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Effect of Dust Level Towards Working Comfort among Employees in Train Depot

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Abstract: A research was conducted at a locomotive depot from the month of August 2009 until April 2010. The air quality was measured at seven sampling stations using HVS and analyzed using the NMAM 7300, HACH DR 2800 method. The level of comfort among 64 workers was determined by issuing some questionnaire forms. The air pollutants that studied were heavy metals, cation and anion. Results from the research showed that the highest content of heavy metals was arsenic with an average concentration of 2.152±0.352 g/m^3, followed by plumbum with 1.127±0.138 µg/m^3 and cadmium with 0.371±0.467 µg/m^3. Heavy metals has been produced from the released smoke from motor vehicles and most of them exist in lubricating oil. Whereas for the cations parameter, Ca^{2+} ion recorded the highest average concentration 51.119±29.154 µg/m^3 followed by Al^{3+} ion (18.104±23.183 µg/m^3), K^+ ion (10.316±2.316 µg/m^3) and Mg^{2+}ion (2.969± 0.446 µg/m^3). The highest composition of anion is NO_3^- ion with an average concentration of 0.068±0.006 µg/m^3 followed by SO_4^{2-} ion (0.058±0.004 µg/m^3). Cations and anions are produced due to the fact that these elements reside abundant in the earth's crust and are polluted as a result of the exposure to the air of the outer surface. The highest average concentration of the total suspended particles was 0.694 ± 0.953 µg/m^3 whereby this value did not exceed the permissible exposure limit. Overall, the parameters are all below the permissible exposure limit and the questionnaire showed that as much as 56.25% of the workers stated they were comfortable. As a conclusion, the condition of the working environment that was unpolluted with dust provided comfort or convenience of working.

Key words: Dust · Depot Industry · Working Comfort

INTRODUCTION

Air pollution can be defined as the presence of any pollutants in the air that can cause disruption in the health and well-being or produce harmful effects of the environment. Indoor air-quality problems are caused by the presence of contaminants or failure to control pollutants including dust in a building. In addition, the poor ventilation system within a building can contribute to this problem. Furthermore, the usage effect on the use of inappropriate materials, toxic gas release due to the smoke and the building occupants itself where each individual will liberate carbon dioxide during breath also can be the cause of indoor air quality problems. Contaminated working environments contribute to discomfort and affect the productivity of workers employed [1].

Solid particles (PM) are composed of very fine solid particles and liquid that can be found in the atmosphere. These particles cannot be seen by the naked eye and can exist in black soot, dust or haze. The main cause particulates in the atmosphere is the result from fossil fuel that can produce soot and ash [2].

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Fine particles resulting from combustion activities and chemical reactions include sulfur dioxide and nitrogen dioxide. Gross particles resulting from pollution on the roads and the construction industry contain pollutants such as hydrocarbons, biological materials, organic and inorganic compounds and heavy metals [3].

Fine particles (PM_{10}) may contain elements such as sulfate, ammonium, nitrate, carbon and organic compounds. In addition, there are also carcinogenic compounds and heavy metals such as arsenic, selenium, cadmium and zinc contained in these particles. Coarse particles are like sand, fly ash, wood dust, soot and spores are the results of primary composting activities involving minerals, silica, aluminum, potassium, zinc, calcium and other alkaline elements [4].

Small particles of dust or particles consist of dry solids in the sizes ranged from less than 1µm to 100 µm and can exist in the form of airborne or not only depends on the physical characteristics and condition. Certain environmental condition can produce a cloud of dust or airborne particles into the air, whereas something that is more likely to move fell to the ground from floating to other places such as water vapor. Dust consists of solid particles, which contain a large number of atoms or molecules and typically has a non-volatile characteristic [1].

Train depot workers in the maintenance of locomotives, passenger coaches and car power generator are vulnerable to the contaminants. The objective of this study was to determine the effect of dust level towards working comfort among employees in train depot.

MATERIALS AND METHODS

Background of the Study: This study involved the location of the Kuala Lumpur Central Depot as this area is an enclosed space. Activities involved there are the maintenance of locomotives, passenger coaches and power generation car before the train begins its journey to the destination. The respondents involved in this study were employees working in Kuala Lumpur Central Depot. The sample size for this study was 59 respondents. A total of seven sampling stations have been set in this study in which each sampling station features were different environment.

Air Sampling: The air sample collection was performed using High-Volume Air Sampler model Con-2 Area Collection System with flow rates from 2 to 30 liters per minute at the pressure of 7 psi. Sampling was done in eight hours at each sampling station and the flow rate was set at five liters per minute. Filter papers SKC Omega Specialty Division, Membrane Cellulose Acetate with the pore size of 0.8 µm and diameter 37 mm was used.

Acidic Digestion: The sample extraction process was done by dissolving the samples in a mixture of 16 ml of nitric acid (HNO_3) and 4 ml of Perchloric acid ($HClO_4$). It was then heated on the heating plate for 1 hour. Then, the samples were filtered using cellulose acetate filter paper Munktell filter (0.2µm) using a vacuum pump [4]. The filtrate was then diluted to 50 ml in a volumetric flask using distilled deionized water. The samples were stored in polietina bottles at 4°C so that the quality of the sample will not change.

The concentrations of heavy metals were analyzed by using Mass Spectrometry Inductively Coupled Plasma techniques model SCIEX ELAN 9000 Perkin Model or ICP-MS: Inductively coupled Plasma-Mass Spectrophotometry.

Cation and Anion Extraction Method: Filter paper was the second part of the analysis parameters for PM10 (1 cm × 1 cm) included in a separate centrifuge tube. A total of 40 ml of deionized distilled water was added to the centrifuge tube. Then, the sample was blended using a mechanical shaker ROTOFIX model 32 with 1500 RPM for 1 hour to remove the cations and anions dissolved from the filter paper in distilled water. The samples were then filtered by filter paper Munktell cellulose acetate filters (0.2 µm) using a vacuum pump. The filtrate was then diluted to 100 ml in a volumetric flask. Samples were stored in polietina bottle at 4°C before the analysis was performed.

Analysis of the cation concentration was carried out using ICP-MS: Inductively coupled Plasma-Atomic Mass Spectrophotometry. While the analysis of anion concentration was done using HACH DR 2800 spectrophotometer model and Spectroquant® Pharo 300.

Questionnaire: The socio demography data were collected using questionnaires. The questionnaire was focused on the working comfort among employees at the depot. Questionnaires would be completed only by the employees with guidance from the researcher. This questionnaire was divided into 3 main sections namely, Part A-socio demographic, Part B-health status and Part C-the comfort level.

Table 1: Average concentration parameters for each sampling station

	Average ± standard deviation of concentration (µg/m3)								
Station	As	Cd	Pb	Al	Ca	K	Mg	SO42-	NO3-
Station 1	1.456 ± 0.058	0.035 ± 0.043	0.176 ± 0.006	6.374 ± 1.359	51.119 ± 29.154	10.316 ± 2.316	2.969 ± 0.446	0.056 ± 0.096	0.051 ± 0.005
Station 2	1.311 ± 0.043	0.371 ± 0.467	1.127 ± 0.138	13.419 ± 13.548	29.221 ± 12.628	6.828 ± 4.142	2.556 ± 1.107	0.056 ± 0.096	0.049 ± 0.002
Station 3	1.315 ± 0.362	0.067 ± 0.011	0.79 ± 0.091	9.258 ± 3.935	17.518 ± 3.289	5.195 ± 2.704	1.797 ± 0.651	0.055 ± 0.048	0.057 ± 0.006
Station 4	1.413 ± 0.301	0.343 ± 0.455	0.816 ± 0.035	18.104 ± 23.183	31.755 ± 29.091	4.677 ± 1.512	2.870 ± 3.062	0.000±0.000	0.068 ± 0.006
Station 5	1.709 ± 0.156	0.075 ± 0.008	0.628 ± 0.056	3.921 ± 2.253	19.217 ± 6.338	3.822 ± 0.384	1.557 ± 0.197	0.058 ± 0.004	0.058 ± 0.004
Station 6	2.152 ± 0.352	0.074 ± 0.006	0.603 ± 0.021	4.268 ± 0.129	26.794 ± 15.044	4.533 ± 0.5254	1.983 ± 0.449	0.05 ± 0.004	0.05 ± 0.004
Station 7	1.56 ± 0.074	0.105 ± 0.021	0.57 ± 0.012	3.217 ± 0.666	23.51 ± 2.86	5.27 ± 1.533	1.751 ± 0.407	0.04 ± 0.007	0.04 ± 0.007
F ratio	4.828	0.981	54.833	0.885	1.238	2.897	0.599	1.201	8.72
*p value	0.007	0.474	0.000	0.531	0.345	0.047	0.727	0.362	0.00
Standard value	10	10	50	10 000	-	-	-	-	-

* Significant at p value <0.05

RESULTS AND DISCUSSION

Arsenic: Based on one-way ANOVA, arsenic parameters showed a significant difference (p <0.05) for average arsenic concentration between sampling stations. Table 1 shows the average concentration of arsenic in the station 6 (maintenance work in coaches II) which was the highest 2.152 ± 0.352 µg/m^3 due to the production of smoke during the train operated. In addition, the location of the sampling stations was located away from outdoor air. Poor ventilation and air circulation contributed to high arsenic pollution. However, the arsenic concentration for each station did not exceed the allowed exposure limit of10 µg/m^3 [5]. This indicated that the arsenic concentration in the Kuala Lumpur Central Depot still at the safe level for all employees.

Cadmium: One-way ANOVA test showed that no significant difference (p> 0.05) for the average cadmium concentration between the sampling stations. Based on Table 1, Station 2 (maintenance locomotive) recorded the highest cadmium concentration 0.371 ± 0.467 µg/m^3 due to the smoke produced and lots of lubricant usage. During the locomotive repair, source of cadmium concentrations is high. Metal cadmium resulted from motor vehicle emissions and most of the cadmium is found in motor lubricants and tires [6]. However, the average concentration of cadmium shown for each station did not exceed the permissible exposure limit of 10 µg/m^3 [5].

Lead: One-way ANOVA test showed a significant difference (p <0.05) for an average lead concentration at each sampling station. Based on Table 1, station 2 (maintenance locomotive) recorded the highest lead concentration values ??of all sampling stations 1127 ± 0138 µg/m^3 because Station 2 is the area where many locomotive maintenance task produce smoke and soot. Lead in the atmosphere, mainly in the form of tetraethyl lead in gasoline which is then released through the vehicle exhaust [7]. This situation is similar to the activities at station 2, because the locomotive must be repaired and the engine should be turned on for an hour for heating the engine before the trip to certain destinations. The average value for lead concentration for each station was found to be above the permissible exposure limit of 50 µg/m^3 [5].

Aluminum Ion: Based on Table 1, Station 4 (maintenance PGC) recorded the highest average concentration of Al^{3+} ions in the range of 23.183 ± 18.104 µg/m^3 because it has the power car maintenance (PGC) area and located near the outdoor air [8]. The station also produced smoke and used lots of lube oil during the car maintenance as the engine power generator needs to supply electric power to move the train. In addition, aluminum is often mixed with a little prone to other metals to produce aluminum alloy, which has a feature that is harder [8]. Activities at station 4 involving high level of dust which contains other metals are aluminum elements in it. The average concentration of Al^{3+} ion did not exceed the permissible exposure limit of 10.000 µg/m^3 [5].

Calcium Ion: Analysis of one-way ANOVA test for the average concentration of Ca^{2+} ions showed no significant difference (p> 0.05) at each station. Based on Table 1, station 1 (major route) recorded an average concentration of Ca^{2+} ions with a high range of 51.119 ± 29.154 µg/m^3. Previous studies showed an increase of windblown sand particles into the atmosphere caused by land activity [9, 10]. Calcium is a key element of the earth which is usually produced by the dust from the ground [11].

Table 2: Average concentrations of total suspended particles for each sampling station

Sampling Station	Average concentrations ± standard deviation for total suspended particulate (µg/m^3)	F_{ratio}	*p value
Station 1	0.125 ± 0.110	1.41	0.278
Station 2	0.222 ± 0.637		
Station 3	0.097 ± 0.048		
Station 4	0.953 ± 0.694		
Station 5	0.07 ± 0.048		
Station 6	0.125 ± 0.083		
Station 7	0.681± 0.457		

Table 3: Distribution of respondents according to socio demographic characteristics

Socio demographic factors	Frequency (n)	Percentage (%)
Gender		
Male	64	100.0
Female	0	0.0
Race		
Malay	53	82.8
Chinese	0	0.0
India	11	17.2
Citizen		
Malaysia	64	100
Not Malaysia	0	0
Educational level		
High	22	34.4
Low	42	65.6
Duration of work		
0-15 years	45	70.3
15-30 years	19	29.7
Smoking habits		
Smoke	28	43.8
No smoking	36	56.2

Table 4: Relationship of socio demographic and comfort level of working

	Stage of work comfort Comfortable			
Socio Demography factor	N (%)	Not comfortable N (%)	x^2	*p value
Educational level				
High	15 (68.2)	7 (31.8)	2.463	0.117
Low	20 (47.6)	22 (52.4)		
Duration of work				
0-15 years	24 (53.3)	21(46.7)	0.112	0.738
15-30 years	11 (57.9)	8 (42.1)		
Smoking habits				
No smoking	20 (55.6)	16 (44.4)	0.016	0.899
Smoking	16 (57.1)	12 (42.9)		

Potassium: One way ANOVA test for the average concentration of K^+ ion showed a significant difference ($p < 0.05$) for each sampling station. Based on Table 1, station 1 (major route) showed that the average concentration of K^+ is in the high range 10.316 ± 2.316 µg/m^3 because the first station is close to outdoor air and are more susceptible to pollutants compared to the outdoor air. Potassium is derived from the earth's crust [9, 12]. This resulted in release of potassium from the earth's crust into the atmosphere and spread into the indoor air.

Magnesium: Analysis of one-way ANOVA for the average concentration of Mg^{2+} ions showed no significant difference ($p > 0.05$) at each sampling station. The average value of the concentration of Mg^{2+} ion is very small compared to the average concentration of the other parameters. This is so because, Mg^{2+} ions rose from sea spray [9]. The sampling station located far from the sea resulted in lower values of the Mg^{2+} ion concentration at each station. Based on Table 1, station 1 (major route) showed the highest average concentration of Mg^{2+}

between other stations with the range of 2.969 ± 0.446 $\mu g/m^3$ because it is close to the ambient air compared to other stations. This shows that station 1 is exposed to pollutants than outdoor air.

Sulphate: One-way ANOVA test for the average concentration of ion SO_4^{2-} showed no significant difference (p> 0.05) at each sampling station. Based on Table 1, station 2 (maintenance locomotive) and station 3 (maintenance range coaches II) showed that the average concentration of the ion SO_4^{2-} high in the range of 0.055 ± 0.048 $\mu g/m^3$. Sulfate is emitted from petrol and sulfur-rich diesel used by motor vehicles [11]. As known, the two stations produced smoke and frequent use of lubricants.

Nitrate: Analysis of one-way ANOVA test for the average concentration of NO^{3-} ions showed a significant difference (p <0.05) at each sampling station. Based on Table 1, station 4 (maintenance PGC) has an average value of NO^{3-} ion concentration in the highest range 0.006 ± 0.068 $\mu g/m^3$. Station 4 is the powered generator car (PGC) maintenance station, uses lots of lube oil and produces lots of smoke. The high average concentration of nitrate was caused by burning activity and cigarette smoke [11].

One-way ANOVA test analysis for total suspended particles showed no significant difference (p> 0.05) at each sampling station. Based on Table 2, station 4 (maintenance PGC) showed that the average concentration of total suspended particles in the highest range 0.953 ± 0.694 $\mu g/m^3$. Through previous discussion, station 4 (maintenance PGC) is the area of the car maintenance generator that produces smoke and high consumption of lubricants. Total suspended particles are derived from sources such as power systems, industrial processes and diesel trucks. It is present in the atmosphere through the clouds of gas exchange. Overall, total suspended particles found in Kuala Lumpur Central Depot is under permissible exposure limits where the limit is 15 mg/m^3 [5].

Distribution of Respondents According to Socio Demographic Characteristics: According to Table 3, all the respondents were male, with the majority of Malay ethnic and Malaysians. Among 64 workers 36 employees were nonsmokers while 28 workers were smokers.

Relationship of Socio Demographic Characteristics and Comfort Level of Working: The chi-square test showed no significant difference (p> 0.05) between the levels of education, working hours and smoking habit with the comfort level work (Table 4). This showed that there is no relationship between the comfort level of working and socio demographic characteristics.

Relationship Between the Average Concentrations of Total Suspended Particles and Working Comfort Level: In determining the relationship between the average concentration of total suspended particles with the working comfort level, the Pearson correlation test showed no significant difference, p = 0089 (p> 0.05). Pearson correlation results showed that the value of r is -0.306 where weak correlation relationship is inversely proportional. This showed that, the higher amount of suspended particles decreases the comfort level of working in Kuala Lumpur Central Depot. Contaminated working environment contributes to the discomfort condition and affect the productivity of workers employed [1]. In addition, the average concentration of total suspended particles does not exceed the permissible exposure limit of 15 mg/m^3

Major pollution sources produce heavy metals (As, Cd and Pb) are due to depot activities that produce a lot of smoke, soot and use lots of lubricant. Station 4 (repair PGC) is the station that contained the highest amount of particulates compared to other stations as a result of smoke production and use lots of lubricant. Socio demographic factors, such as level of education, working hours and smoking did not affect the comfort level of working among employees in Kuala Lumpur Central depot. The higher dust contents the lower comfort level of working because the contaminated working environment contributes to discomfort.

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