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Area and Personal Exposure Levels to Formaldehyde and Its Variation among Undergraduate Students during Gross Anatomy Laboratory Practice

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Abstract

Formaldehyde emitted from the cadavers in Gross Anatomy Laboratory may fluctuate leading to a variation in exposure level of the participants during practice. This study aimed to evaluate the variation of formaldehyde levels and to determine the relationship between area and personal exposure concentration. Formaldehyde levels were measured in six sampling areas repeatedly during three types of study sessions; thoracic, abdominal, and brain and nerve study session. The highest formaldehyde level of area sampling (0.712 ppm) was found during the abdominal study session. Even though, formaldehyde levels were inconsistent but there were no statistical differences of areal formaldehyde concentrations among the sampling areas and the types of study sessions *($p>0.05$)*. Personal samplings were conducted concurrently with 15 students. Average formaldehyde levels of the 15 students ranged from 0.317 to 0.912 ppm. Personal formaldehyde concentrations in the different types of study sessions were statistically different *($p<0.05$)*. The relationship between personal and area formaldehyde concentrations of these 15 participants indicated that the correlation coefficients ranged from -0.529 to 0.600 with an average of 0.377. This result suggested there was a limitation in using area concentration to estimate personal exposure levels.

Keywords: formaldehyde; area sampling; personal exposure; gross anatomy laboratory

1. Introduction

Formaldehyde (FA) is an antiseptic substance used in embalming fluid to preserve the cadavers. It is conceivable that during practice in Gross Anatomy Laboratory, the participants may be exposed to formaldehyde emitted from the cadavers. Many studies indicated that there were adverse health effects for both students and instructors due to their exposure to formaldehyde (Park *et al.,* 2006; Mathur *et al.,* 2007; Wei *et al.,* 2007). Formaldehyde can cause irritation with tissues that it comes in contact with. Short-term exposure to airborne formaldehyde at concentrations ranging from 0.4 to 3 ppm can cause irritation to one's eyes, nose, and throat, as well as the upper respiratory tract (ATSDR, 1999). The minimal risk levels (MRLs) of formaldehyde for acute exposure, intermediate exposure, and chronic exposure are 0.04, 0.03, and 0.008 ppm respectively (ATSDR, 1999). Even though there is no definite relationship between formaldehyde and nasopharyngeal cancer found in long term exposure, formaldehyde has been classified as a class B1 carcinogen and its inhalation unit risk is 1.3E-5 per µg/cu.m (US. EPA, 2005). It means that there is an excess carcinogen case of 13 cases in one million exposed to 1 µg/cu.m. The OSHA Permissible Exposure Limit (PEL) for an 8-hr time-weighted average exposure of formaldehyde is 0.75 ppm (TWA) and for Short-Term Exposure Limit (STEL) is 2 ppm, whereas a Recommended Exposure Level (REL-TWA) of formaldehyde proposed by NIOSH is 0.016 ppm and for a 15 minute-exposure is 0.1 ppm (NIOSH, 2007).

Formaldehyde concentrations in the gross anatomy laboratory ranged between 0.05-3 ppm, which frequently exceeded the exposure limit level (Wantke *et al.,* 2000; Kunugita *et al.,* 2004; Shiraishi, 2006). However, exposure to airborne formaldehyde depends on many contributing factors, not only formaldehyde concentration but also exposure duration, ventilation, as well as task and posture of the participants. Fluctuations of formaldehyde concentrations were found in many studies. Thongsri and Petkasem (2007) demonstrated that formaldehyde concentrations of the front room and those of the back room were different. Oosthuizen (1998) stated that formaldehyde concentrations, ranging from 0.19 to 2.29 ppm, fluctuated considerably depending on the stage of dissection process. A variation of formaldehyde concentrations among the sessions and area were also reported (Shiraishi, 2006; Tanaka *et al.,* 2003). Furthermore, personal exposure concentrations were also inconsistent and actually higher than the indoor concentrations (Ohmichi *et al.,* 2006; Ohmichi

et al., 2006; Costa *et al.,* 2008). Ryan *et al.* (2003) found that the averages of personal exposure concentrations and area concentrations were 0.21 and 0.16 ppm respectively. In addition, the excessive exposure levels occurring during dissection were presumably due to short distances between formaldehyde source and the participants' noses.

The objectives of this study were to examine the variation of formaldehyde levels that might be influenced by the area within the laboratory and/or types of study sessions, and to determine the relationship between areal formaldehyde and personal exposure concentrations.

2. Materials and Methods

2.1. Site of the study

This study was part of the research entitled "formaldehyde concentrations in indoor air and the breathing zone of medical students and instructors and clinical symptoms during gross anatomy laboratory" at the Faculty of Medicine, Thammasat University. The result on formaldehyde concentration and clinical symptom was presented in a separate published article, not depicted in this report. However, the methodology specified here represented the objectives of this study. The study was performed at the Faculty of Medicine of Thammasat University during a gross anatomy course. The gross anatomy room was approximately 30 m x 10 m x 2.8 m. Windows along three sides of the room were open during practice. Electrical fans, placed on the entrance side, were used to ventilate the room throughout the period of session. There were 20 cadavers on the dissection tables arranged across the room as shown in Fig. 1. Embalming fluid consisted of approximately 3.6% w/w of formaldehyde and 0.2% w/w of phenol.

2.2. Measurement of formaldehyde concentration

Air sampling and analysis for formaldehyde followed the method of NIOSH number 2541 (NIOSH, 2003). Active sampling pumps with a flow rate of 100 ml/min were used to draw air into solid sorbent tube containing 10% (2-hydroxymethyl piperidine on XAD-2). Then the sorbent tubes were analyzed by gas chromatography with a flame ionization detector (GC-FID).

Formaldehyde concentrations were evaluated in three types of anatomy sessions; 1) thoracic study session in September 2) abdominal study session in November and 3) brain and nerve study session in December. Laboratory sessions were operated for three hours each day. Sampling was conducted twice for each session so that the measurements were made on six separate days with the sampling period of 3 hours throughout the entire session.

In the room, six area sampling points, named as A1 to A6, were determined by setting air sampling instruments 1.5 m above the floor and 2 m apart from the dissection tables. These sampling points were divided into 2 sides, the left and the right side. The left side was near the entrance consisting of A1, A3 and A5 while the right side was near windows consisting of A2, A4 and A6 (Fig. 1).

Each dissection table was assigned to 6-7 students for practicing. Approximately 140 students and instructors were in the laboratory each day. A total of 15 students, practicing at tables no 2, 3, 5, 6, 7, 8, 9, 10, 11, 13 15, 16, 17, 19, and 20, participated in personal samplings. Air sampling pumps were attached to the students during in the laboratory. The solid sorbent tube was worn on the collar of the student gown near the breathing zone. All 15 students were sampled repeatedly for 6 days. Both area and personal sampling were conducted concurrently within each day. Total of 126 samples were obtained in the study; 36 of area samples and 90 of personal samples.

2.3. Data analysis

For data analysis reasons, formaldehyde concentration of 0.0005 ppm (half of the detection limit) was assigned for samples with FA concentrations lower than the detection limit (33 samples out of total 126 samples). Formaldehyde concentrations, both area sampling and personal sampling were described and were then analyzed for differences among groups by parametric and non-parametric analytical methods at p-value of 0.05. The relationship between area and personal sampling concentrations was determined by Pearson's Correlation test. The statistical package, SPSS (Windows version), was used for data analysis.

3. Results and Discussion

Table 1 showed the areal formaldehyde concentrations in the gross anatomy room. The highest level of areal FA concentration was 0.712 ppm found in an abdominal study session while the lowest levels, less than the detection limit (0.001 ppm) of the method, were found in all three types of study sessions. The averages of FA concentrations of A1 to A6 were 0.519, 0.253, 0.330, 0.418, 0.229, and 0.68 ppm respectively. Variations of FA concentrations of each sampling point were relatively high as depicted by its standard deviation value. Consequently, FA concentrations among these

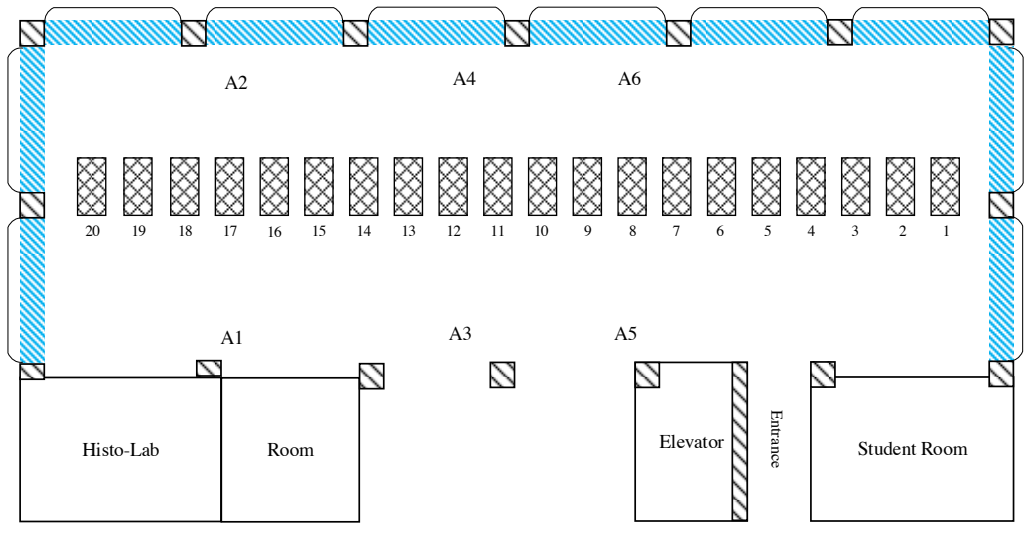

Figure 1. Layout of gross anatomy laboratory

six sampling points were not significantly different (Oneway ANOVA; *p*-value = *0.205*). However, areal FA concentrations of this study were comparable to other studies which reported that FA concentrations ranged from 0.23-1.03 ppm and in a range of 0.11-0.33 ppm respectively (Ohmichi *et al.*, 2006; Wantke *et al.,* 2000). The National Institute of Occupational Safety and Health (NIOSH, 2007) set a ceiling recommended exposure level for FA (REL-C) at 0.1 ppm while of the American Conference of Governmental Industrial Hygienists (ACGIH, 2012) set a ceiling limit (TLV-C) at 0.3 ppm, meaning that FA concentration, at any particular time, should not exceed these limit. According to the results, the maximum levels and the overall area average of FA concentrations were higher than the limits. Moreover, 24 out of the 36 measurements also exceeded TLV-C of 0.3 ppm. The result pointed out that mitigation measures to reduce risk from exposure to formaldehyde were needed.

In accordance with the side of the room, median FA concentration of the left side was 0.454 ppm whereas that of the right side was 0.421 ppm as shown in Fig. 2. Comparison of FA concentrations of the left and the right side, the result showed that there was no statistical difference of both sides (Mann-Whitney test; *p*-value = *0.640*). Among three study sessions, the abdominal study session had the highest median of area FA concentrations of 0.526 ppm followed by the brain and nerve study session and the thoracic study session for the amount of 0.441 and 0.364 ppm respectively. Nevertheless, FA concentrations among these three study sessions were not significantly different (Krusksal-Wallis test; *p*-value = *0.072*). The above results suggested that fluctuation of FA concentration in the room may be attributed to laboratory sessions and/or location in the laboratory. However there might be other important contributing factors not included into this study, such as room temperature, air exchange rates and direction of the air flow, all of

Table 1. FA concentration of each area sampling points

Area	FA concentrations (ppm)				
	N	Minimum	Maximum	Average ± SD	Median
A1	6	0.407	0.712	0.519 ± 0.105	0.492
A2	6	<0.001	0.577	0.253 ± 0.281	0.205
A3	6	<0.001	0.613	0.330 ± 0.273	0.411
A4	6	<0.001	0.593	0.418 ± 0.212	0.482
A5	6	<0.001	0.457	0.220 ± 0.241	0.206
A6	6	<0.001	0.573	0.226 ± 0.261	0.157
Total	36	Average of overall area = 0.328 ± 0.246, Median 0.441			

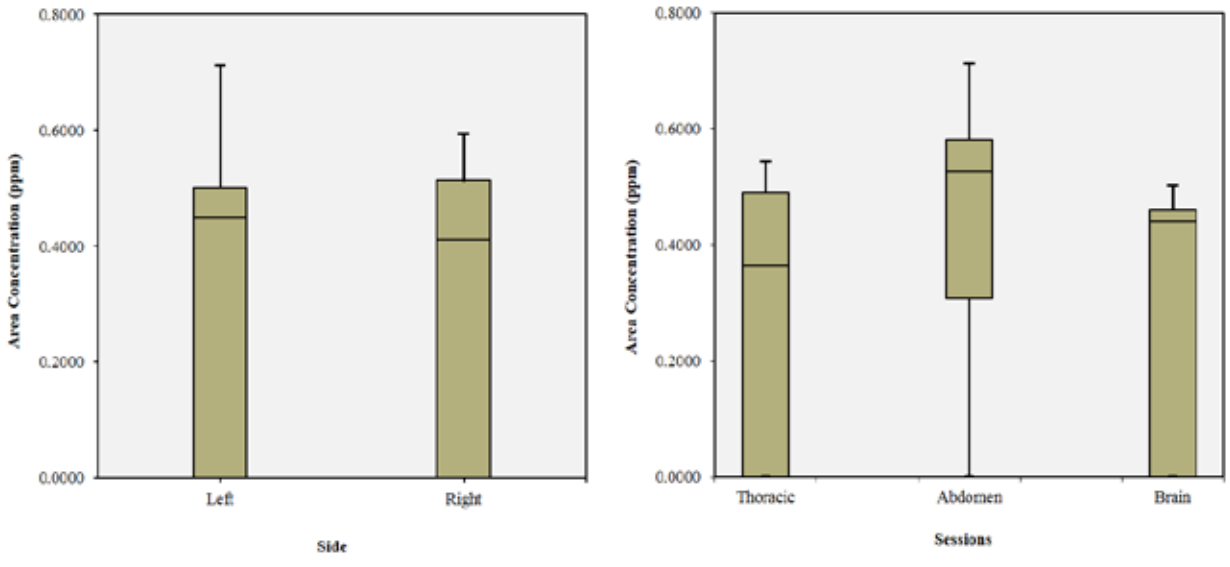

Figure 2. Area FA concentrations classified by side and study sessions

which may affect the variation of FA in the laboratory.

Fig. 3 presented the distributions of personal concentrations of 15 students. The highest personal FA level of 1.126 ppm was found during in abdominal study session, whilst the lowest levels, less than 0.001 ppm, were found in all three types of study sessions. In addition, most of them were notably found in brain and nerve study session. The averages of personal exposure to FA of these 15 students ranged from 0.317 to 0.912 ppm, indicating that all 15 students were exposed to FA higher than the limits of NIOSH and ACGIH. From the study of Ohmichi *et al.* (2006) personal exposure levels ranged from 0.33 to 1.47 ppm whereas Costa *et al.* (2008) evaluated the mean level of FA exposure at 0.44 ppm (0.04-1.58 ppm). Personal FA concentrations of this study were comparable to those results and additionally showed that there was a variation of personal exposure concentrations among the

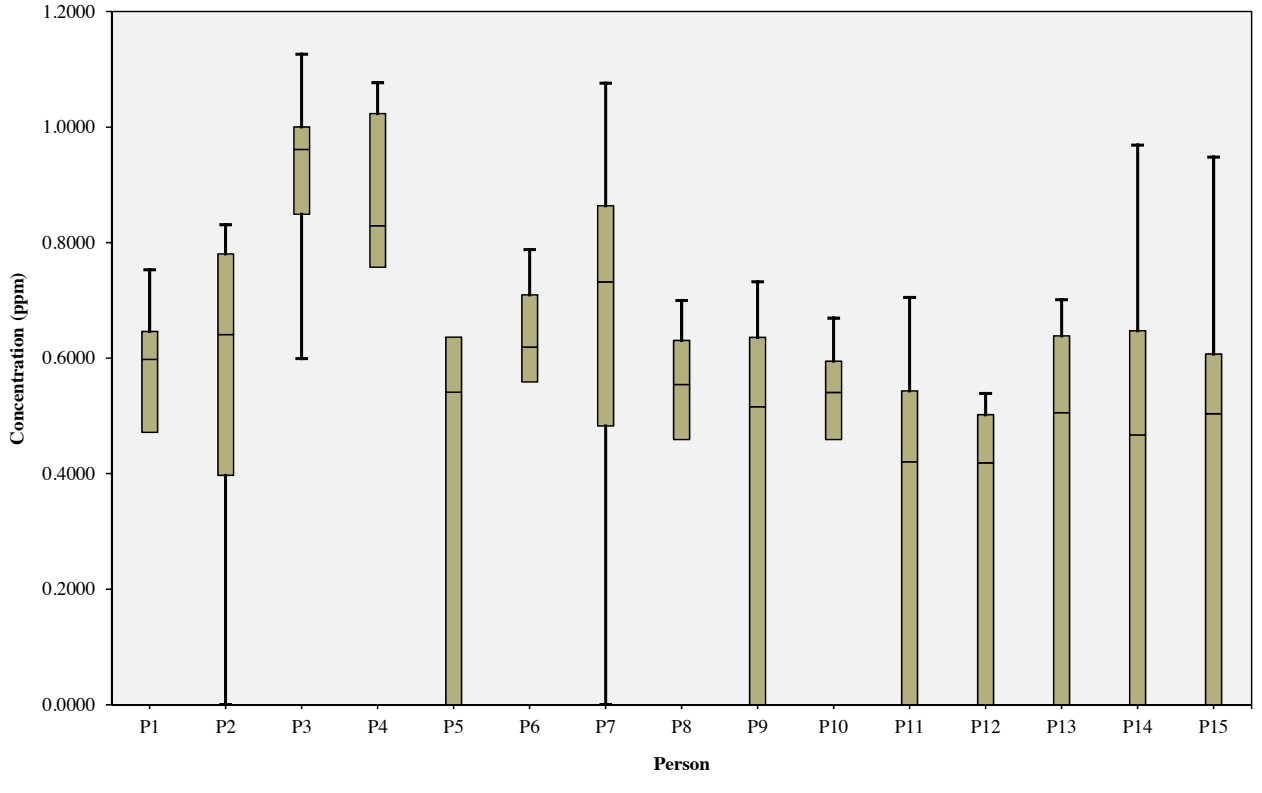

Figure 3. Distributions of personal concentrations of 15 students

Table 2. Correlation coefficients between personal and area FA concentrations of 15 students

Person	Correlation Coefficient	p-value	Person	Correlation Coefficient	p-value
1	0.025	0.962	9	0.585	0.222
2	0.362	0.481	10	0.476	0.340
3	0.570	0.238	11	-0.529	0.281
4	0.360	0.484	12	0.531	0.279
5	0.581	0.226	13	0.513	0.298
6	0.555	0.253	14	0.599	0.209
7	0.600	0.208	15	-0.150	0.792
8	0.573	0.234	Average Correlation Coefficient = 0.377		

students. However, personal exposure concentrations of these 15 students were not significantly different (Oneway ANOVA; *p*-value = 0.111).

Median personal exposure levels in the abdominal, thoracic and brain and nerve study session were 0.650, 0.485 and 0.261 ppm respectively. Personal exposure concentrations were statistically different among these three study sessions (Kruskal-Wallis test; *p*-value = 0.009). It stated that types of study sessions might influence on personal exposure level more than those of areal FA levels. Moreover, the overall median of FA exposure concentration, 0.558 ppm, was statistically higher than the overall median of areal FA concentration, 0.441 ppm (Mann Whitney Test; *p*-value = 0.001). This finding was agreeable with those of the earlier studies (Ohmichi *et al.,* 2006; Ryan *et al.,* 2003).

The individual correlation coefficients between personal and areal FA concentrations of 15 students varied widely, ranging from -0.529 to 0.600 as presented in Table 2. The overall average correlation coefficient was 0.377 which indicated that personal formaldehyde concentrations had a low correlation with the area concentrations. Since, there were two negative correlation coefficients, the average of correlation coefficient increased to 0.487 when those two values were excluded. However, these correlation coefficients were still not statistically significant. The reason was presumably due to too small sample size. The result suggested that there may be other factors influencing on personal exposure level, such the distance between each student and cadaver and/or their performance and activities in the anatomy room as mentioned in the other studies (Ohmichi *et al.,* 2006; Ryan *et al.,* 2003). Thus, using of area concentration as surrogate of personal exposure, especially in the health impact epidemiological study, should be done with caution and may lead to possibly underestimating personal exposure concentrations.

4. Conclusion

Based on data obtained from the study, most of the area formaldehyde concentrations of the anatomy laboratory exceeded a ceiling limit of ACGIH. Even though the area concentration fluctuated between different study sessions and the area within the laboratory, there was no significant difference. Personal exposure concentrations were considerably higher than area concentrations and likely to be affected by the different types of study sessions. Since there was a rather low relationship between area and personal formaldehyde concentration, using area concentrations might underestimate personal exposure levels. The result indicated that the gross anatomy laboratory might pose a health risk from a high exposure to formaldehyde during practice for 3 hours. Therefore, mitigation measures should be determined to reduce health risks for all participants, instructors, students and scientists.

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References

ACGIH. 2012 TLVs and BEIs. American Conference of Governmental Industrial Hygienists; ACGIH, Cincinnati, USA. 2012.

ATSDR. Toxicological profile for formaldehyde [monograph on the Internet]. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, USA. 1999 [cited 2013 Jauary 10]. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp111.pdf.

ATSDR. Formaldehyde: minimal risk levels for haz ardous substances [monograph on the Internet]. Division of Toxicology, Agency for Toxic Substances and Disease Registry, USA. 1999 [cited 2013 Febuary 20]. Available from: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls.pdf.

Costa S, Coelho P, Costa C, Silva S, Mayan O, Santos LS, Gaspar J, Teixeira JP. Genotoxic damage in pathology anatomy laboratory workers exposed to formaldehyde. Toxicology 2008; 252(1-3): 40-48.

Kunugita N, Nakashima T, Kikuta A, Kawamoto T, Arashidani K. Exposure to formaldehyde during an anatomy dissecting course. Journal of the University of Occupational and Environmental Health (UOEH) 2004; 26(3): 337-48.

Mathur N, Rastogi SK. Respiratory effects due to occupational exposure to formaldehyde: Systematic review with meta-analysis. Indian Journal of Occupational and Environmental Medicine 2007; 11(1): 26-31.

Mizuki M, Tsuda T. Relationship between atopic factors and physical symptoms induced by gaseous formaldehyde exposure during an anatomy dissection course. Allergy 2001; 50(1): 21-28.

NIOSH. Formaldehyde: method 2541, NIOSH manual of analytical methods, 4th ed [homepage on the Internet]. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health, USA. 2003; 1-5 [cited 2008 August 15]. Available from: http://www.cdc.gov/niosh/docs/2003-154/method-f.html.

NIOSH. Formaldehyde: NIOSH pocket guide to chemical hazards, 3rd printing [homepage on the Internet]. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, USA. 2007; 149 [cited 2013 January 10]. Available from: http://www.cdc.gov/niosh/npg/npgd0293.html.

Ohmichi K, Komiyama M, Matsuno Y, Takanashi Y, Miyamoto H, Kadota T, Maekawa M, Toyama Y, Tatsugi Y, Kohno T, Ohmichi M, Mori C. Formaldehyde exposure in a gross anatomy laboratory-personal exposure level is higher than indoor concentration. Environmental Science and Pollution Research International 2006; 13(2): 120-24.

Ohmichi K, Komiyama M, Matsuno Y, Sawabe Y, Miyaso H, Fukata H, Ohmichi M, Kadota T, Nomura F, Mori C. Relationship between exposure to formaldehyde and immunoglobulin E (IgE) production during the gross anatomy laboratory. Journal of Health Science 2006; 52 (5): 642-47.

Oosthuizen JD. The control of formaldehyde vapor in the human anatomy laboratory of a traditionally disadvantaged South African medical school. International Journal of Environmental Health Research 1998; 8(1): 47-57.

Park SY, Kim CY, Kim JY, Sakong J. The health effect of formaldehyde during anatomy dissection course. Korean Journal Occupational and Environmental Medicine 2006; 18(3): 171-78.

Ryan TJ, Burroughs GE, Taylor K, Kovein RJ. Video exposure assessments demonstrate excessive laboratory formaldehyde exposures. Applied Occupational and Environmental Hygiene 2003; 18(6): 450-57.

Shiraishi N. Levels of formaldehyde, phenol and ethanol in dissection room air and measures for reduction. Japanese Journal of Occupational Medicine and Traumatology 2006; 54(1): 1-9.

Tanaka K, Nishiyama K, Yaginuma H, Sakaki A, Maeda T, Kaneko SY, Onami T, Tanaka M. Formaldehyde exposure levels and exposure control measures during an anatomy dissecting course. Acta Anatomica Nipponica 2003; 78(2): 43-51.

Thongsri T, Petkasem S. Health risk from exposure to formaldehyde dispersed in anatomy class. Journal of Department of Science Services 2007; 55: 9-15 (in Thai language).

US.EPA. Formaldehyde: quantitative estimate of carcinogenic risk from inhalation dxposure [homepage on the Internet]. Integrated Risk Information System, US. EPA. 2005 [cited 2013 January 10]. Available from: http://www.epa.gov/iris/subst/0419.htm.

Wantke F, Focke M, Hemmer W, Bracun R, Wolf-Abdolvahab S, Götz M, Jarisch R, Götz M, Tschabitscher M, Gann M, Tappler P. Exposure to formaldehyde and phenol during an anatomy dissecting course: sensitizing potency of formaldehyde in medical students. Allergy 2000; 55(1): 84-87.

Wei CN, Harada K, Ohmori S, Wei QJ, Minamoto K, Ueda A. Subjective symptoms of medical students exposed to formaldehyde during a gross anatomy dissection course. International Journal of Immunopathology and Pharmacology 2007; 20 (2 Suppl 2): 23-25.

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