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Exposure Assessment of Formaldehyde and its Symptoms among Anatomy Laboratory Workers and Medical Students

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ABSTRACT

Formaldehyde has commonly been used as an embalming agent in the anatomy laboratory besides being used during production of wood, resins and plastics. This current study involved the measurement of formaldehyde exposure level among anatomy laboratory workers and medical students in anatomy laboratory using the NIOSH 2541 method. The study determined the symptoms resulted from formaldehyde exposure using self-reported symptom questionnaire that has been modified. Mean area concentration of formaldehyde 8 h Time Weighted Average (TWA) in the dissection hall and specimen preparation laboratory were 0.1±0.03 and 0.17±0.04 ppm, respectively. Both of these formaldehyde concentrations were below the ceiling limit of 0.30 ppm. Statistically, there was no significant difference between the formaldehyde concentration in the dissection hall and specimen preparation laboratory. The personal exposure 15 min Short Term Exposure Limit (STEL) formaldehyde concentration was 2.30±1.53 ppm and it was higher than 15 min STEL of 2 ppm. Results from the anatomy laboratory workers and medical students reported through the self-reported symptom questionnaires revealed that the most common symptoms they experienced during working hour and off working hour where eye and nose irritations which are 71.3, 57.5 and 4.6, 8%, respectively. In conclusion, the personal exposure 15 min STEL exceeded the United State Occupational Safety and Health Administration (USOSHA) standard. Even though the formaldehyde concentration for the area was under the limit, still there were risks to develop an adverse health effect.

Key words: Formaldehyde, irritation, embalming agent, anatomy laboratory workers

INTRODUCTION

Despite its various uses, formaldehyde can cause adverse health effects which are acute and chronic effects. The acute effects include eye irritation and irritation at the upper respiratory system such as nose and throat (Akbar-Khanzadeh and Mlynek, 1997). A study found that these acute effects always occur among medical students, anatomists, embalmers, histologist technicians and the wood production workers (ATSDR, 1999). Next, the chronic effects are, for examples, cancer of nasopharyngeal, ocular melanoma, lung cancer, brain cancer and leukaemia (Akbar-Khanzadeh *et al*., 1994. Dufresne *et al*., 2002; EPA, 2010; Fleisher, 1987). There were several studies that measured the concentration of formaldehyde in the anatomy laboratory. A study compared the prevalence rates of formaldehyde-specific IgE or IgG antibodies with self-symptoms associated with formaldehyde exposure among medical students (Matanoski, 1989).

The students were also given a questionnaire with listed responses about any symptoms that they experienced during the dissection. Results showed that formaldehyde concentrations within the laboratory ranged from 0.16-9.16 ppm. The questionnaire revealed that 92.8% of the students complained of eye soreness, 51.5% headaches, 26.3% sore throat and 25.1% shortness of breath. These results showed that the students were exposed to formaldehyde concentrations higher than the university's recommended limits during dissection practices.

Same study stated that the area and personal 8 h TWA were 0.25 and 0.59 ppm, respectively (Kim *et al*., 1999). Both formaldehyde concentrations were under the US OSHA standard limit. Another study found mean personal exposure 8 h TWA for student and instructors were 1.0 and 0.6 ppm, respectively. These personal exposures were higher than area formaldehyde concentrations which was 0.5 ppm. Both personal exposures were higher than US OSHA 15 min STEL while the mean area concentration was below the standard limit US OSHA 8 h TWA (Kriebel *et al*., 1993).

The authors conducted the present study to determine area and personal formaldehyde exposure level and its symptoms among medical students and anatomy laboratory workers in anatomy laboratory.

MATERIALS AND METHODS

Chemicals and instruments: Chemicals used were: 37% formaldehyde solution, toluene and dimethylformamide. The instruments consisted of Gillian LFS-113 low flow personal air sampling pump (Sensidyne USA), GilAir-5 air sampling pump (Sensidyne USA), Gilibrator 2 Primary Flow Calibrator, Hygitech sorbent tube 120×60 mg containing XAD-2 coated by 2-HMP, tube holder (Sensidyne USA), pump connector tube (Sensidyne USA), Teflon plastic end caps (Sensidyne USA), mL^{-1} vials, GC vials, 5 μL pipette, 100 mL conical flask and gas chromatography-flame ionisation detector GC-FID (Agilent Technology 7890A auto sampler injection).

Measurement of formaldehyde concentration in air: Air sampling pumps were pre-calibrated with XAD-2 adsorbent tubes in the train. The air sampling pump was pre-calibrated to 0.2 L min^{-1} to sample STEL concentrations, as stated in the NIOSH analytical method. The air sampling pump was pre-calibrated to 0.1 L per minute using a Gilibrator 2 Primary Flow Calibrator to sample the breathing zone TWA concentrations. Data collection was performed by positioning the sampling train near breathing zone and 4 ft off the ground to determine personal and area exposure of formaldehyde, respectively (as stated in NIOSH method 2541). Two locations of this study were dissection hall and specimen preparation laboratory. In the dissection hall, the assessment of formaldehyde concentration was conducted during dissection activity by the medical students. In contrast, in the specimen preparation laboratory, the air was sampled during specimen preparation and cleaning activity. Area exposure assessment was conducted at dissection hall and specimen preparation laboratory while the personal exposure involved the anatomy laboratory workers at the specimen preparation laboratory only. The durations of exposure among anatomy laboratory workers and medical students were 48 h×month and 3 h×month, respectively. However, the air sampling was performed for 4 h in each session to calculate the concentration of formaldehyde 8 h TWA. The samples were analyzed by desorbing them with dimethylformamide and toluene before they were quantitated using GC-FID. The final concentration was compared to two standard limits, namely (Law of Malaysia, 1994) ceiling limit of 0.30 ppm and US OSHA 15 min STEL of 2 ppm.

Questionnaire: Based on sample size calculation, 84 medical students and 3 anatomy laboratory workers were chosen to be the respondents in this study (Naing *et al.*, 2006). The respondents were chosen by simple random sampling. The questionnaire used was modified from (OEHHA, 1999) The particulars asked in the questionnaire were their sociodemographics and 11 symptoms related to formaldehyde exposure during working hour and off working hour. A pilot study was conducted to test the reliability (Cronbach alpha = 0.82). The questionnaire was approved by the university ethical committee with serial number NN-004-2012. The inclusion criteria were second year medical students and anatomy laboratory workers while exclusion criteria were smokers and asthmatic persons. The mean symptom score was categorized according to 25th percentile (respondent with = 1 reported symptom), 50th percentile (respondent with 2-3 reported symptoms) and 75th percentile (respondent with 4-9 reported symptoms).

Statistical analysis: Data analysis started with descriptive statistics for sociodemographic variables (data not shown). The Mann-Whitney U test was used to compare formaldehyde concentration measured between dissection hall and specimen preparation laboratory. The one-sample t-test was used to compare mean formaldehyde concentration in both location with the ceiling limit value and US OSHA 15-min STEL value and also between mean symptom score workers and medical students. The Wilcoxon signed-rank test was used to compare between mean symptom score during and off working hour. The Spearman's correlation test was used to identify correlation between exposure duration and symptom score.

RESULTS AND DISCUSSIONS

Determination of formaldehyde concentration: Table 1 shows the comparison between formaldehyde concentrations measured in the dissection hall and specimen preparation laboratory. The mean average of formaldehyde concentrations was 0.17 ppm for both locations, ranging from 0.14-0.20 ppm. Statistically, by using the Mann-Whitney test, there was no significant difference in formaldehyde Concentration between these two locations ($p>0.05$).

The results of mean area formaldehyde concentrations 8 h TWA in both locations were below the (Law of Malaysia, 1994). ceiling limit value of 0.30 ppm (Table 1). Statistically, by using one sample t-test, there were no significant differences between the concentrations in both locations with the ceiling limit. In contrast, the mean for formaldehyde concentration 15 min STEL was high and exceeded the US OSHA 15 min STEL value of 2.0 ppm. However, statistically, by using one sample t-test, there were no significant differences between the concentrations in both locations with the US OSHA 15 min STEL.

Self-reported symptoms of formaldehyde exposure: Table 2 shows 11 symptoms related to formaldehyde exposures that have been reported by the respondents. The most commonly reported symptoms due to formaldehyde exposure during dissection were eye irritation (71.3%) and nose irritation (57.5%). There were no wheezing symptoms reported during the dissection session. This

Table 1: Comparison between formaldehyde concentration 8 h TWA in dissection hall and specimen preparation laboratory

	8 h TWA (area) conc. ceiling (ppm) limit (ppm)	15 min STEL (personal) conc. 15 min (ppm) stel
Dissection hall	0.17±0.03 (n = 3) 0.30	-
Specimen preparation laboratory	0.17±0.04 (n = 3) 0.30	2.30±1.53 (n = 3) 2.0 ppm

Table 2: Self-reported symptoms related to formaldehyde exposure

Symptoms	Working hour n (%)	Off working hour n(%)	p-value
Eye irritation	62 (71.3)	4 (4.6)	0.000**
Nose irritation	50 (57.5)	7 (8)	0.000**
Headache	23 (26.4)	14 (16.1)	0.039*
Runny nose	23 (26.4)	18 (20.7)	0.197
Itchy skin	19 (21.8)	10 (11.5)	0.007*
Fatigue	19 (21.8)	11 (14.9)	0.134
Shortness of breath	17 (19.5)	1 (1.1)	0.000**
Dry throat	16 (18.4)	4 (4.6)	0.003*
Sore throat	13 (14.9)	10 (11.5)	0.439
Chest tightness	12 (13.8)	1 (1.1)	0.002*
Wheezing	0 (0)	1 (1.1)	0.317

*,**Significant at $p<0.05$ and $p<0.001$

finding is similar to previous studies. The symptoms that showed a significant difference between during and after dissection were eye irritation, nose irritation and shortness of breath with $p<0.001$. Other symptoms that showed a significant difference between during and after dissection were headache, itchy skin, dry throat and chest tightness with $p<0.05$. The symptoms such as runny nose, fatigue, sore throat and wheezing showed no significant difference between during and after dissection with $p>0.05$.

Formaldehyde concentration: The formaldehyde concentration was calculated using the calibration graph resulted from the GC-FID analysis ($R^2 = 0.6508$).

The formaldehyde concentrations in this study were relatively lower than previous studies (Kim *et al*., 1999. Skisak, 1983). The two location have the same formaldehyde concentration, it could be due to the body structure that was soaked earlier in the same cadaver tank. Furthermore, the results also showed that formaldehyde concentrations were not influenced by different work activities. Due to high formaldehyde concentration for STEL-15 min in the specimen preparation laboratory, such high formaldehyde level has the potential to cause some acute effects such as eye and nose irritations (Dufresne *et al*., 2002).

A study suggested that the personal exposure level for a person who is dissecting during the laboratory session can be roughly estimated to be 2-3 times greater than the mean indoor formaldehyde concentration (Takigawa *et al*., 2005). This might be related to the distance between the sources of formaldehyde and the sampler. For personal exposure, the sampler is near the breathing zone whilst for area exposure, the sampler is 3 m away from the body structure examined. In addition to the area exposure, there might be confounding factors such as ventilation and room volume that can dilute the amount of concentration (Uba *et al*., 1989; WHO, 2001).

Symptoms of formaldehyde: Irritant is one of the characteristics of formaldehyde (Hauptmann *et al*., 2004; WHO, 2002). which could be the cause of those two symptoms as reported by most of the respondents. The nose irritation is caused by the tissues of the respiratory tract that readily absorb the chemical on exposure (Dufresne *et al*., 2002). As for eye irritation, other studies also found that it is the most common type of irritation after exposure to formaldehyde among students (Matanoski, 1989; Naing *et al*., 2006).

Comparison between mean symptom score during working hour and off working hour: The mean symptom score during working hour, 2.92±2.47 is higher than off working hour, 0.95±1.70. Statistically, by using the Wilcoxon signed-rank test, there was a significant difference ($p<0.05$) between mean symptom score of during working hour and off working hour. This resulted from the respondents who were exposed to relatively higher formaldehyde vapour that derived from embalming and dissection activity (Akbar-Khanzadeh *et al*., 1994). During working hour than no exposure during off working hour.

Comparison of mean symptom score between medical students and anatomy laboratory workers: The mean symptom score for anatomy laboratory workers was higher than the mean symptom score for medical students which was 6.33±1.53 and 2.8±2.640, respectively. Statistically, by using independent t-test, there was a significant difference between the mean symptom score for anatomy laboratory workers and mean symptom score for medical students. This could be resulted from the length of exposure duration between anatomy laboratory workers and medical students were 48 and 3 h per month, respectively. Thus, the anatomy laboratory workers were more exposed to formaldehyde and experienced more symptoms than the medical students. This was proven by a Spearman correlation test that showed a significant positive weak correlation between exposure duration and symptom score ($p<0.05$, $r_s = 0.244$). This resulted from the small sample size. Other reason that can influenced the differences is the behaviour of the workers that being close the cadaver during specimen preparation, on the other hand the student were usually walking around in order to do their observation on the cadaver. These behaviour might reflect their symptoms (Ohmichi *et al*. 2006).

CONCLUSION

In summary, although the medical students and the anatomy laboratory workers were exposed to formaldehyde concentration at lower concentration than ceiling limit, they still reported intermediate to high symptom score. The mean formaldehyde concentration 15-min STEL exceeded the US OSHA 15-min STEL and might influence the respondent to report the high symptom score. This was justified with the significant correlation between exposure duration and symptom score.

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