INDOOR AIR QUALITY IN AN AUTOMOTIVE ASSEMBLY PLANT IN SELANGOR, MALAYSIA

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Abstract. The purpose of this study was to determine the indoor air quality (IAQ) status of an automotive assembly plant in Rawang, Selangor, Malaysia using selected IAQ parameters, such as carbon dioxide (CO_2), carbon monoxide (CO), temperature, relative humidity (RH) and respirable particulate matter (PM10). A cross-sectional study was conducted in the paint shop and body shop sections of the plant in March 2005. The Q-TRAK™ Plus IAQ Monitor was used to record the patterns of CO, CO_2, RH and temperature; whilst PM10 was measured using DUSTTRAK™ Aerosol Monitor over an 8-hour time weight average (8-TWA). It was found that the average temperatures, RH and PM10 in the paint shop section and body shop sections exceeded the Department of Safety and Health (DOSH) standards. The average concentrations of RH and CO were slightly higher in the body shop section than in the paint shop section, while the average concentrations of temperature and CO_2 were slightly higher in the paint shop section than in the body shop section. There was no difference in the average concentrations of PM10 between the two sections.

INTRODUCTION

Indoor air quality has become an important occupational health and safety concern in the workplace. The indoor environment is important not only because of the amount of time spent inside buildings but because there are indoor sources of pollution, including, heating and cooking appliances, open fires, building and insulation materials, furniture, fabrics and furnishings, glues, cleaning products, other consumer products, and various biological sources, such as house dust mites, fungi, and bacteria. There is also the inflow of polluted outdoor air through windows, evaporation of substances from water, and, in some locations, infiltration of radon and other gases into the building from the underlying soil and bedrock (Harrison, 2002).

In an automotive assembly plant, exposure to indoor air pollutants is probably one of the most dangerous health hazards for the workers. Workers involved in auto body repair are potentially exposed to a multitude of air contaminants. During structural repair, activities such as sanding, grinding, and welding generate aerosols that are released

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into the worker's breathing zone. If the surface of the car being repaired contains toxic metals, such as lead, cadmium, or chromium, exposure to these metals, is possible. Workers who paint cars can be exposed to organic solvents, hardeners that may contain isocyanate resins and pigments that may contain toxic components (NIOSH, 1993).

In Malaysia, IAQ has been recognized by the Department of Occupational Safety and Health (DOSH) as a critical issue (DOSH, 2006). In order to ensure all workers are protected from indoor air pollutants, the department has set forth a code of practice entitled "Code of Practice on Indoor Quality" (DOSH, 2005). This code of practice is applied to all industries in Malaysia including the automotive industry. One of the aims of the code was to establish a set of maximum exposure limits for common indoor air contaminants, such as carbon monoxide, carbon dioxide and respirable particulates (DOSH, 2005).

In Malaysia, although indoor air pollutants pose a risk to the worker's health, few studies have been conducted in this industry. This is a serious omission because the automotive industry is a key player in the manufacturing sector, a high income generating industry and a government-linked company in Malaysia. In 2004, Malaysia was the largest producer of passenger cars in the Association of Southeast Asian Nations (ASEAN), accounting for 24.4% of the total ASEAN motor vehicle production. For commercial vehicles, Malaysia was the third largest producer, accounting for 11.0% of the total ASEAN production (Prime Minister's Department, 2005). Therefore, the aim of this study was to determine the concentration of five common IAQ contaminants [carbon dioxide (CO_2), carbon monoxide (CO), respirable particulate matter (PM10), temperature and relative humidity (RH)] in the paint shop and body shop sections of an automotive assembly plant in Rawang, Selangor, Malaysia.

MATERIALS AND METHODS

A cross-sectional study of the two sections (paint and body shops) was conducted in March 2005 at an automotive industry plant located in Rawang, Selangor. After walk-through surveys of the sites, data collection was done using direct-reading instruments [the Q-TRAK™ Plus IAQ Monitor (TSI Inc, 2003a) and the DUST-TRAK™ aerosol monitor (TSI Inc, 2003b)] during an eight hour work shift from 9:30 AM to 5:30 PM during painting and sanding operations. The instruments were located in both sections (body and paint sections). The Q-TRAK™ Plus IAQ Monitor (TSI Inc, 2003a) was used to record the CO, CO_2, temperature and RH levels using a survey mode at one second intervals. This mode was used to display the real-time readings of all parameters simultaneously. Before sampling, the Q-TRAK™ Plus IAQ Monitor was calibrated for CO_2 and CO by running a span gas with a known concentration and a zero gas through the monitor by the local TSI distributor. The span gas concentrations for CO_2 and CO were 1,000 ppm and 35 ppm, respectively. If measurements were not within specifications, the instrument was recalibrated. The Q-TRAK™ Plus IAQ Monitor (TSI Inc, 2003a) uses a non-dispersive infrared sensor for measuring CO_2 concentration, an electrochemical sensor for measuring CO concentration, a thermistor for measuring temperature, and a thin-film capacitive element for measuring relative humidity (Ramachandran *et al*, 2002). A DUST-TRAK™ aerosol monitor (TSI Inc, 2003b) was used to measure PM10. The DUST-TRAK™ aerosol monitor measures PM10 at one minute intervals at a flow-rate of 1.7 l/minute. Before sampling, pre- and post-zero checks of the DUST-TRAK aerosol monitor were carried out. The DUST-TRAK aerosol monitor is an optical instrument that detects particles in the air matrix by optical scattering, using the optical diameter instead of the aerodynamic diameter (Guo *et al*, 2004). The data was analyzed using TrakProTM v3.41 software.

RESULTS

Temperature and RH

Fig 1 shows the average temperature and RH obtained in the paint and body shop sections. The average temperature in the paint shop section was 32.5 ± 1.2ºC (29.7 - 33.9ºC and, in the body shop section the average temperature was 29.7 ± 1.0ºC (27.8 - 30.8ºC). The relative humidity in the body shop section ranged from 69.8 to 78.4% with an average of 72.9 ± 2.4%. The RH in the paint shop section was 65.5 ± 2.3% (62.6-71.3), higher than that in the body shop. The temperature and RH of both sections exceeded those recommended by the DOSH (Table 1).

CO

Fig 2 shows the concentrations of CO in the paint and body shop sections. The results show that the concentration of CO in the body shop ranged from 1.4 to 3.1 with an average of 2.0 ± 0.4 ppm. In the paint shop, the concentration of CO ranged from 0.5 to 1.8 ppm with an average of 1.1 ± 0.2 ppm. The average concentration of CO in the body shop was higher than that in the paint shop. However, the concentrations of CO in both sections were within DOSH standard limits (Table 1).

CO_2

Fig 3 shows the concentrations of CO_2 in the paint and body shop sections. The results show the average concentration of CO_2 in the paint shop was 252.8 ± 30.7 ppm, which was slightly higher than in the body shop (252.5 ± 28.3 ppm). The concentrations of CO_2 in the paint and body shop sections were 204-360 and 204-339 ppm, respectively. These concentrations were within the DOSH standard limits (Table 1).

PM10

Fig 4 shows the concentrations of PM10 in the paint and body shop sections. The PM10 concentration in the paint shop section ranged from 0.2 to 1.6 ppm, with an average of 0.4 ± 0.1 ppm, in the body shop

Table 1
Descriptive summary of selected IAQ parameters in the paint shop and body shop sections.

Parameters	DOSH standard[a] in 8-TWA	Paint shop section				Body shop section			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Temperature (ºC)	20-26	32.5	1.2	29.3	33.9	29.7	1.0	27.8	30.8
RH (%)	40-60	65.5	2.3	62.6	71.3	72.9	2.4	69.8	78.4
CO ppm	10	1.1	0.2	0.5	1.8	2.0	0.4	1.4	3.1
CO_2 ppm	C1,000	252.8	30.7	204	360	252.5	28.3	204	339
PM_{10} mg/m^3	0.15	0.4	0.1	0.2	1.6	0.4	0.1	0.2	2.4

C, ceiling limit; mg/m^3, milligrams per cubic meter of air at 25ºC and one atmosphere pressure; ppm, parts of contaminated air vapor or gas per million parts air by volume; 8-TWA, the time-weighted average for up to 8 hours/day.
[a](DOSH, 1996) and (DOSH, 2005).

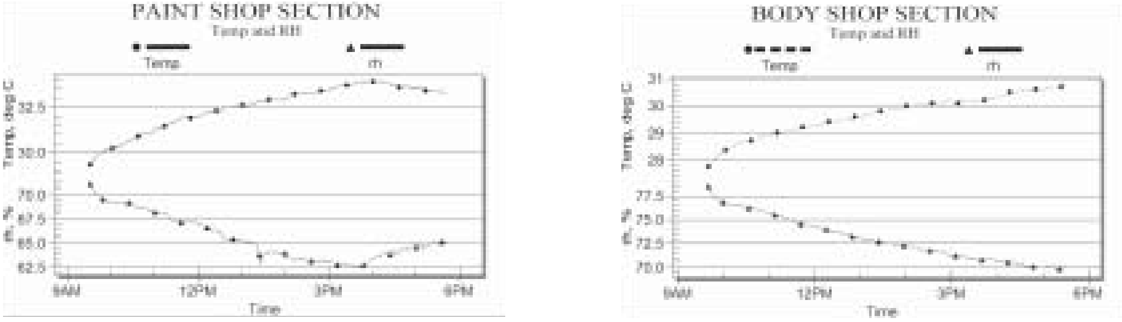

Fig 1–Temperature and RH in the paint shop section (a) and body shop section (b).

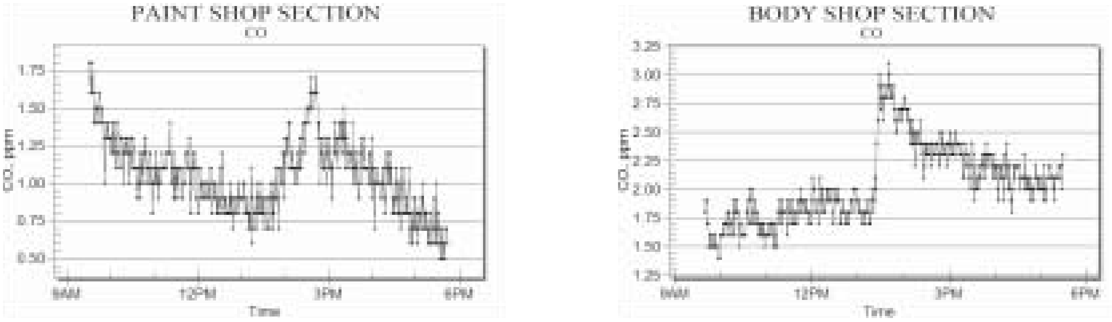

Fig 2–Concentration of CO in the paint shop (a) and body shop sections (b).

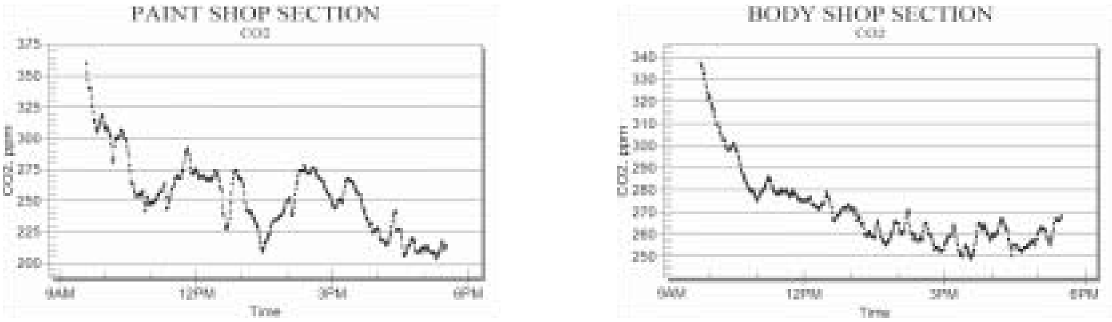

Fig 3–Concentrations of CO_2 in the paint shop (a) and body shop sections (b).

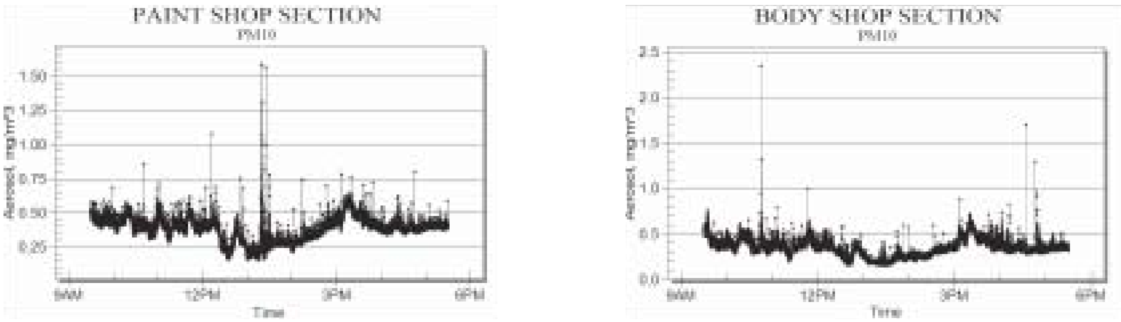

Fig 4–Concentrations of PM10 in the paint shop (a) and body shop sections (b).

section it was 0.4 ± 0.1 ppm (0.2-2.4 ppm). The average PM10 in both sections exceeded the DOSH standard limits (Table 1).

DISCUSSION

The temperature and RH in both sections exceeded the DOSH standard limits. The recommended optimum comfort range for RH according to DOSH is 40% to 60%. Low humidity can cause dryness of the eyes, nose and throat and may also increase the frequency of static electricity shocks. The relative humidity in the body shop ranged from 69.8 to 78.4% with an average of 72.9 ± 2.4%. High humidity, above 80%, can be associated with fatigue and "stuffiness" (DOSH, 1996). We suggest the air-conditioning in this area should be monitored regularly. Humidity can result in the growth of mould and dust mites within the area if allowed to become too high. Rapid growth occurs when levels of humidity are above 60%, with a negative effect on respiratory illnesses such as asthma. If the level of humidity becomes too low, below 30%, this too can have adverse effects, with some people developing sore throats due to dryness of the air (DOSH, 1996). In this study, the concentration of CO and CO_2 were within the DOSH standard limits.

Our study found that the mean PM10 levels in both sections exceeded the DOSH recommendations at 0.15mg/m^3. Inadequate ventilation of the sanders occurred during sanding in the body shop which probably contributed to increased levels of PM10 in the body shop. In the paint shop the high concentration of PM10 could be due to various organic solvents and paint overspraying. Thus, respirators need to be used properly to prevent worker exposure to air contaminants in the paint shop. Exhaust ventilation and process isolation are commonly used controls for PM10 reduction.

There were several limitations of our study. Since the data was collected in only one day, our findings may not represent other days of the year. Since we did not conduct a survey to obtain information about IAQ status, our results were only limited to the parameters measured. Further study needs to be conducted using both methods (monitoring and surveys) over a longer period. However, this study is still useful as an indicator of IAQ status in this factory, which may be applicable to assessing compliance with IAQ regulations in this country.

In conclusion, the workers in the paint and body shop sections were exposed to high concentrations of RH, temperature and PM10. Therefore, IAQ management programs, engineering controls, training and education should be conducted in these sections to minimize IAQ problem exposure.

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