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A Study on Exposure to Air Pollutants and Their Effects to the Respiratory Level among Employees of Sentul Railway Electric Multiple Unit (Emu) Depot

[1]Normah Awang, [1]Nur Faratun Mohd. Alwi, [1]Siti Hajar Yaacob and [2]Ismarulyusda Ishak

[1]Environmental Health and Industrial Safety Programme, Faculty of Health Sciences,
Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia
[2]Biomedical Science Programme, Faculty of Health Sciences,
Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia

Abstract: Sentul Railway Electric Multiple Unit (EMU) Depot is a place for maintenance and storage of trains. A study was conducted to investigate the exposure to air pollutants and their effects to the respiratory level among employees in the depot. The method used in this study included sampling of air pollutants and lung function tests to the workers. Sampling was conducted at three stations in the depot and in the FSK Dean's Office, UKM. The study found that total volatile organic compounds (TVOC) and PM_{10} concentrations at the first station were 9.0 ± 7.35 ppm and 166.67 ± 176.78 μg/m^3, respectively, thus exceeded the permitted standard limits. The concentration of CO, CO_2, Pb and As in every station did not exceed the permitted standards. Results of statistical analysis showed that only the concentration of CO had a significant difference between each station. The results of lung function tests showed that all FVC, FEV_1 and ratio of FEV_1/FVC for both exposed and control subjects were normal as they were higher than normal level of 80%. There was no significant difference on diagnosis of spirometry between the exposed subjects and the control subjects but the exposed subjects had lower respiratory level as compared to the control subjects. There was a significant difference on diagnosis of spirometry between employees who had served less than 10 years with employees who had served 10 years and above. In conclusion, employees who had a long-term exposure to air pollutants in the depot had a low respiratory level.

Key words: Indoor air · CO · CO_2 · TVOC · PM_{10} · Pb · As · Lung function test

INTRODUCTION

Air pollution either indoor or outdoor is often regarded as a major cause of environmental health problems. In recent years, people are more concerned about the problem of indoor air quality (IAQ) because people spend more than 90% of their time indoor [1] in which the concentrations of air pollutants generally far exceed outdoor levels. Indoor air pollution can be caused by activities conducted in a building and from goods or furniture in the building [2].

There are varieties of air pollutants that have been reported. They differ in chemical composition, types of reaction, emissions, persistency in the environment and their effects on human or animal health [3]. Carbon monoxide (CO) is a colourless and odourless gas that is poisonous to humans and it is a product of incomplete combustion of fuels that contain carbon [4]. Carbon dioxide (CO_2) is colourless and odourless gas that is produced from the metabolic activity. Humans and animals exhale carbon dioxide when they breathe. Burning activities and emission from motor vehicles also produce the gas. Next, volatile organic compounds (VOCs) can be found in any internal environment of buildings. Chemicals, paints, air fresheners, stored fuel, solvents, dry cleaning, vehicle exhaust and various other household items can contribute to the emission of VOCs in indoor air [5]. Particulate matters can be generated from natural processes such as from bacteria, viruses, fungi, yeast and human activities such as driving diesel trucks,

Corresponding Author: Normah Awang, Environmental Health and Industrial Safety Programme, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia.

power stations and industrial firewood. These particles can be released directly into the atmosphere or through a number of chemical and physical reactions of a gas or vapour (MCA 1997). Lead, Pb can be released into the environment by motor vehicles that use leaded petrol [6] while arsenic, As may be present at low levels in the environment due to Environmental Tobacco Smoke [7].

This study aimed to determine whether the concentration of air pollutants in Sentul Railway EMU Depot complied with the specified standards. In addition, the respiratory levels of the workers exposed to the air pollutants in the depot were also determined.

MATERIALS AND METHODS

This study was divided into two parts, which were (1) air sampling to determine the level of exposure of air pollutants in the depot and (2) lung function test to determine the workers' respiratory levels. Among the parameters studied were CO, CO_2, TVOC, PM_{10}, Pb and As. For lung function test, it was done using spirometry test.

Sampling Sites: The study was conducted in Sentul Railway EMU Depot, which was an electric train storage and maintenance workshop. The depot was located near the Sentul Railway station. The three stations were selected based on primary work activities. Station 1 was the location for air conditioner test, station 2 was the location for undergear maintenance and station 3 was the location for air conditioning washhouse. Sampling was also conducted in Faculty of Health Sciences (FSK) Dean's Office, Universiti Kebangsaan Malaysia (UKM).

Air Sampling Procedure: The three gases namely CO, CO_2 and TVOC were sampled using direct reading instruments. Area air sampling for CO_2 and TVOC was done using Aeroqual Series 500. Multilog 2000 Gas Detector was used for sampling CO. Sampling was done by taking the readings of gases concentration directly or *in situ*. The sensor on the sampling devices was placed at levels between 75 cm to 125 cm from the floor of the central room. Readings for CO, CO_2 and TVOC were taken every 10 min intervals for a period of 30 min.

Air sampling for PM_{10} was done using low-volume air sampler with flow rates from 2 to 30 L/min at a pressure of 7 psi. The air sampling was carried out for 8 h at each sampling station and the flow rate was fixed at 5 L/min. Glass microfibre filter paper with 8 µm pore size and diameter of 47 mm was used in the air sampler to filter PM_{10}. Blank filter paper was used to identify contamination that may be present during the sampling. The blank filter paper was also used to identify problems that may arise during the process of sample preparation and analysis. Filter paper was weighed before and after sampling.

Laboratory analysis was conducted in order to know the concentration of heavy metals in the air. Pb and As were extracted from samples of PM_{10} through acidic digestion method that was based on NIOSH Method 7300.The samples were then analysed using ICP-MS to obtain the concentration of Pb and As in the air.

Lung Function Test Procedure: The test was conducted on the maintenance workers who were exposed to the air pollutants at the depot. The test was carried out on 28th February 2013 from 10 a.m. until 1 p.m. at Sentul Railway EMU Depot. The recruited subjects were all males and from Malay ethnic. Workers who smoked and had a history of chronic respiratory disease were excluded in order to avoid procedural errors. The control subjects were taken among workers in FSK Dean's Office, UKM.

A table of random numbers was used to select subjects among the workers working at the depot. The sample size was calculated based on a formula used by Krejcie and Morgan (1970). A total of 20 exposed subjects were chosen while only 4 subjects represented for control group.

Based on [8], the basic standard spirometric test requires the subject to exhale as forcefully as possible after taking in a full, deep breath. The subject's effort was called the forced expiratory manoeuvre. Forced Vital Capacity (FVC) is the maximum volume of air exhaled forcefully after a maximal inspiration. For adults, this forced exhalation should last at least 6 s; however, persons with COPD may take considerably longer to exhale all their air. Forced Expiratory Volume in One Second (FEV_1) is the volume of air exhaled during the first second of a forced expiratory manoeuvre. Normally, a healthy person can be expected to exhale from 70 to 80 percent of the FVC in the first second of a forced expiration manoeuvre.

Then, the participant's individual spirometric measurements were compared to standards established from [8]. These standards were calculated based on an individual's age, height, sex and race/ethnicity since the diagnostic thresholds for obstructive lung disease differ by body size and by demographic subgroups.

Statistical Analysis: The results were analysed using *Statistical Package for Social Sciences* (SPSS) statistical program version 20.

RESULTS AND DISCUSSIONS

Measurements: Table 1 shows the average concentrations of air pollutants for each sampling station in the depot. The bold values are the highest concentration value for each parameter at each station.

Carbon monoxide (CO): Based on one-way ANOVA test, there was significant difference between the average concentration of CO in station 3 and FSK Dean's Office station. The average concentration of CO in station 3 was the highest i.e., 4.0 ± 2.1 ppm. Station 3 was located in a separate building that was quite open and the location was close to the road. Sources of CO were from indoor air, external sources such as vehicle emissions that entered the building and internal sources such as environmental tobacco smoke [1]. During the sampling, it was found that some employees smoked in the area around the station 3. However, all of the CO concentration readings at each station did not exceed the permissible standard limit of 10 ppm. This showed that the concentration of CO in Sentul Railway EMU depot was still at the safe level.

Carbon dioxide (CO_2): CO_2 readings in the Dean's Office station were the highest because the station was a closed area and the area was dense with workers. The high CO_2 readings most probably resulted from the metabolic activity of the workers as they exhaled CO_2 when they breathed [9]. CO_2 readings at station 1, station 2 and station 3 were lower than CO_2 readings at the Dean's Office station because the depot was a vast and semi-open type of building. According to [10], usually carbon dioxide concentrations are higher indoors than in an open environment. Therefore, the concentration of CO_2 in the Dean's Office station was higher than the stations in the depot. The results of Kruskal-Wallis test showed no significant difference between the average CO_2 concentrations at each station. DOSH (2010) has set the standards for CO_2 at C1000 ppm in which every person should never be exposed to CO_2 more than the prescribed ceiling limit at any time to avoid the health effects or death. Results showed that all of the CO_2 concentrations at the stations were below the standard limits.

Total Volatile Organic Compound (TVOC): Kruskal-Wallis test showed no significant difference between the average TVOC concentrations at each station. However, station 1 and Dean's Office station had TVOC concentrations that exceeded the acceptable limit with reading 9.0 ± 7.4 ppm and 3.1 ± 0.1 ppm. The standard limit allowed by Dosh (2010) is 3 ppm. Station 1 was the location for air conditioner test. The sources of TVOC at station 1 were the refrigerant gas that was inserted into the air conditioner and the residual chemical detergent used to wash the air conditioner. Refrigerant gas type R-22 was used and it was a volatile gas and had a sweet and sharp odour (MSDS 2008). TVOC concentration at Dean's Office station exceeded the acceptable limit because this office had recently been renovated and had a new internal structures such as furniture and wall paint, thus these were the sources of TVOC in that area. According to [2], new furniture, cabinets, paint, printer and photocopy machine in a building are the sources of TVOC.

Particulate matter (PM_{10}): Based on the Kruskal-Wallis test, there was no significant difference between the average PM_{10} concentrations at each station. All stations except station 1 had PM_{10} concentrations remained below the standard level. Standard limit allowed by Dosh (2010) is 150 μg/m^3. The PM_{10} concentration in station 1 was 166.67 ± 176.78 μg/m^3 and it exceeded the standard limit. This was because, at station 1, the air conditioners were being tested and were operated at all time. Thus, the dust around station 1 would fly in the air and indirectly increased the PM_{10} concentration in the area. PM_{10} sources at the depot may have come from dust brought in by commuters that stopped at the depot, occupational

Table 1: The average concentrations of air pollutants for each sampling station

	Average concentration ± Standard deviation					
Station	CO (ppm)	CO_2 (ppm)	TVOC (ppm)	PM_{10} (μg/m^3)	Pb (μg/m^3)	As (μg/m^3)
Station 1	1 ± 2	560±211	9.0±7.4	166.67±176.78	25.56±0.74	1.68±0.21
Station 2	2 ± 0	590±98	0.5±0.4	41.67±0.00	25.16±9.72	1.56±0.04
Station 3	4 ± 2	584±171	2.6±1.0	62.50±29.44	20.22±1.47	1.67±0.23
FSK Dean's Office	0 ± 0	723±18	3.1±0.1	62.50±29.44	13.62±1.24	0.35±0.04
Acceptable limits	10	C1000	3	150	50	10
p value	0.034*	0.563	0.082	0.561	0.197	0.238

* significant value at $p < 0.05$

Notes: Bold values indicate the highest concentration value for each parameter at each station

activities carried out, cigarettes smoke and other sources from the external environment. The intrusion of outdoor PM_{10} may be higher if there were significant sources of PM_{10} near the building, such as industrial activities, construction and traffic conditions [1]. In addition, the location of the depot was located at the centre of the city and surrounded by roads. According to [11], indoor PM_{10} concentrations are high in the buildings located in urban areas or near highways.

Lead (Pb): One-way ANOVA test showed no significant difference between the average Pb concentrations at each station. Pb concentrations at each station did not exceed the time weighted average (TWA) 8 h set at 50 μg/m^3. Station 1 recorded the highest concentrations of Pb with an average of 25.56 ± 0.74 μg/m^3. Heavy metal concentrations were obtained from samples of PM_{10} that had undergone acidic digestion. Pb was usually found in smoke produced by motor vehicles [12]. Accordingly, the depot was located close to the road and the traffic conditions thus increased the Pb content in the air and it can be spread over long distances through PM_{10}. In addition, there were also vehicles such as trucks, which were used to transport the train body parts, entering the depot.

Arsenic (As): The highest reading for As was at station 1 with an average of 1.68 ± 0.21 μg/m^3. The result of Kruskal-Wallis statistical test showed no significant difference in the concentrations of As in every station and there was no reading of As concentration that exceeded the 8-hour TWA limit. As along with other heavy metals was adsorbed on the surface of the total suspended particulate [13]. According to [7], As is usually found in suspended particulate matter, environmental tobacco smoke and construction activities. While the air sampling was conducted, there were some employees who smoked in the workplace and that contributed to an increase in As levels in the air.

Study Population: The total number of subjects of the lung function test was 24 persons with 20 subjects from the exposed group and 4 subjects from the control group. Table 2 shows the demographic characteristics of the subjects involved in the spirometry test. Majority of the exposed subjects were 40 years old and over (55%) and had served for 10 years and over (70%), while for the control group, most of the subjects were under 40 years old (75%) and had served less than 10 years (75%).

Lung Function Diagnosis: Table 3 shows the lung function diagnosis of the exposed group and control group. All of the subjects in control group (100%) had normal spirometry diagnosis. About 70% of the subjects from exposed group had a normal spirometry diagnosis and the rest had a diagnosis of mild restriction (15%), moderate restriction (5%) and severe restriction (10%).

Based on chi square, Fisher's exact test, there were no significant differences in spirometry diagnosis between the exposed group and the control group. However, there were subjects from the exposed group who had a diagnosis of abnormal spirometry while none of control subjects showed abnormal spirometry diagnosis. This was because the subjects from the exposed group consisted of depot maintenance workers who were at great risk of exposure to various types of air pollutants found at the workplace. Many studies indicate that all types of air pollutants at high concentrations can affect the respiratory tract. The effect is the result of long-term exposure to air pollutants at low concentrations [3]. Exposure to particulate particles may take a long time for its effects on lung function to be diagnosable [14].

Table 2: Demographic characteristics

Sociodemography	Exposed group (N=20) n (%)	Control group (N=4) n (%)
Age		
< 40 years old	9 (45%)	3 (75%)
≥ 40 years old	11 (55%)	1 (25%)
Length of service		
< 10 years	6 (30%)	3 (75%)
≥ 10 years	14 (70%)	1 (25%)

Table 3: Spirometry diagnosis of exposed group and control group

Diagnosis	Exposed group n (%)	Control group n (%)	p value
Normal spirometry	14 (70%)	4 (100%)	0.288
Mild restriction	3 (25%)	-	
Moderate restriction	1 (5%)	-	
Severe restriction	2 (10%)	-	

Table 4: Diagnosis of spirometry among the workers at the depot (age and length of service)

	Sentul Railway EMU Depot workers		
Sociodemography	Normal spirometry n (%)	Abnormal spirometry n (%)	p value
Age			
< 40 years old	9 (64%)	1 (17%)	0.070
≥ 40 years old	5 (36%)	5 (83%)	
Length of service			
< 10 years	7 (50%)	-	0.044*
≥ 10 years	7 (50%)	6 (100%)	

* significant value at $p < 0.05$

Table 4 shows a comparison of spirometry diagnosis among Sentul Railway EMU Depot workers according to age and length of service. About 64% of the workers of below 40 years old had a normal diagnosis and only 17% of them had an abnormal diagnosis. Moreover, 83% of workers of 40 years old and above had abnormal diagnosis and only 36% of the workers showed normal diagnosis. In terms of length of service, all of the workers who had worked for more than 10 years showed an abnormal diagnosis. Based on the results obtained, majority of the workers of 40 years old and above had an abnormal diagnosis. According to [15], the age factor could influence lung function; increase in age would cause the lung function to deteriorate.

The result of chi square, Fisher's exact test found a significant difference ($p < 0.05$) between the diagnosis of spirometry for workers who had served less than 10 years and workers who had served 10 years and above. Exposure to air pollutants at low concentrations over a long time can affect a person's breathing level [3]. Thus, for the respondents in this study, workers who had been exposed to air pollutants in the depots for over 10 years were more at risk of having a low level of respiration.

CONCLUSION

As a conclusion, station 1 was found to be an area that had an unsafe environment because there were some air pollutants that exceeded the standard limits, which were TVOC and PM_{10}. In addition, the study showed that all sampling stations had recorded low concentration of CO, CO_2 and heavy metals Pb and As and they were all below the standard limits. For lung function test, there was a significant difference between the result of spirometry diagnosis for workers exposed to air pollutants in the depot with the control group. The respiratory level of the exposed group was lower than the control group. The relationship between the demographic characteristics of the lung function tests indicated factors such as workers' age and length of service could affect the respiratory level of the workers who had been exposed to the air pollutants in the depot. Workers who had long-term exposure to the polluted air had a low level of respiration.

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