Pertanika J. Sci. & Technol. 31 (5): 2413 - 2426 (2023)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Occupational Formaldehyde Exposure and the Health Symptoms Among Histopathology Laboratory Workers in North Borneo

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ABSTRACT

In hospitals, the chemical formaldehyde is commonly utilised to preserve tissues. The healthcare personnel exposed to formaldehyde the most work in histopathology laboratories. This study aims to determine the health effects of everyday formaldehyde exposure on healthcare professionals in the histopathology laboratory. Cross-sectional comparative research was used for the study design. The 8-hour time-weighted-average (TWA_8) formaldehyde level was measured at the histopathology laboratory at Hospital Queen Elizabeth in Sabah and the administration office (control) using the real-time colorimetric tube method. Workers in both places were required to answer a questionnaire on their health status. The TWA_8 formaldehyde level was higher in the exposed area (0.113 ppm) than in the unexposed area (0.031 ppm). Air samplings showed that formaldehyde exposure levels in the exposed area (0.108 ± 0.026 ppm) were significantly higher than in an unexposed area (0.028 ± 0.018 ppm) at $p < 0.001$. Symptoms closely related to formaldehyde exposure were 51% in the histopathology laboratory workers, greater than 35% in the control group ($p < 0.05$). The workers showed six symptoms: irritated eyes, sore throat, cough, runny nose, sneezing and headache. Although the level of occupational workplace exposure to formaldehyde in the histopathology laboratory was below the recommended limit, the health symptoms related to formaldehyde among the exposed group were detected. Enhancing control measures for indoor air quality improvement in the working area is required to minimise the health risk among laboratory workers.

Keywords: Health symptoms, healthcare workers, histopathology, occupational formaldehyde exposure

ARTICLE INFO

Article history:
Received: 21 August 2022
Accepted: 25 January 2023
Published: 21 July 2023

DOI: https://doi.org/10.47836/pjst.31.5.19

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ISSN: 0128-7680
e-ISSN: 2231-8526

INTRODUCTION

Formaldehyde is a combustible, colourless, pungent-smelling, and easily polymerised gas at standard room temperature and pressure (WHO, 2000). Despite having the potential to cause cancer, it is often applied in medical settings around the globe, including as a disinfectant in surgical units, a sterilising agent, and the preservation of tissues in histopathology laboratories (Bono et al., 2012; Xu & Zhang, 2003). Many healthcare workers are exposed to formaldehyde during occupational activities (Kim et al., 2011). Formaldehyde, an occupational indoor air pollutant, is quickly volatilised and released into the workplace atmosphere (Jerusalem & Galarpe, 2015; Norbäck et al., 2017).

Health practitioners who work in histopathological and anatomical laboratories are more at risk compared to other laboratory workers due to the higher levels of formaldehyde exposed to them every day as a result of their routine, whether by inhaling or direct contact with their skin (Zain et al., 2019). Symptoms linked to exposure to formaldehyde among healthcare workers can be acute or chronic (Binawara et al., 2010; Hauptmann et al., 2009). According to some studies, brief and long-term exposure by inhaling formaldehyde is correlated to respiratory disorder manifestations and eye, nasal, and throat discomfort (Takahashi et al., 2007).

Based on a recent study investigating formaldehyde exposure and health symptoms in several hospitals in the Klang Valley of Malaysia, 37% of personnel working in the histopathology laboratories and 16% of unexposed workers thought their symptoms were connected to their present working environment (Zain et al., 2019). A formaldehyde exposure level beyond the permitted amount degrades the air quality and increases the risk to workers' health (Elshaer & Mahmoud, 2017), especially in hospital pathology laboratories (Ghasemkhani et al., 2005; Jerusalem & Galarpe, 2015).

There are numerous standards for evaluating hazards and risk assessments in the workplace. Aside from broad standards in Malaysia, special criteria for substances that are often used or are primarily dangerous should be followed (Malaysia DOSH, 2018). Under the requirements of the Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) (OSH (USECHH)) Regulations 2000, the amount of formaldehyde in the air should not exceed 0.3 ppm (ceiling limit of airborne concentration) throughout a working hour (Malaysia DOSH, 2000). However, the OSH (USECHH) Regulations 2000 does not state the formaldehyde level airborne that a worker may be exposed to over an 8-hour day (TWA_8). Among the standards proposed by the international organisation for formaldehyde, TWA_8 limit values are 0.75 ppm by the Occupational Safety and Health Administration (OSHA-USA) and 0.1 ppm by the American Conference of Governmental Industrial Hygienists (ACGIH-USA), which is similar to the Malaysia Industry Code of Practice on Indoor Air Quality (ICOP) 2010 (Ministry of Human Resources, 2010; Motta et al., 2021; Salthammer et al., 2010). Employers are required and

accountable under OSH (USECHH) Regulation 2000 to complete Chemical Health Risk Assessments (CHRA) on any chemicals used at the workplace (Malaysia DOSH, 2018). Additionally, under specific conditions, the employer must carry out Chemical Exposure Monitoring (CEM) to track chemicals and Medical Surveillance to monitor exposed workers' health (MOH, 2010).

The exposure to formaldehyde and its relation to health symptoms among healthcare workers in histopathology laboratories in North Borneo still needs to be adequately studied. Hence, to fill in the knowledge gap, this study aims to assess the exposure to formaldehyde and determine the association between formaldehyde exposure and health symptoms among healthcare workers in the histopathology laboratory in North Borneo.

METHODOLOGY

Cross-sectional comparative research was used for the study design to determine formaldehyde exposure and health symptoms among healthcare workers in the histopathology laboratory in comparison to the staff of the administration office (as control) in Hospital Queen Elizabeth, Sabah, Malaysia. The study was performed from March 2021 until May 2021, involving air sampling measurements and a survey on health symptoms.

Workplace exposure was measured from 8 a.m. to 5 p.m., i.e., the standard working hour to reflect the 8-hr time-weighted-average (TWA_8) formaldehyde level. Real-time formaldehyde exposure levels were collected from the histopathology laboratory and the administrative office using Dräger-Tube pump type accuro with the selection of colorimetric Dräger tubes of 0.2/a (0.2 to 5 ppm) with activation tube. All samples were collected during working days as the sampling strategy is based on a similar exposure group (Clerc et al., 2020; Parikh et al., 2009).

The formaldehyde level of exposure was measured by employing the real-time method. This sampling method complied with the standard recommended by the Department of Occupational Safety and Health (DOSH) Malaysia (Ministry of Human Resources, 2010). The research team was trained by a certified industrial hygienist to avoid measurement bias. The instrument was calibrated before use, and the colorimetric tubes had not passed their expiration date. Data collection was conducted by positioning the instrument at the middle point of the workspace area. Sampling was done at the height of 1.5 meters of the sampling areas, namely the administrative office and the histopathology laboratory.

The sampling procedure for the survey on health symptoms is non-probability purposive sampling among healthcare workers in the histopathology laboratory and administrative office in Hospital Queen Elizabeth, Sabah. The healthcare workers were asked for consent before filling in sociodemographic data and answering the questionnaire. The questionnaire assessing symptoms of formaldehyde exposure among healthcare workers listed the symptoms linked to occupational formaldehyde exposure (Zain et al., 2019). Follow-up

on responses from the healthcare workers was carried out by sending reminders from time to time to control non-response bias.

Data were analysed using Microsoft Excel. Statistical analysis was done using IBM Statistical Packages for Social Sciences (SPSS) version 20.0. Descriptive statistics were computed to examine and characterise the data. The first hypothesis, the difference in formaldehyde exposure levels between the histopathology laboratory (exposed) and administrative office (unexposed), was assessed using the Mann-Whitney U test. The second hypothesis, the relationship between categorical variables of symptoms and formaldehyde exposure, was evaluated using the chi-square or Fisher's exact test. Every statistical test was performed with a 95% confidence interval and *p*-value of 0.05.

RESULTS

A total of 20 samples of formaldehyde exposure levels were measured, with 10 samples from the histopathology laboratory (exposed area) and 10 samples from the administrative office (unexposed area). The measurements in both areas are less than Malaysia's Occupational Safety and Health Act 1994 permitted level (Table 1).

Table 1

Formaldehyde exposure levels in histopathology laboratory and administration office

	Histopathology Laboratory (ppm)	Administration Office (ppm)
1 hour before 8 working hours	0.125	0
8 working hours:		
Hour-1	0.125	0
Hour-2	0.125	0.05
Hour-3	0.125	0.05
Hour-4	0.1	0.025
Hour-5	0.1	0.025
Hour-6	0.125	0.025
Hour-7	0.125	0.05
Hour-8	0.075	0.025
1 hour after 8 working hours	0.05	0.025
TWA_8	0.113	0.031
Reference limit	**0.750**[a]	**0.3**[b]

[a]The United States Occupational Safety and Health Administration (US OSHA) Permissible Exposure Limit (PEL), 1993.
[b]Malaysia Occupational Safety and Health Act 1994 (Act 514) Ceiling Limit Airborne Concentration, 2000.

The TWA_8 level of formaldehyde exposure recorded in the histopathology laboratory was higher than in the administrative office (unexposed) at 0.113 ppm and 0.031 ppm, respectively. This result stipulated that the amount of formaldehyde exposure for the histopathology laboratory was 365% greater than the administrative office.

Formaldehyde exposure levels in the histopathology laboratory were greater ($p <$ 0.001) compared to the administrative office in Hospital Queen Elizabeth with the means of 0.108 ± 0.026 ppm and 0.028 ± 0.018 ppm, respectively (Table 2).

Table 2

Formaldehyde exposure in the histopathology laboratory compared to the administration office in Hospital Queen Elizabeth

Variable	Histopathology laboratory (n = 10*)	Administration office (n = 10*)	Z value	*p*-value
	Mean ± S.D.			
Formaldehyde exposure (ppm)	0.108 ± 0.026	0.028 ± 0.018	-3.762	< .001**

* Results should be interpreted cautiously due to the small sample sizes (n < 40)
** Significant at $p < 0.01$ (Mann-Whitney U Test)

There were 205 survey participants, comprising 164 from the histopathology laboratory and 41 from the administrative office. The distribution of responses (Table 3) corresponds to the socio-demographic characteristics of both groups. The 73.8% and 75.6% of healthcare workers, respectively, were predominately female. The age range of 31 to 40 made up 57.6% of the respondents. Almost all the respondents were non-smoking.

Table 3

Socio-demography characteristics of the histopathology laboratory workers and administration office staff

	Histopathology Laboratory workers N = 41, n (%)	Administration Office staff N = 164, n (%)
Gender		
Female	31 (75.6%)	121 (73.8%)
Male	10 (24.4%)	43 (26.2%)
Age group		
21 – 30	-	24 (14.6%)
31 – 40	35 (85.4%)	83 (50.6%)
41 – 50	5 (12.2%)	39 (23.8%)
51 – 60	1 (2.4%)	18 (11.0%)

Table 3 *(Continue)*

	Histopathology Laboratory workers N = 41, n (%)	Administration Office staff N = 164, n (%)
Ethnicity		
Chinese	6 (14.6%)	7 (4.3%)
Indian	3 (7.3%)	1 (0.6%)
Malay	12 (29.3%)	29 (17.7%)
Sabahan	20 (48.8%)	127 (77.4%)
Smoking		
No	39 (95.1%)	158 (96.3%)
Yes	2 (4.9%)	6 (3.7%)

Table 4 shows the distribution of respondents according to their occupational backgrounds in both groups. In terms of occupation, 63.4% of the unexposed group were general workers or clerks, whereas 34.1% of the exposed group worked were medical laboratory technologists, and 43.9% were medical officers. The total number of participants working at the same workplace for over a year was 92.2%.

Table 4

Occupational backgrounds of the histopathology laboratory workers and administration office staff of Hospital Queen Elizabeth, Sabah, Malaysia

	Administration Office staff N = 164, n (%)	Histopathology Laboratory workers N = 41, n (%)
Duration of years working at current workplace		
< 1	19 (11.6%)	5 (12.2%)
1 – 2	59 (36.0%)	12 (29.3%)
3 – 4	22 (13.4%)	2 (4.9%)
5 – 6	18 (11.0%)	8 (19.5%)
7 – 8	22 (13.4%)	1 (2.4%)
9 – 10	9 (5.5%)	4 (9.8%)
> 10	15 (9.1%)	9 (22%)
Job title		
Medical laboratory technologist	-	14 (34.1%)
Medical officer	2 (1.2%)	18 (43.9%)
Science officer	-	2 (4.9%)

Table 4 *(Continue)*

	Administration Office staff N = 164, n (%)	Histopathology Laboratory workers N = 41, n (%)
Medical laboratory technologist	-	14 (34.1%)
Attendant	13 (7.9%)	1 (2.4%)
Clerk	104 (63.4%)	6 (14.6%)
Accountant	4 (2.4%)	-
Medical assistant	6 (3.7%)	-
Nurse	4 (2.4%)	-
Others	31 (18.9%)	-

Strained eyes symptom was reported by 51% of the laboratory workers and 35% of the administration staff while working at their current job area, as shown in Table 5. Strained eyes were the most common symptom in both groups (> 35%), whereas wheezing was the least common (< 3%). There is a significant association between formaldehyde exposure and health symptoms among the workers in the histopathology laboratory. There are six symptoms (irritated eyes, sore throat, cough, runny nose, sneezing and headache) that were significantly more prevalent in the exposed group than the unexposed group ($p < 0.05$).

Table 5

Formaldehyde exposure symptoms of histopathology laboratory and administration office

Formaldehyde exposure-related symptoms	Administration Office staff n (%)	Histopathology Laboratory workers n (%)	X^2	*p*-value
Irritated eyes	20 (12.2%)	15 (36.6%)	13.782	0.001[a]
Strained eyes	57 (34.8%)	21 (51.2%)	3.772	0.052[a]
Sore or dry throat	13 (7.9%)	16 (39.0%)	26.117	**0.001[a]**
Cough	5 (3.0%)	10 (24.4%)	22.029	**0.001[a]**
Shortness of breath	4 (2.4%)	3 (7.3%)	2.367	0.145[b]
Chest tightness	5 (3.0%)	3 (7.3%)	1.593	0.201[b]
Wheezing	2 (1.2%)	1 (2.4%)	0.338	0.491[b]
Runny nose	17 (10.4%)	10 (24.4%)	5.641	**0.018[a]**
Sneezing	16 (9.8%)	9 (22.0%)	4.556	**0.033[a]**
Headache	34 (20.7%)	17 (41.5%)	7.543	**0.006[a]**
Stress or irritability	35 (21.3%)	12 (29.3%)	1.166	0.28[a]
Drowsiness	33 (20.1%)	11 (26.8%)	0.875	0.349[a]

Table 5 *(Continue)*

Formaldehyde exposure-related symptoms	Administration Office staff n (%)	Histopathology Laboratory workers n (%)	X^2	*p*-value
Shoulder pain	53 (32.3%)	20 (48.8%)	3.877	0.05[a]
Difficulty in concentrating	19 (11.6%)	3 (7.3%)	0.624	0.578[b]
Feeling depressed	6 (3.7%)	2 (4.9%)	0.13	0.662[b]

[a] Pearson Chi Square test, $p < 0.05$; [b] Fisher's Exact Test, $p < 0.05$.

DISCUSSION

Occupational formaldehyde exposure in hospital facilities has been the subject of some research in various countries, including a couple of studies that have been performed in Malaysia, as shown in Table 6 (Ahmed, 2011; Bono et al., 2012; Ghasemkhani et al., 2005; Jerusalem & Galarpe, 2015; Ladeira et al., 2011; Ogawa et al., 2019; Orsière et al., 2006; Ya'acob et al., 2013; Zain et al., 2019). Concerning methodology and sample area, this research is comparable to the work (Zain et al., 2019). The TWA_8 level of formaldehyde exposure described in this study with the range of 0.082 to 0.134 ppm was within the range of values of 0.076 to 0.252 ppm reported by (Zain et al., 2019). The TWA_8 values with a wider range from 0.01 to 0.51 ppm were obtained by other studies (Bono et al., 2012; Viegas et al., 2010; Ya'acob et al., 2013). Conversely, higher TWA_8 levels ranging from 0.1 to 1.19 ppm were recorded (Jerusalem & Galarpe, 2015; Orsière et al., 2006). Ghasemkhani et al. (2005) discovered that formaldehyde concentrations in pathology laboratories surpassed the recommended limits.

Table 6

Comparing occupational formaldehyde exposure in Hospital Queen Elizabeth, Sabah, Malaysia with other studies

Location	Method	Sampling area	TWA_8 concentration (ppm)	Reference
Sabah, Malaysia	Colorimetric tube	Histopathology laboratory	0.113 Range: 0.082 – 0.134	This study
		Administrative office	0.031 Range: 0.01 – 0.046	
Klang Valley, Malaysia	OSHA 52 and NIOSH 2541	Histopathology laboratory	0.076 – 0.252	Zain et al. (2019)

Table 6 *(Continue)*

Location	Method	Sampling area	TWA_8 concentration (ppm)	Reference
Cagayan de Oro, Philippines	DNPH and DNPH-coated silica	Histopathology laboratory	0.14 – 1.03	Jerusalem and Galarpe (2015)
Selangor, Malaysia	NIOSH 2541	Anatomy laboratory	0.10 – 0.17	Ya'acob et al. (2013)
Piedmont region, Italy	NIOSH 2016	Pathology laboratory	0.012 – 0.454	Bono et al. (2012)
The University of Sharjah, United Arab Emirates	NIOSH 3500	Anatomy laboratory	0.013 – 0.105	Ahmed (2011)
Lisbon and Tagus Valley, Portugal	NIOSH 2541	Histopathology laboratory	0.04 – 0.51	Ladeira et al. (2011)
South of France	Passive air monitoring badges	Pathology and anatomy laboratory	0.1 – 0.7	Orsière et al. (2006)
Tehran, Iran	NIOSH 3500	Pathology laboratory	0.73 – 1.19	Ghasemkhani et al. (2005)

The TWA_8 levels of formaldehyde exposure in the histopathology laboratory and the administrative office in this study were still lower than the limit of 0.75 ppm, an acceptable exposure level for workplace formaldehyde exposure set by the OSHA-USA or 0.3 ppm as imposed by the Malaysia Occupational Safety and Health Act 1994 (Act 514) Ceiling Limit Airborne Concentration, 2000 and close to 0.1 ppm as imposed by the Malaysia ICOP 2010.

Formaldehyde is routinely utilised in Malaysian hospitals, specifically histopathology units, to preserve human tissue samples. As a result of laboratory activities, high levels of formaldehyde vapours are introduced to laboratory workers. The existence of formaldehyde in the administrative office might be ascribed to a variety of sources, including pressed wood materials, glue, paints, furnishings, flooring, and other indoor objects (Du et al., 2014; Salthammer et al., 2010).

Respondents from the administrative office and histopathology laboratory reported health symptoms in this study. Symptoms experienced by administrative office employees might be related to their job role since well over 60% of those employed as general workers or clerks use or have exposure to computers, laser printing machine, or copier regularly. Numerous volatile organic compounds (VOCs) are also emitted by these devices, such

as formaldehyde (Viegas et al., 2010). As a result of their regular job processes, the exposure of these VOCs to the workers could have caused their symptoms. Irritated eyes, sore throat, cough, runny nose, sneezing, and headache based on statistical analysis were all shown to be more among workers in histopathology laboratory in which the exposure of formaldehyde concentrations was higher than unexposed individuals in this research. Irritated eyes and upper respiratory tract are key indicators of acute formaldehyde effects (WHO, 2010). According to the United States Department of Labour, formaldehyde levels between 0.05 and 0.5 ppm irritate the eyes, including burning, itching, redness, and tears (USDOL, 2021). The WHO stated that 0.293 ppm of formaldehyde for 4 hr is the minimum amount documented to produce irritated eyes in individuals (WHO, 2010).

It justifies the significant symptoms of irritated eyes in this study since the exposure to formaldehyde was higher in the histopathology laboratory than in the administrative office. Ocular and irritated nasal were the very often documented symptoms (55%) after exposure to formaldehyde when dissecting in an anatomical laboratory, according to another research (Ya'acob et al., 2013). Over 50% of employees in an anatomical laboratory reported cough, sore throat, and runny nose, while irritated eyes were recorded by 48% (Azari et al., 2012). Other studies have found a substantial difference in the occurrence of irritated eyes, irritated nose, dyspnoea, headache, throat dryness, and chest tightness for the duration of dissection periods versus nonworking periods (Ya'acob et al., 2013). Latex gloves, a 3-ply mask, a plastic apron, a lab coat, and cover shoes were frequently utilised by laboratory personnel, even though this personal protective equipment is not appropriate for handling formaldehyde. Unsuitable personal protective equipment in the laboratory had been ineffective as a control device in reducing formaldehyde exposure. As an individual adjusts to formaldehyde exposure, they become less sensitive to the odour and less discomfort in the eyes. Overexposure to formaldehyde might result if workers assume that typical formaldehyde characteristics would alert them to probable exposure (Amoore & Hautala, 1983).

This study was conducted in the pathology department of Hospital Queen Elizabeth, Sabah, Malaysia which is one of the important tertiary government hospitals under the Ministry of Health Malaysia. The pathology department is separated from the main ward building. The histopathology laboratory complies with international and national quality standards of IS 9002, ISO 15189 and MSQH hospital quality accreditation. It also follows the Guidelines on Chemical Management in Health Care Facilities Ministry of Health in which CHRA are conducted under the requirement of OSH USECHH regulation 2000 (MOH, 2010). The control of hazardous chemicals was also practised in the guidelines according to the OSH hierarchy of control, which includes elimination, substitution, engineering controls, administrative controls and personal protective equipment.

The amount of formaldehyde in this study was shown to be substantially impacted by the control measures, workplace area, and environmental settings. According to a study by the Institute of Medical Research (IMR), TWA_8 concentrations were lower in two hospitals which used a mechanical exhaust ventilator, fume hoods, a ducted backdraft grossing station, and appropriate specimen storage than in another two hospitals which used fewer control measures (Zain et al., 2019). An investigation was conducted on the efficiency of five ventilation methods in pathology laboratories to minimise exposure to formaldehyde (Xu & Stewart, 2016). The study discovered that the most effective control measures were ducted backdraft grossing stations, and this should be utilised instead of other types of grossing stations to reduce formaldehyde exposure during the grossing procedure. The leading causes of elevated formaldehyde levels in the sampling areas were inadequate processing measures, such as local exhaust ventilation in pathology laboratories (Ghasemkhani et al., 2005; Ogawa et al., 2019; Orsière et al., 2006).

When not in use, chemical containers, for example, must be kept away from the work site into storage areas or chemical cabinets. An airtight and leak-proof screw cap container is advised when storing formaldehyde-containing specimens since it can minimise the quantity of formaldehyde emitted into the air. Before being disposed of, all specimens should be kept in isolation in a separate room at a safe distance from the work area or in a formalin storage cabinet. These engineering control and administrative control of good work practice methods help to reduce the possible health risks to workers.

Even though every attempt was made to ensure that the study was free of biases and errors, the following limitations were noted when analysing the findings. The assumption by the study was that environmental hazard exposure constantly existed the whole year. Another assumption is that the activities done during working hours are also constant throughout the year. Recall bias exists in self-report questionnaires, but it was reduced by applying a brief recall interval in which the suggested time to complete the questionnaire is 15 min. On the other hand, the formaldehyde exposure level assessment can only capture exposure at work and does not account for exposure happening in the household or during off-duty hours. Financial constraints limited the amount of formaldehyde exposure level assessments. Scarce resources limited the researchers to utilise available tools. Cross-sectional research merely summarises the current health state and cannot identify causal relationships. The findings of this study represent Sabah as the sole histopathology laboratory under the Ministry of Health Malaysia located in the state, which may not be fully representative of histopathology laboratories all over Malaysia. Despite the limitation, the sampling size was sufficient to give a reliable result backed up by several studies.

Nevertheless, this study contributes to additional knowledge on occupational formaldehyde exposure and health symptoms in the histopathology laboratory in Hospital Queen Elizabeth, Sabah, Malaysia. Future health intervention planning and health education programmes may utilise the findings of this study as a baseline.

CONCLUSION

The specific activity performed by the employees, working place environment and control measures have notable impacts on formaldehyde exposure levels. Although the levels of occupational workplace exposure to formaldehyde were under the recommended limit, the laboratory workers had considerable symptoms, implying high formaldehyde exposure. Several control measures may be applied based on the findings to lessen the hazard linked to laboratory employees' occupational exposure to formaldehyde in terms of work process and environment. A program such as good work practices, health promotion to increase awareness and educational activities can be considered in addition to the existing control measures for reducing the risk from occupational formaldehyde exposure.

ACKNOWLEDGEMENT

The authors thank the Director General of Health Malaysia for his permission to publish this article. This study received ethical approvals from the Ethical Committee of Faculty Medical and Health Science, Universiti Malaysia Sabah (Approval code: JKEtika 1/21 (7)) and the Ethical Committee of the Ministry of Health Malaysia (Ethical approval: NMRR-21-213-58518 (IIR)). We sincerely thank the Institute for Medical Research and Hospital Queen Elizabeth, Sabah, Malaysia for their cooperation and support.

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