phlegm and chronic phlegm among bus drivers were 55.9%, 73.5% and 35.3%, respectively, significantly higher compared to the comparative group ($p < 0.001$). Moreover, the duration of employment with bus operators for more than four years was significantly related to the manifestation of phlegm (OR = 8.27, 95% CI = 3.12-21.89) and cough (OR = 4.57, 95% CI = 1.66-12.59). Among the pollutants measured, concentrations of $PM_{2.5}$ (92.1 $\mu g/m^3$) and CO_2 (486.8 ppm) inside the buses were significantly higher in the morning compared to afternoon hours ($p < 0.001$). These findings provide important evidence for further surveillance programs that could reduce the occupational exposure for bus drivers.
Keywords: Bus driver, In-vehicle pollutants, $PM_{2.5}$, CO_2, Respiratory symptoms

1. Introduction

A considerable amount of epidemiological studies have linked in-vehicle air pollutants, including particulate matters (PM), nitrogen dioxide (NO_2), ozone (O_3) and sulphur dioxide (SO_2) with respiratory morbidity and mortality, particularly asthma and chronic obstructive pulmonary disease (COPD) [1,2]. Taxi drivers, bus drivers, truck drivers as well as passengers are commonly exposed to the in-vehicle air pollutants in the course of their work or travel times. Additionally, they represent a substantial proportion of workforce in urban areas [3]. Furthermore, the concentration of air pollutants in urban areas increased proportionally to the density of vehicles on the road, which can be infiltrated into the vehicles [4,5].

More recently, two reviews found associations between longer average periods of exposure to in-vehicle pollutants and reduction of respiratory performance, airway inflammation and manifestation of respiratory symptoms among commercial drivers [1,6]. Nevertheless, there is scarcity of evidence-based data on the assessment of the effects of the in-vehicle pollutants on bus drivers. Thus, it becomes necessary to consider this problem in a more thorough way. For these reasons, we conducted the present study to determine level of in-vehicle concentrations of $PM_{2.5}$, CO_2, and NO_2 during the Movement Control Order (MCO) period and to explore association of duration of employment with the prevalence of respiratory symptoms in commercial bus drivers in Kota Bahru, Malaysia.

2. Material and Methods

2.1. Study Location and Population

This cross-sectional study was carried out in Kota Bahru City, Kelantan, Malaysia, which is experiencing rapid urbanization. Based on a 2010 census data, Kota Bahru has a population of 44,757 and a size of 394 km^2 [7]. A total of 85 respondents, including 34 bus drivers (exposed group) and 51 employees from the administrative department (comparative group) were enrolled in this study. They were randomly selected from the public bus operators in Kota Bahru.

The inclusion criteria of the respondents were restricted to male drivers, between 20 and 56 years old who had been working with bus operators for at least one year prior to this study. The employees with past history of severe underlying diseases were excluded. This study was conducted from February 2021 to March 2021.

The study protocol was approved by the Ethic Committee for Research Involving Human Subjects in Universiti Putra Malaysia (JKEUPM-2021-027), and obtained all necessary approvals from bus operators. Written informed consent was obtained from all individual participants prior to the study.

2.2. Health Effect Monitoring and Exposure Assessment

A validated American Thoracic Society (ATS-DLD-78-A) questionnaire was self-administered in the native language by the participants to obtain information on personal characteristics and respiratory symptoms. We focused on four different respiratory symptoms: cough, phlegm, wheeze and breathlessness, which were treated as outcome variables. Then, a quick face-to-face interview was carried out to verify the information in the questionnaire.

The occupational exposure to $PM_{2.5}$, NO_2 and CO_2 were recorded with DustTrak™ II Aerosol Monitor (Model 8532 TSI Incorporated, Minnesota, USA), Aeroqual Series 500 (Aeroqual, Auckland, New Zealand) and TSI Q-TRAK Indoor Air Quality Monitor (Model 7565 TSI Incorporated, Minnesota, USA), respectively. These devices were calibrated and secured near the bus driver's seat. All measurements were continuously recorded for two time slots in a day, comprising of the morning hours (7.00 AM-11.00 AM) and afternoon hours (1.00 PM-5.00 PM), to understand the impact of traffic on the levels of $PM_{2.5}$, NO_2 and CO_2. All the respondents were monitored once during the eight hours of work as previously described [8]. The pollutant monitoring was deployed in 22 different commercial buses, which have a capacity for 40 passengers, powered by a diesel engine and equipped with an air-conditioning system. All buses used different urban routes networks in Kota Bahru, but had similar traffic conditions.

2.3. Statistical Analysis
Statistical analyses were performed using the Statistical Package for Social Science (SPSS) 25.0. The Chi-square test was used to evaluate the association and comparison between two groups. A Mann-Whitney test was carried out to evaluate the differences of pollutant concentrations between morning and afternoon hours. Analyses were two-sided and p less than 0.05 were considered statistically significant.

3. Results
3.1. Characteristics and Prevalence of Respiratory Symptoms of Studied Groups
The personal characteristics obtained from the questionnaire are summarized in Table 1. All of the participants were male. The majority of the respondents for both groups were between 32 and 60 years old ($p < 0.001$). Current smokers represented 73.5% and 62.7% of bus drivers and administrative staff, respectively ($p > 0.005$). Furthermore, more than half of the bus drivers had education beyond high school level ($p < 0.05$).

The prevalence of cough, phlegm and chronic phlegm were significantly higher in bus drivers group (55.9%, 73.5% and 35.3%, respectively) compared to comparative group (13.7%, 35.3% and 3.9%, respectively) ($p < 0.001$) (Table 2).

Table 1. Personal characteristics of bus drivers (n = 34) and administrative staff (n = 51).

Characteristics		Bus drivers n (%)	Administrative staff n (%)	*p*-value
Age	20 to 31 (year)	6 (17.6)	30 (58.8)	< 0.001**
	32 to 60 (year)	28 (82.4)	21 (41.2)	
Education level	Low	25 (73.5)	21 (41.2)	0.003*
	High	9 (26.5)	30 (58.8)	
Duration of employment	≤ 4 years	1 (2.9)	44 (86.3)	< 0.001**
	> 4 years	33 (97.1)	7 (13.7)	
Smoking status	Yes	25 (73.5)	32 (62.7)	0.300
	No	9 (26.5)	19 (37.3)	

* $p < 0.05$; ** $p < 0.001$

Table 2. Prevalence of respiratory symptoms of the studied groups.

Respiratory symptom		Bus drivers n (%)	Administrative staff n (%)	*p*-value
Cough	Yes	19 (55.9)	7 (13.7)	< 0.001**
	No	15 (44.1)	44 (86.3)	
Chronic cough	Yes	2 (5.9)	1 (2.0)	0.343
	No	32 (94.1)	50 (98.0)	
Phlegm	Yes	25 (73.5)	18 (35.3)	0.010*
	No	9 (26.5)	33 (64.7)	
Chronic phlegm	Yes	12 (35.3)	2 (3.9)	< 0.001**
	No	22 (64.7)	49 (96.1)	
Wheezing	Yes	2 (5.9)	0 (0)	0.053
	No	32 (94.1)	51 (100)	
Breathlessness	Yes	1 (2.9)	0 (0)	0.174
	No	33 (97.1)	51 (100)	

* $p < 0.05$; ** $p < 0.001$

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3.2. Trend of Pollutants Measured inside the Buses

The observed average concentrations of $PM_{2.5}$ and CO_2 inside the bus for five days in the morning were significantly higher compared afternoon hours ($p < 0.001$) (Figure 1). Similarly, distinct patterns of $PM_{2.5}$ and CO_2 were observed in the day time series (Table 3). Concentration of $PM_{2.5}$ peaked on day two, while CO_2 peaked on day one with the median values of 109 μg/m^3 (IQR = 46.75) and 554.5 ppm (IQR = 75.0), respectively. However, the concentrations of NO_2 measured inside the bus were found to be very less and not statistically different between morning and afternoon hours ($p > 0.05$).

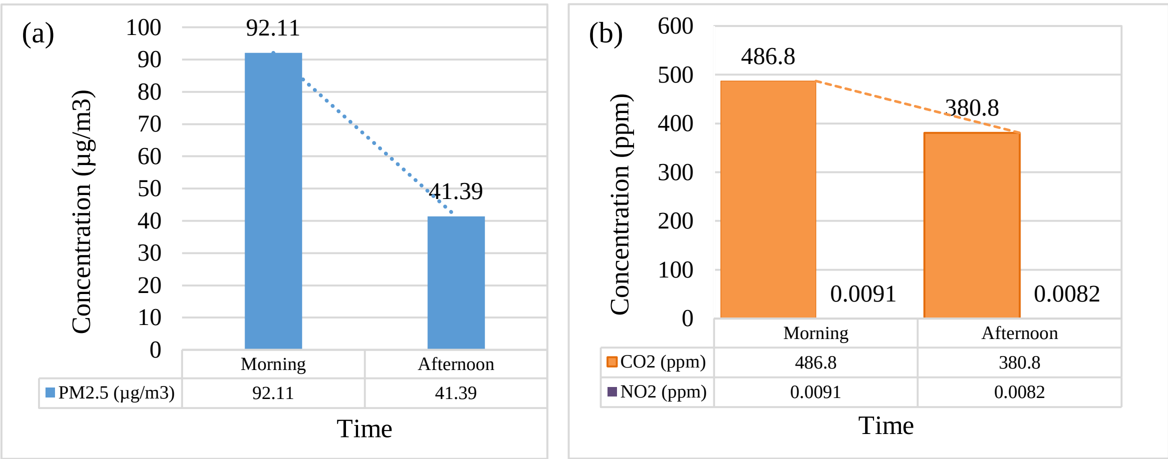

Figure 1. Comparison of average concentration of (a) $PM_{2.5}$ and (b) CO_2 and NO_2 between morning and afternoon hours.

Table 3. Comparison of pollutants in the morning and afternoon hours.

Day	Pollutant	Morning Median (IQR)	Afternoon Median (IQR)	*p*-value
Day 1	$PM_{2.5}$ (μg/m^3)	73.0 (36.50)	34.50 (8.75)	< 0.001**
	CO_2 (ppm)	554.5 (75.0)	368.0 (82.0)	< 0.001**
	NO_2 (ppm)	0.001 (0.014)	0.008 (0.01)	0.317
Day 2	$PM_{2.5}$ (μg/m^3)	109.0 (46.75)	41.0 (9.75)	< 0.001**
	CO_2 (ppm)	522.5 (54.0)	369.5 (38.0)	< 0.001**
	NO_2 (ppm)	0.006 (0.016)	0.01 (0.008)	0.577
Day 3	$PM_{2.5}$ (μg/m^3)	69.50 (26.25)	38.50 (14.50)	< 0.001**
	CO_2 (ppm)	404.0 (59.0)	382.0 (51.0)	< 0.001**
	NO_2 (ppm)	0.00 (0.008)	0.003 (0.005)	0.218
Day 4	$PM_{2.5}$ (μg/m^3)	88.50 (30.50)	39.0 (13.25)	< 0.001**
	CO_2 (ppm)	481.0 (83.0)	390.0 (52.0)	< 0.001**
	NO_2 (ppm)	0.004 (0.015)	0.009 (0.008)	0.353
Day 5	$PM_{2.5}$ (μg/m^3)	88.50 (55.0)	40.50 (17.25)	< 0.001**
	CO_2 (ppm)	472.0 (38.0)	394.50 (26.0)	< 0.001**
	NO_2 (ppm)	0.007 (0.015)	0.005 (0.005)	0.786

** $p < 0.001$
IQR = Interquartile range

3.3. Association between Duration of Employment and Respiratory Symptoms

Table 4 lists the prevalence and odd ratio for respiratory symptoms in relation to the duration of employment. Overall, respiratory symptoms were more common among respondents employed for more than four years than for those with a shorter duration of employment with bus operators. In particular, the risk of phlegm occurrence was the highest among the four respiratory symptoms (OR = 8.27, 95% CI = 3.12-21.89), followed by manifestation of cough with an odd of 4.57 (95% CI= 1.66-12.59).

Table 4. Prevalence of respiratory symptoms by duration of employment (N= 85).

Respiratory symptom		Duration of employment ≤ 4 years n (%)	> 4 years n (%)	*p*-value	OR	95% CI
Cough	Yes	7 (15.9)	19 (46.3)	0.002*	4.57	1.66-12.59
	No	37 (84.1)	22 (53.7)			
Chronic cough	Yes	1 (2.3)	2 (4.9)	0.512	2.21	0.19-25.28
	No	43 (97.7)	39 (95.1)			
Phlegm	Yes	12 (27.3)	31 (75.6)	< 0.001**	8.27	3.12-21.89
	No	32 (72.7)	10 (24.4)			
Chronic phlegm	Yes	0 (0)	14 (34.1)	< 0.001**	-	-
	No	44 (100)	27 (65.9)			
Wheezing	Yes	0 (0)	2 (4.9)	0.085	-	-
	No	44 (100)	39 (95.1)			
Breathlessness	Yes	0 (0)	1 (2.4)	0.225	-	-
	No	44 (100)	40 (97.6)			

* $p < 0.05$; ** $p < 0.001$
OR = Odd ratio ; CI = Confidence interval

4. Discussion

This study demonstrated that manifestation of respiratory symptoms of cough, phlegm and chronic phlegm were more common among bus drivers than administrative employees. This similar pattern of prevalence was observed in previous studies conducted in Kuala Lumpur, Malaysia [5], City of Dakar, Senegal [9] and Bursa City, Turkey [10]. Review reported that occupational exposure to air pollution among commercial drivers is linked to adverse health outcomes [3]. Moreover, a high proportion of active smokers (73.5%) among bus drivers was observed in this current study and those reported by Mbelambela et al. [11], where they found that 71.0% of bus driver in Kinshasa, Republic of Congo were active smokers.

Furthermore, this study provides evidence in line with previous epidemiology studies that bus drivers employed for more than four years demonstrated a higher prevalence of respiratory symptoms than those with shorter employment history [12]. Additionally, there are two previous studies that discovered both smokers and non-smokers bus drivers with longer employment history had a higher risk of COPD. They found that the duration of employment of more than 10 years and 20 years exhibited higher prevalence of respiratory symptoms among bus drivers in Hyderabad City, India and urban areas of North Macedonia, respectively [13,14]. Taken together, these findings suggest that bus drivers are experiencing a cumulative effect of occupational exposure.

This current study confirms that bus drivers are exposed to very high levels of $PM_{2.5}$ while at work, especially in the morning. In five days of monitoring, the concentrations of $PM_{2.5}$ were exceeding the 24 hours mean of World Health Organization (WHO) guideline (25 $\mu g/m^3$), the National Ambient Air Quality Standard by U.S. EPA (35 $\mu g/m^3$) and the new Malaysian Ambient Air Quality Standard 2018 Interim Target-2 (50 $\mu g/m^3$). Up to the present time, there is no particular standard level for $PM_{2.5}$ set by the Occupational Safety and Health Act (OSHA, Act 514 1994) or other work exposure standards for Time Weighted Average (TWA) [15]. Therefore, $PM_{2.5}$ exposure level cannot be compared directly with OSHA standard. These findings further support the results from previous studies that in-vehicle concentrations of particulate matter were often higher compared with outdoor micro-environment, which originate from external sources including exhaust emissions [16,17]. One study from Istanbul city, Turkey reported that the concentration of fine and course particles inside buses and cars were greater during rush hours than those during off-peak hours, mostly caused by exhaust emission and resuspension of particles [18].

Our results demonstrated that the NO_2 concentrations inside the buses measured for five days were considerably lower than the standards set by the WHO guidelines (200 μg/m^3) [19] and the National Ambient Air Quality Standard by U.S. EPA (100 ppb) [20]. Moreover, NO_2 concentrations inside the buses reported from various countries were in the range between 15 ppb and 117 ppb [21,22], which is significantly higher compared to our own result. Several factors are known to be partially responsible for this variation. Many studies have demonstrated that the variation of NO_2 concentrations in-vehicle were significantly influenced by idle/close ventilation conditions, ambient temperature, time of the day, seasons, road traffic patterns, filters, fuel type, vehicle age, level of exhaust emissions and outdoor NO_2 levels [23–25]. Nevertheless, our study has been unable to demonstrate the differences of NO_2 concentration between morning and afternoon hours. This result may be explained by the fact that this study was performed during the Movement Control Order (MCO) to reduce the number of coronavirus 2 (SARS-CoV-2) infections, which caused low traffic intensity and eventually reduced the concentrations of air pollutants, including NO_2, CO, CO_2, PM_{10} and $PM_{2.5}$. This is supported by a recent study conducted in Klang Valley, Malaysia during the MCO by Latif et al. [26], who identified that the air concentrations of NO_2 were reduced between -55% and -72% compared with the concentrations from the same periods in 2019 and 2018.

In this current study, the average concentrations of CO_2 ranged from 368.0 to 554.5 ppm, therefore they were much lower than the recommended limit of 1,000 ppm set by the WHO guidelines and the Industrial Code of Practice on Indoor Air Quality (ICOP-IAQ) 2010. This could be explained by the fact that mechanical air circulation inside the vehicle is able to reduce cabin air pollutants [6]. Furthermore, the concentration of CO_2 in-vehicle is also proportional to the number of passengers as demonstrated in a study conducted by Li et al. [27] using CO_2 sensor MH-Z16 and machine learning analysis. More recently, one study conducted using the public bus system in Barcelona, NE Spain reported that in-vehicle CO_2 concentration not only depends on occupancy ratios, but also travelling time, speed of vehicle, ventilation system and opening of the doors and trapdoors on the roof [28]. Another factor that has a significant impact on the concentration of CO_2 is linked with MCO implementation. A recent review reported that the CO_2 emissions in Malaysia were decreased significantly by 9.7% from 250.09 $MtCO_2$ in 2019 to 225.97 $MtCO_2$ in 2020 due to stringent MCO implementation [29].

There are several limitations in this study. First, the nature of cross-sectional study design did not allow the determination of causal relationship. Second, the information on the respiratory symptoms was obtained from a self-administrated questionnaire, which was subject to recall bias. Nevertheless, the impact of this bias was controlled with verification procedures through face-to-face interview after completing the questionnaire. Third, the bus occupancy and traffic density were lower than usual, due to implementation of the MCO and the fear of SARS-CoV-2 infection. Finally, other factors such as different bus travelling routes, ambient air pollution and meteorological variables could have biased our results.

5. Conclusion

In conclusion, our findings showed that the manifestation of cough and phlegm were more common among respondents employed for more than four years than for those with a shorter history of employment with bus operators. Furthermore, the average concentration of CO_2 and NO_2 were below the recommended limits set by the WHO, and the National Ambient Air Quality Standard by U.S. EPA, except for the concentration of $PM_{2.5}$. The diurnal patterns demonstrated an increase in all measured pollutants except NO_2 in the morning hours. This study suggests further longitudinal study design to examine the long-term effects of exposure to in-vehicle pollutants and surveillance programs to reduce the effects of occupational exposure for bus drivers.

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