ORIGINAL ARTICLE

RELATIONSHIP BETWEEN INDOOR AIR POLLUTANTS EXPOSURE AND RESPIRATORY SYMPTOMS AMONG BUS DRIVERS IN A MALAYSIAN PUBLIC UNIVERSITY

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ABSTRACT
Bus drivers are continuously exposed to air pollutants such as particulate matter while working; hence, they have a high risk for respiratory diseases. This study aimed to investigate the associations of exposure to particulate matter (PM2.5, PM10) and nitrogen dioxide (NO2) inside campus transit buses with respiratory symptoms among bus drivers. A cross-sectional comparative study was conducted among 38 bus drivers as the exposed group and 38 office workers as the comparative group at a Malaysian public university. Indoor air monitoring was performed for 8 hours using SidePak Personal Aerosol Monitor, DustTrak II Aerosol Monitor, and Air Quality Monitor, while background information and self-reported respiratory symptoms were obtained using an adapted American Thoracic Society (ATS-DLD-78-A) questionnaire. Air pollutants (PM2.5, PM10 and NO2) exposure between both groups was significantly different at p<0.05. The exposed group had higher odds of getting cough (OR=2.5), chronic cough (OR=2.2) and chronic phlegm (OR=4.6) than the comparative group. Moreover, there were significant associations between PM10 and PM2.5 concentrations with cough (OR=2.2), chronic cough (OR=2.2), and chronic phlegm (OR=2.2). Meanwhile, only cough was significantly associated with NO2 (OR=2.4). Multiple logistic regression showed that the main predictor for cough was PM2.5 (OR=3.2), for chronic cough was PM10 (OR=5.0), and for chronic phlegm was work duration (OR=1.3). In short, the exposed group was exposed to higher concentrations of air pollutants than the comparative group, leading to a higher prevalence of respiratory symptoms among the bus drivers. These findings provide important evidence for future programs to improve the air quality in buses. It is recommended that the indoor air quality inside the bus should be monitored periodically to ensure the drivers and the passengers are not exposed to air pollutants above the permissible limit.

Keywords: Indoor air quality, occupational exposure, traffic air pollution, respiratory health, PM2.5, PM10

INTRODUCTION

The issue concerning traffic-related air pollution (TRAP) has been highlighted nowadays. This issue is critical as it contributes to various detrimental public and environmental health effects. TRAP consists of various groups of air pollutants such as carbon monoxide (CO), carbon dioxide (CO2), volatile organic compounds (VOCs) or hydrocarbons (HCs), nitrogen oxides (NOx), and particulate matter (PM). Other than vulnerable populations such as children, individuals working in the transportation sector are particularly vulnerable to air pollution from traffic ¹. Public transport workers such as bus drivers are continuously exposed to various air pollutants throughout their working hours ².

Occupational hazards linked with bus drivers can be classified into five classes, namely physical, psychosocial, biological, ergonomic, and chemical hazards ³. TRAP is one of the chemical hazards. The associations between occupational exposure to coarse particulate matter (PM10), various fine particulate matter (PM2.5) constituents, and a range of health endpoints have been reported in a few studies ⁴,⁵,⁶,⁷. For instance, black carbon (BC), polyaromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), which mainly come from combustion sources, have been reported to be associated with genotoxic and epigenetic modification ⁸,⁹,¹⁰. There is evidence of the effects of short-term exposure to PM10 on respiratory health, but for mortality, and especially as a consequence of long-term exposure, PM2.5 is a stronger risk factor than PM10 ¹¹,¹². Many epidemiological studies have revealed a significant association between PM2.5 and human health, particularly cardiovascular and respiratory diseases ¹³,¹⁴.

The indoor air quality (IAQ) inside the buses could be an early indicator of the bus drivers’ respiratory health as they spent around 8–9 hours per day of their working time in this microenvironment ¹⁵. Exposure to poor IAQ in air-conditioned buses can increase the risk of respiratory illnesses among bus drivers ¹⁶. The threat could be worse for older drivers or drivers with underlying medical conditions. As there is a growing concern about vehicle IAQ, this study was performed to give an insight into the association between exposure to air pollutants concentration (PM2.5, PM10 and NO2) inside campus transit buses with respiratory symptoms among bus drivers. Currently, there is no clear standard, guideline, or policy on IAQ, energy usage, and energy efficiency for transportation in Malaysia. Therefore, the outcomes from this study will contribute to forming a safety and health manual,
guideline, or policy toward a better microenvironment for both drivers and passengers.

METHODS

Study design and population
This cross-sectional comparative study was conducted from January to March 2020, which was during the hot season in Malaysia with little rain and wind. There were 38 respondents among bus drivers as the exposed group and 38 respondents among office workers as the comparative group. Both groups of respondents were employees at a public university in Selangor, Malaysia. This campus is only a 10-minute drive from the federal territory of Putrajaya. The office workers were chosen from two faculties: Faculty of Medicine and Health Sciences and Faculty of Science. The respondents were randomly selected from the name list provided by the management of the university. They were all males, non-smokers, aged between 20 to 56 years old, of Malaysian nationality, had at least one year of working experience in the current position, and had no history of chronic lung and respiratory diseases. None of the office workers were passive smokers, but all bus drivers were exposed to second-hand smoke in the workplace when they were not driving the buses.

Questionnaires
Background information and reported respiratory symptoms of respondents were obtained using a validated questionnaire from the American Thoracic Society (ATS-DLD-78-A), which was translated into Malay and used in a previous local study to ease literacy among the respondents. The questionnaire comprised information such as sociodemographic status, personal and family history of diseases, reported respiratory symptoms, and workplace environment. Moreover, a quick face-to-face interview was carried out to verify the questionnaire information. The questionnaires were pre-tested with the total respondents of 10% of the total sample size to ensure their validity and reliability.

Exposure assessment
Personal exposure monitoring is deemed most fully developed in relation to air pollution, particularly in the workplace. For each respondent, the occupational exposure to PM$_{2.5}$, PM$_{10}$ and NO$_2$ was measured using SidePak Personal Aerosol Monitor (TSI, USA; model 8532), DustTrak II Aerosol Monitor (TSI, USA; model 8532) and Air Quality Monitor (Aeroqual, New Zealand; series 500), respectively. All instruments in this study were calibrated according to manufacturer’s specifications before being used. Moreover, these instruments had suitable detection ranges and limits of detection to cover the study aims. During the exposure measurement, all instruments were placed near the working area of the respondents to simulate personal exposure. The instruments were positioned 1.1 m from the floor and right in front of the air supply diffusers. For bus drivers, the instruments were placed securely on passenger seats just behind the drivers for 8 hours from 7 a.m. to 4 p.m., as previously described. In addition, the cyclone for SidePak was clipped onto the driver’s collar to simulate the near-breathing zone measurement. The data was taken every 5 minutes at the sampling point with the data logging instruments. In addition, no housekeeping activities were carried out during the sampling period.

These instruments were deployed in 5 different campus transit buses aged less than 5 years, powered by a diesel engine, and supplied with an air-conditioning system. All buses in this study were obtained from the same manufacturer and had passed the biannual routine inspection at Puspakom Sdn. Bhd., the only national vehicle inspection company appointed by the Malaysian government to perform all mandatory inspections for both commercial and private vehicles. The buses which operated between the locations on-campus and selected destinations off-campus were excluded to match similar traffic conditions among the bus drivers. Each bus is a single coach that can transport up to 42 passengers at one time. Data were sampled from Monday to Friday for three sessions on each bus, with 5 different intercampus routes based on the main areas of the university that they serve. For the measurement among the office workers, the instruments were placed near their working desks for 8 hours of their working hours, from 8 a.m. to 5 p.m., away from direct sources of particulate matter such as windows and printers. The personal monitoring did not include the 1-hour lunch break from 1 to 2 p.m.

Statistical analyses
The data collected from this study was analysed using Statistical Package for Social Science (SPSS) Version 25. Univariate, bivariate and multivariate tests were used to analyse the variables of this study. The criterion of statistical significance was set at $p<0.05$.

Ethical concern
The ethical approval had been granted by the Ethics Committee for Research Involving Human Subjects (reference number: JKEUPM-2019-474). Permission to conduct the study had also been obtained from the management of the bus and office. Informed consent was also obtained from the respondents before performing the study.

RESULTS

Background of respondents
Due to the implementation of lockdown, known as movement control order (MCO) in Malaysia on 18 March 2020, when this study was undergoing data collection phase, only 38 bus drivers and 38 office
workers from the public university participated in this study. Normally, they have to be present at work at 5.30 a.m. and end at 2 p.m. daily for the morning shift. For the evening shift, they are present at the campus at 1.30 p.m. and end their shift at 10 p.m. Hence, the average working hours are 8-10 h daily.

The bus drivers were predominantly Malay males, so the office workers were also selected from the same ethnic group to ensure homogeneity among the study groups. Based on the statistical analysis of sociodemographic information of the respondents, there was a significant difference in age between the exposed group and the comparative group (Table 1). Age, weight and height are considered important factors in this study to understand the susceptibility to respiratory health effects from exposure to air pollution. However, there was no significant difference between the study groups in weight and height. The work duration between the study groups shows a significant difference. The mean work duration for the exposed group was 3, ranging from 1 to 17 years, while the mean work duration for the comparative group was 10, ranging from 1 to 36 years. None of the bus drivers wore face masks while working because they lacked awareness of how they could protect themselves from aerosol and dust.

Table 1: Respondents' background

<table>
<thead>
<tr>
<th>Variables</th>
<th>Exposed (N=38)</th>
<th>Comparative (N=38)</th>
<th>t/z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agea (year)</td>
<td>40.58 ± 8.41</td>
<td>37.24 ± 8.45</td>
<td>2.720</td>
<td>0.043*</td>
</tr>
<tr>
<td>Weightb (kg)</td>
<td>73.84 ± 13.62</td>
<td>77.54 ± 15.83</td>
<td>-1.640</td>
<td>0.101</td>
</tr>
<tr>
<td>Heightc (cm)</td>
<td>168.05 ± 5.20</td>
<td>169.16 ± 3.66</td>
<td>-1.071</td>
<td>0.288</td>
</tr>
<tr>
<td>Work Durationd (year)</td>
<td>3 ± 5</td>
<td>10 ± 10</td>
<td>-2.945</td>
<td>0.005*</td>
</tr>
</tbody>
</table>

a: Independent t-Test; b: Mann U Whitney-Test; *Significant at p<0.05

Table 2: Comparison of average exposure to air pollutants

<table>
<thead>
<tr>
<th>Variables</th>
<th>Exposed (N=38)</th>
<th>Comparative (N=38)</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM10 (µg/m3)</td>
<td>63.00 (11.00)</td>
<td>32.00 (2.00)</td>
<td>-7.00</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>PM2.5 (µg/m3)</td>
<td>61.00 (5.00)</td>
<td>25.00 (6.00)</td>
<td>-7.00</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>NO2 (µg/m3)</td>
<td>49.90 (55.20)</td>
<td>3.20 (1.80)</td>
<td>-5.96</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*Significant at p<0.05

Comparison of reported respiratory symptoms and their associations with indoor air pollutants

The results show that the reported respiratory symptoms were higher in the exposed group compared to the comparative group for all studied symptoms (Figure 1). The bus drivers mainly reported experiencing cough, followed by chronic cough, phlegm, chronic phlegm and breathlessness. On the other hand, the office workers mostly experienced cough, followed by phlegm, chronic cough, chronic phlegm and none for breathlessness. However, only cough, chronic cough and chronic phlegm had significant differences between the two groups.

The statistical results show associations between exposure to air pollutants and reported respiratory symptoms among all respondents (Table 3). There were significant associations between PM10 and cough ($\chi^2=9.14$, p=0.003), chronic cough ($\chi^2=6.68$, p=0.004), and chronic phlegm ($\chi^2=3.93$, p=0.021). Similarly, PM2.5 was found to have significant associations with cough ($\chi^2=9.14$, p=0.003), chronic cough ($\chi^2=6.68$, p=0.004) and chronic phlegm ($\chi^2=3.93$, p=0.021). Furthermore, NO2 was significantly associated with cough ($\chi^2=4.06$, p=0.044) but no other studied respiratory symptoms. On the contrary, there was no significant association between phlegm and breathlessness with any of the studied pollutants.

Exposure to indoor air pollutants

Mann-Whitney U test was conducted, and the results show that there were significant differences in personal exposure to PM10, PM2.5 and NO2 between the two groups (Table 2). The exposed group was exposed to almost twice higher concentrations of PM10 than the comparative group. Besides, the exposed group was exposed to a 2.3 times higher level of PM2.5 than the comparative group. To determine the risk of health effects to the respondents, exposures to concentrations of air pollutants need to be compared to the Industry Code of Practice (ICOP) Malaysia on Indoor Air Quality 2010. Although the respondents had workplace exposures to total dust, Occupational Safety and Health Act (OSHA) Permissible Exposure Levels (PEL) for 8-h Time Weighted Average (TWA) is not suitable to refer in this study because the workers did not work in an enclosed area intended to be used as industrial purposes. Exposure to PM10 and PM2.5 among respondents in this study was less than the regulatory limit of ICOP set by Department of Occupational Safety and Health (DOSH), Malaysia of 150 µg/m3 for respirable particulates. However, there is no indoor air quality standard for NO2 in Malaysia.

Comparison of average exposure to PM10, PM2.5 and NO2 between the two groups (Table 2). The exposed group had almost twice higher concentrations of PM10 than the comparative group. PM2.5 was significantly associated with cough ($\chi^2=9.14$, p=0.003), chronic cough ($\chi^2=6.68$, p=0.004) and chronic phlegm ($\chi^2=3.93$, p=0.021). Furthermore, NO2 was significantly associated with cough ($\chi^2=4.06$, p=0.044) but no other studied respiratory symptoms. On the contrary, there was no significant association between phlegm and breathlessness with any of the studied pollutants.
In order to estimate the probability of respondents getting respiratory symptoms, a binary logistic regression was performed. The results show the factors that influenced the respiratory symptom of the study groups (Table 4). The probability of getting respiratory symptoms was estimated using PM$_{10}$, PM$_{2.5}$, NO$_2$, age, and work duration. PM$_{2.5}$ was the most significant predictor for cough, PM$_{10}$ was the most significant predictor for chronic cough, and work duration was the most significant predictor for chronic phlegm.

**Table 4: Factors that influenced reported respiratory symptoms**

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\beta$</th>
<th>SE</th>
<th>p</th>
<th>AOR</th>
<th>95% CI</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.435</td>
<td>1.164</td>
<td>0.038*</td>
<td>3.2</td>
<td>1.06 - 9.65</td>
<td>0.200</td>
</tr>
<tr>
<td>PM$_{2.5}^a$</td>
<td></td>
<td></td>
<td>0.262</td>
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<tr>
<td>Chronic Cough</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.512</td>
<td>1.608</td>
<td>0.026*</td>
<td>5.0</td>
<td>1.21 - 20.59</td>
<td>0.246</td>
</tr>
<tr>
<td>PM$_{10}^b$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Chronic Phlegm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>3.360</td>
<td>0.258</td>
<td>0.020*</td>
<td>1.3</td>
<td>1.04 - 1.61</td>
<td>0.532</td>
</tr>
<tr>
<td>Work Duration$^b$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N=72; $^a$Regression Coefficient; $^b$Standard Error; AOR: Adjusted Odds Ratio; $^a$: continuous variable; $^b$: categorical variable; *Significant at p<0.05
DISCUSSION

Based on the observation, the comparative group had a longer work duration compared to the exposed group. The bus company administration stated that these bus drivers work within their contracts for only a few years and tend to shift their jobs after a few years.

The higher particle exposure to the bus drivers may be due to the elevated presence of PM$_{10}$ and PM$_{2.5}$ sources around the bus. Anthropogenic sources of PM$_{10}$ are highly variable and include solid-fuel combustion, erosion of the pavement by road traffic, and abrasion of brakes and tyres. It could also be due to the bus passengers on board carrying the air particles with their footsteps. This finding was supported by an experimental study on walking-induced resuspension, which explained that shoe type and flooring materials are involved in releasing particles from a foot moving on a surface. On average, the bus drivers will stop at 6 different checkpoints to drop off and pick up the students along their trips. Frequent door opening at scheduled stops and movement of passengers had caused resuspension of the particles originating from non-tailpipe emissions.

Besides, diesel engine as an internal combustion engine, produces more torque for large vehicles and generates more particulates, including soot during the combustion. Some particles are also generated by the lubricating oil in the engine. This current finding was consistent with a previous local study, which discovered that the bus drivers in Klang Valley were exposed to 2.4 times higher concentrations of PM$_{2.5}$ than the office workers. Moreover, the concentrations of PM$_{2.5}$ and PM$_{10}$ inside the buses in this study seemed to be relatively lower than the concentration of PM$_{2.5}$ and PM$_{10}$ in Klang Valley (PM$_{2.5}$= 72 µg/m$^3$, PM$_{10}$= 94 µg/m$^3$). The finding on NO$_2$ was coherent, which revealed that the exposure of bus drivers to NO$_2$ was significantly higher than that of administrative workers ($p<0.001$), with differences close to 75%. On the other hand, the NO$_2$ concentration in the buses in this study was higher than the NO$_2$ concentration in a previous local study in Kota Bharu (NO$_2$= 17 µg/m$^3$). The vast differences in exposure levels between the study groups may be due to the elevated presence of NO$_2$ sources around the bus. Moreover, occupational exposure to NO$_2$ can be elevated in indoor spaces with the use of diesel-fuelled machines.

A local study reported that bus drivers had a significantly higher prevalence of cough (85.7%, $p=0.002$) and phlegm (90.0%, $p<0.001$) compared to the comparative group. All these symptoms might indicate an elevated level of air pollutants in the work environment of the bus drivers, particularly in the cabin. Exposure to urban air pollutants without any preventive measures has caused bus drivers to be highly susceptible to respiratory symptoms over time. These findings on the associations between the reported respiratory symptoms among bus drivers and their exposure to vehicle emissions provide evidence in line with previous studies in Kota Bharu, Malaysia, Bursa City, Turkey, Dakar, Senegal and Kinshasa, Democratic Republic of Congo. Moreover, a study was done in Kerala, India, which looked at the respiratory morbidities among bus drivers and conductors and discovered that chronic respiratory diseases occur as a public health problem concerning roughly one in ten bus drivers and conductors in Kochi city, who have been occupationally exposed to air pollutants continuously.

Inhalation of particulate matter triggers many mechanisms and is not limited to the activation of oxidative stress and reactive oxygen species, which later exacerbates respiratory symptoms. The impairment of the lungs usually depends on direct or indirect exposure to air pollutants. However, other factors such as physical activities, dietary intake, and level of awareness could also partly contribute to respiratory health status. Work duration is usually in line with age. How long a worker had been working for both groups was important because it reflects the long-term exposure to any level of pollutants faced by the workers during those periods. A study performed among bus drivers and conductors discovered that working for >15 h/day showed 2.8 times more risk of developing chronic respiratory diseases than those working for ≤14 h/day.

Health effects from occupational exposure usually develop over an extended period of time, are cumulative in nature, and often become complicated by non-occupational factors. Therefore, the call for risk mitigation is crucial for the bus drivers who breathe in contaminated air from the bus engine and from surrounding traffic. The Malaysian government has mandated that all diesel fuels for commercial and passenger vehicles be compliant with Euro 5M diesel to replace Euro 2M diesel started on 1 April 2021. Euro 5 has a lower sulphur content, which means lesser toxic emissions is released into the air; hence, releasing cleaner fuel that is better for the environment. Additionally, the combustion engine of current fossil fuel may be modified to operate with biofuels both in liquid and gaseous form. Meanwhile, conventional engines may be enhanced by methods of hybridisation with an electric motor to cater to alternating propulsion types.

There were several shortcomings in this study. The sampling duration was only taken thrice per week, which was unavoidable as the study halted due to the increasing trend of COVID-19 worldwide. Further studies should be conducted for a more extended period, with a larger sample size, and include more air quality parameters and
other health assessments for a more accurate evaluation of the exposure of bus drivers to air pollutants and their subsequent health implications. Besides, there were difficulties in measuring personal exposure and getting the actual exposure duration because these bus drivers frequently change working hours depending on their shifts and schedule.

CONCLUSION

In conclusion, the bus drivers were exposed to a higher concentration of air pollutants than the office workers, leading to a higher prevalence of respiratory symptoms among the bus drivers. The bus drivers are working in an unfavourable situation for their health. However, these bus drivers have no other options as they need to fulfil their duties to serve the commuting community. As for recommendations, housekeeping tasks, including sweeping and trash disposal should be continued. As for the ventilation system, management should ensure the air conditioner works properly. Moreover, the bus management should also provide personal respiratory protection or masks when the bus drivers are working and regular health screening such as lung function test to monitor their workers’ health.

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Conflict of interest

The authors declare no potential conflict of interest.

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