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$PM_{2.5}$, RESPIRATORY HEALTH RISK AND IL-6 LEVELS AMONG WORKERS AT A MODERN BUS TERMINAL IN KUALA LUMPUR

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ABSTRACT

Background: A recent study in Taipei found that the levels of $PM_{2.5}$ in a bus terminal were 1.6 to 1.8 times higher than in the urban background and were far above the permissible exposure limits (PEL). Since there has been no such research conducted in Malaysia, the present study aims to assess the level of $PM_{2.5}$ in a new bus terminal in Kuala Lumpur and to measure the possible respiratory health risk of the workers.

Materials and Methods: Fifty workers were selected randomly to participate in lung function tests. Their urine samples were taken to measure the concentration of IL-6, an indicator for inflammatory response. The IUALTD Questionnaires were distributed to study participants to assess their bronchial symptoms. The 8-hours average of $PM2_{.5}$ levels were measured at three different locations.

Result: Findings indicated that the highest level of $PM_{2.5}$ was found at the boarding area (32.19µg/m^3) followed by at the ticketing counter (31.61µg/m^3). Both levels were above the PEL and approximately 6 times higher than that level found at the administrative office (5.44µg/m3). The prevalence of cough among workers in both areas was twice (32%) as high as those workers in the administrative office (16%). Among non-office workers, 38% showed an abnormal lung function of FEV1% predicted. The lung function (FEV1/FVC) was found to have a moderate strength of significant association with IL-6 levels (r=0.31).

Conclusion: This is a new and among the most modernised bus terminal in Malaysia but findings of the present study indicated workers at the bus terminal were at risk to get respiratory illnesses due to occupational particulates exposure. Therefore, appropriate control measures, and awareness programmes are warranted among these workers and management of the bus terminal.

Keywords: Bus terminal, $PM_{2.5}$, lung function test, IL-6, bronchial symptoms

1.0 Introduction

In Malaysia, the need for an efficient public transport system becomes more important as Malaysia continues to become a high-income nation with increasing population and economic growth. Thus, transport networks must be able to support the economic growth, growing populations and the diversity of urban activities. However, transportation has been recognized in previous studies as a significant source of ambient particulate matters (PM) in urban areas (Charron and Harrison, 2005; Allaban et al., 2007).

Particulate matter (PM) is the term used for a mixture of solid particles and liquid droplets suspended in the air (WHO, 2011). According to WHO (2011), these particles originate from a variety of sources, such as power plants, industrial processes, and diesel trucks, and they are formed in the atmosphere by transformation of gaseous emissions. PM is composed of both coarse and fine particles. $PM_{2.5}$ is also called as fine particles that have an aerodynamic diameter of less than 2.5 micron. $PM_{2.5}$ can penetrate deeper into the lower respiratory tract and the gas–exchange region of the lungs, where they can pass to the bloodstream (Pozzi et al., 2003; Oberdorster et al., 2005).

Short- and long term exposure to $PM_{2.5}$ was found to be associated with various health effects, including respiratory and cardiovascular diseases (Pope et al., 2004; Dominici et al., 2006). For examples, results from a recent study in Sweden showed that for every $10\mu g \bullet m^{-3}$ increase of wear particles (PM_{1-10}) from road traffic, the odds for blocked nose or hay fever, chest tightness or cough and restricted activity days increased by 1.5 to 2 times (Willerz et al., 2013).

Moreover, some previous studies found that exposure to ambient PM stimulate the inflammatory process of the lung and increased the secretion of pulmonary pro-inflammatory mediators such as interleukin (Stenfors, et al., 2004). According to these researchers, the inflammatory process in the lungs is characterized by the production of leukotrienes, histamine, bradykinin, and a variety of cytokines and chemokines by tissues and migrating cells. Among the pro-inflammatory cytokines, interleukin-6 (IL-6) is considered to contribute to the initiation and extension of the inflammatory process. Findings of a study in Switzerland (n = 6183 adults) showed that for every 10 $\mu g/m^3$ elevation in PM_{10}, blood IL-6 increased by 0.036 (95%CI: 0.015-0.057) pg/m (Dai-Hua Tsai, et al. 2012). However, the number of studies exploring the effect of PM to the level of IL-6 is still insufficient to get an established conclusion.

While many studies have focused on the health effect of PM exposure to road users, police officers and nearby residents, a limited number of studies have explored this health effects among workers in bus terminal. A bus terminal is a structure where city or intercity bus stops to pick up and drops off passengers. The PM emitted directly from buses can accumulate within the buildings, which can adversely affecting the health of passengers and study participants in the terminal (Cheng, Chang, & Hsieh, 2011; Heng, 2011).

Cheng, et al., (2011), have conducted air pollution monitoring in a bus terminal at Taiwan. This terminal is a massive 24-story building housing a bus terminal, a business hotel, a shopping mall, several cinemas, offices, and private residential suites. Findings of their study indicated that PM levels on the station concourse were governed by coarse PM while

particulates found at waiting areas were dominated by fine PM. Cheng, et al (2011) further explain that particulates found in the station concourse were from outdoor traffic and those found at waiting areas were likely exhausted directly from buses.
inside the building.

Some previous studies have examined the health effect of particulates in transporting vehicles (Knibbs et. al., 2010; Petrales et al., 2007). Knibbs et al (2010) measured $PM_{2.5}$ (particulate matters with 2.5µm diameter) and ultrafine particulates (UFP) levels inside trains, buses, ferries, and automobiles in Sydney. Results of their study indicated that the levels of both $PM_{2.5}$ and UFP were found to be highest inside buses compared to the other type of vehicles. Consistently, Perales et al. (2007) demonstrated that $PM_{2.5}$ levels inside mini buses and buses were 49 mg m-3 and 52 mg m^{-3}, respectively, and significantly higher than those inside metro trains in Mexico City.

A Malaysian latest and most modernised bus terminal has been built in Klang Valley known as the Terminal Bersepadu Selatan (TBS). As a modern bus terminal, it is expected that the installed air pollution control measures are excellent and air pollution in this terminal is of good quality. However, there is no data available on air quality levels in this terminal and respiratory health of workers in this building remains unexplored. The present study aims to assess the levels of PM and examine the respiratory health symptoms among workers in the TBS.

2.0 Materials and Methods

2.1 Study design

A cross sectional study was performed among bus terminal's workers at the Terminal Bersepadu Selatan (TBS).

2.2 Study samples

The study participants were 50 male and female workers and aged between 20-65 years old. All participants have no history of chronic lung and respiratory diseases and kidney diseases. The respondents were selected by simple random sampling based on the list from the administrative office of the designated bus terminal. The total number of workers at the bus terminal was 150. Since the total number of workers were small, each member of the population is assigned a unique number and 50 numbers were selected randomly. All study participants undergone lung function tests and the analysis of urine IL-6 concentration.

2.3 Particulate Matter 2.5 (PM2.5) Data

The levels of PM at working area were sampled using SidePak™ AM510 Personal Aerosol Monitor for 8 hours. This instrument was placed at three locations in the bus terminus, which were at the terminal management office, ticketing counter and boarding and arrival area.

2.4 Questionnaire distribution

Questionnaire which was adapted from the International Union against Tuberculosis and Lung Disease (IUATLD) Bronchial Symptoms Questionnaires was distributed to the entire subject that be selected at the beginning. Then, the questionnaire was completed by the study participants. The IUALTD has significant inter-rater reliability (Kappa index = 0.70-0.95) (Burney et al., 1989).

2.5 Measurement of Urine IL-6

The urinary samples were taken from respondent concurrently with the measurement of PM level. Instead of blood serum, urine sample was chosen as it is less invasive. Moreover, it is evident in a previous study that plasmatic and urinary levels of IL-6 did not differ significantly (Sirera, 2003). Fifty ml of urine were taken from each respondent and then put in polyethylene 60ml bottles. All samples were labelled and placed in polystyrene containing ice to maintain the temperature to be less than 4 ^{0}C to stabilize the samples. The samples were taken to the laboratory to be analyzed using Human IL-6 ELISA kit. Urine samples were centrifuged to remove any particulates for 15 minutes at 1000x g, 2 - 8°C and assay immediately or aliquot. The samples were stored at -20°C or -80 °C. The concentrations of the Interleukin-6 were analyzed using Human Interleukin-6 Enzyme-Linked Immunosorbent Assay (ELISA). The IL-6 concentration of the respondents was determined from a 5-parameter curve fit for IL-6. A normal IL-6 level is less than 5.0 pg/ml (Sun, et al. 2002). All biomarkers analyses were conducted at the Chemical Pathological Laboratory, Department of Pathology, University Putra Malaysia.

2.6 Lung Function Test

Lung function test was performed using Spirolab II Model to all 50 respondents. First, the body weight and height of the respondents were measured three times and the average value were obtained. These values were entered in the spirometer system Then, before performing the manoeuvre of the lung function test, the right explanation with simple language about the testing procedure were delivered to the respondents including correct posture with head elevated and standing in straight position, inhale completely, showing proper mouthpiece position and exhale with maximal effort. After that, the respondents were asked to perform the manoeuvre. The respondents were asked to stand during the examination and be sure the bench was positioned behind the respondents. Then the respondents were asked to elevate their chin and extend their neck slightly. When the ready signal is given, respondents inhaled as deep as they can and then placed mouthpieces in their mouth. They exhaled as hard and as fast as they can into the tube. Each respondent repeated this test 2 times and the highest value was taken.

2.7 Statistical Analysis

Data were analyzed using the Statistical Packages for Social Sciences (SPSS, version 21). Man- Whitney U test and Independent T test were used to compare the means of the study variables. Pearson's and Spearman correlation were used to find the correlation between quantitative variables.

2.8 Research Ethics

The present study had obtained approval from the Ethics Committee for Research involving Human Subjects of Universiti Putra Malaysia (JKEUPM). Permission to conduct this study was granted by the bus terminal's management. Participation was only voluntary basis and respondents who agreed to participate gave the written permission.

3.0 Results

3.1 Socio-Demographic Data

The respondents were comprised of 20 males and 30 females. Out of 50, there were 49(98%) Malay and 1(2%) was Chinese. The mean age of the study participants was 27.18±6.51 years. The mean height of the study participants was 161.13±9.92 cm, whereas the mean weight was 67.29±16.68 kg. The mean working experience (month) was 49.91±58.57, the mean daily working duration (hour) in a day was 11.12± 2.02 and the means of working days were 5.14±0.41. There were 20 (40%) males and 30 (60%) females. Only one Chinese and the rest was Malay (98%). See Table1.

Table 1: The social demographic data of the study participants

Variable	Means	Standard deviation	median	IQR	95%CI	
					Lower	Upper
Age (years)	27.18	6.51	26.0	6.00	25.33	29.03
Weight (kg)	67.29	16.68	63.50	15.63	62.55	72.03
Height (cm)	161.13	9.92	161.50	16.05	158.31	163.95
Working experience (months)	49.41	58.57	24.00	48.00	31.6	67.22
Work Hours	11.12	2.02	12.00	3.00	10.547	11.69
Work day	5.14	0.41	5.00	0.00	5.03	5.25

3.2 Particulate Matter 2.5 (PM2.5) levels at the bus terminus

Table 2 presents the measured PM2.5 levels at the three monitoring sites. The results demonstrated that PM2.5 levels at ticketing counter and boarding area were significantly higher than at management office. The eight hour average level of PM2.5 at the management office, ticketing counter and boarding area were 5.44 µg/m³, 31.61 µg/m³ and 32.19 µg/m³ respectively. Normality test was carried out to assess the distribution of PM2.5 concentrations. The result of normality test showed that PM2.5 concentration was not normally distributed

Table 2: Levels of $PM_{2.5}$ at different location inside the bus terminals

Variables	Average (µg/m³)	Maximum (µg/m³)	Minimum (µg/m³)
Office			
Management office	5.44	12.69	2.36
Non-office			
Ticketing counter	31.61	36.25	27.55
Boarding area	32.19	39.15	29.97

3.3 Levels of Urine IL-6 among study participants

The concentration of IL-6 was obtained by using a 5-parameter curve. The mean of IL-6 for office workers were 0.25±0.13 pg/ml and non-office workers were 0.21±0.09 pg/ml. There was no significant difference of urine IL-6 levels between office and non-office workers (z=-1.56, p=0.12).

3.4 Prevalence of respiratory symptoms among study participants

The most prevalent reported respiratory symptoms were cough (48%) followed by chest tightness (16%), phlegm (12%), and wheezing (10%). Chi Square tests were run to explore the association between respiratory symptoms and sampling site. No significant associations were found. See Table 3.

Table 3: Prevalence of Respiratory Symptoms between sampling sites (N= 50)

Respiratory Symptoms		Frequency (*f*)			
		Office (low level of exposure)	Non-office workers (higher level of exposure)	χ^2	P
Cough	Yes	8(16)	16(32)	0.14	0.71
	No	10(20)	16(32)		
Phlegm	Yes	3(6)	3(6)	0.58	0.45
	No	15(30)	29(58)		
Chest	Yes	2(4)	6(12)	0.50	0.48
tightness	No	16(32)	26(52)		
Wheezing	Yes	3(6)	2(4)	1.39	0.24
	No	15(30)	30(60)		

Significant level: $p < 0.05$

3.5 Correlation between socio-demographic data, work characteristics and exposure level to PM2.5 with IL-6 concentration

The relationship between $PM_{2.5}$ concentrations and IL-6 levels was tested. The concentrations of IL-6 and $PM_{2.5}$ were found to be not normally distributed. Therefore, Spearman Rank Correlation test was performed to see the correlation between $PM_{2.5}$ and IL-6. Findings of the tests showed that there was no significant correlation between the exposure level of $PM_{2.5}$ and the concentration of IL-6 (r = -0.22, p=0.12). With regards to the socio-demographic data and work characteristics, working hours was found to be significantly correlated with IL-6 concentration level (r=-0.29, p=0.04).

4.0 Discussion

4.1 Comparison of $PM_{2.5}$ concentration levels between different work areas.

Results from the current study showed that workers who work at ticketing counter (31.61 µg/m³) and boarding area (32.19 µg/m³) were exposed to a higher level of $PM_{2.5}$ compared to the workers working at the office (5.44µg/m³).There were a few sources of $PM_{2.5}$ in the building. $PM_{2.5}$ may come from both outdoor and indoor from the busses and other vehicles. Management office was located at the ground level of the terminal where there were car park, shuttle bus and taxi stand. However, the office had installed access door which was always closed and therefore minimising the entry of particulate matters from outside. Whereas at ticketing counter, the high $PM_{2.5}$ level were originated from the outdoor environmenta such as traffic volume of buses and other vehicles such as car and also from the movement of passengers (Cheng et al., 2011).

A study by Cheng et. al (2011) done at a bus terminal in Taiwan indicated that the level of PM_{10} and $PM_{2.5}$ inside the bus terminal were roughly 1.5 and 1.4 times higher than those measured inside buses, respectively. Results of the study suggests that the PM levels found at the station were higher than that at waiting area as the passenger activity was greater there than at waiting areas. The World Health Organization (WHO) had set 25µg/m³ for 24 hours average concentration. Whereas Environmental Protection Agency (EPA) was 35µg/m³ for 24 hours average concentration. Nevertheless, results showed that the level of $PM_{2.5}$ in the bus terminal were below of those proposed permissible exposure limits.

4.2 Comparison of IL-6 concentration level among office and non-office workers.

The mean of IL-6 concentration levels were 0.25±0.13 pg/ml among office workers and 0.21±0.09 pg/ml among non-office workers. These values were lower than that found in a previous study conducted by Kavitha et al (2011) in Klang Valley. However, in the study by Kavita et al (2011), the type of biological sample and the response group were different. In their study, IL-6 concentration was measured from saliva samples collected after the exposure of $PM_{2.5}$ among bus drivers. Results of the study showed that, the mean concentration of IL-6 for study group was 6.36±3.88 pg/ml and the mean concentration of IL-6 for the comparative group was 5.28±4.14 pg/ml.

4.3 Relationship between exposure level to $PM_{2.5}$ and IL-6 concentration

Findings of the study showed that there was no significant correlation between exposure level of $PM_{2.5}$ and concentration of IL-6 ($r=-0.22$, $p=0.12$). These findings contradict to the results of Kavitha et al (2011) among bus drivers where the levels of IL-6 among them were significantly higher than the IL-6 levels of the comparative group and these levels were found significantly higher with the higher levels of ultrafine particle (UFP) ($z = -2.43$, $p < 0.05$). Since the level of IL-6 was found low in the urine, there is a possibility that the visible increase of IL-6 level at the lung was undetectable in the urine and thus influencing the statistical results of the relationship between the levels of $PM_{2.5}$ and IL-6.

4.4 Relationship between $PM_{2.5}$ and prevalence of respiratory symptoms

In Table 3, although there was not significant association between all respiratory symptoms and the levels of exposure, results indicated that the prevalence of respiratory symptoms were consistently higher among non-office workers than those working in office. These findings were not consistent with the results of Kavita et al (2011) in which higher prevalence of respiratory symptoms were found to be significantly associated with higher exposure level of $PM_{2.5}$. However, findings of the present study supported the results found in two studies (Moolgavkar. 2000; Stieb et al., 2000). In these studies, the increase of respiratory admissions per mg/m^3 of $PM_{2.5}$ was found higher in a less polluted area than those found in a higher exposure area.

5.0 Conclusion

This is a new and among the most modernised bus terminal in Malaysia but findings of the present study indicated that the workers in this terminal were at risk to get respiratory illnesses due their occupational exposure to ultrafine particulates originated from the busses and vehicles. A more detail study are therefore warranted to confirm the findings of the present study. It is recommended that the future study needs to examine the efficiency of the current ventilation system in the terminal. Health promotion and awareness programmes among workers and management of the bus terminal will be beneficial to protect their health as well as consumers of the terminal.

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Declaration

Author(s) declare that this is an original work except for quotations and citations which have been duly acknowledged. The present study obtained approval from the Committee of Ethics of Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

Authors contribution

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