การประเมินความเสี่ยงต่อการเกิดมะเร็งในบุคลากรที่สัมผัสสารฟอร์มาลดีไฮด์ จากการทำงานในโรงเรียนแพทย์แห่งหนึ่ง

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บทคัดย่อ

ฟอร์มาลดีไฮด์จัดเป็นสารที่ก่อให้เกิดมะเร็งในมนุษย์ โดยที่มีการใช้ในหลากหลายอุตสาหกรรม และพบว่ามีการใช้ฟอร์มาลดีไฮด์แพร่หลายภายในโรงพยาบาล บุคลากรทางการแพทย์จำนวนมากมีการสัมผัสในปริมาณสูง ดังนั้น การศึกษานี้มีวัตถุประสงค์เพื่อการตรวจวัดระดับการสัมผัสสารเคมีและการประเมินความเสี่ยงในการเกิดมะเร็งในบุคลากรทางการแพทย์ โดยการวัดปริมาณการสัมผัสฟอร์มาลดีไฮด์แบบติดตัวระหว่างการทำงานของเจ้าหน้าที่แต่ละแผนกภายในโรงพยาบาล เฉลี่ยตลอดระยะเวลาการทำงานโดยใช้วิธี NIOSH 2016 และใช้ข้อมูลดังกล่าวประเมินความเสี่ยงการเกิดมะเร็ง จากการศึกษาการวัดการสัมผัสฟอร์มาลดีไฮด์ทั้ง 77 ตัวอย่าง พบว่าค่าที่วัดได้จากการวัดแบบติดตัว (personal sampler) มีค่าเฉลี่ยอยู่ที่ 0.0286 พีพีเอ็ม โดยที่ลักษณะงานที่มีการสัมผัสสารฟอร์มาลดีไฮด์มากที่สุดคือ การสอนวิชามหกายวิภาคศาสตร์ มีค่าความเข้มข้นเฉลี่ยอยู่ที่ 0.0518 พีพีเอ็ม และลักษณะงานที่สัมผัสน้อยที่สุดคือ การส่องกล้องตัวอย่างปรสิต มีค่าความเข้มข้นเฉลี่ยอยู่ที่ 0.0066 พีพีเอ็ม ซึ่งสามารถแบ่งระดับการสัมผัสฟอร์มาลดีไฮด์เป็น 2 ระดับ คือมีการสัมผัสในระดับสูงและต่ำ โดยค่าการสัมผัสความเข้มข้นของฟอร์มาลดีไฮด์ในระดับสูง คือมากกว่า 0.016 พีพีเอ็ม ได้แก่ บุคลากรที่ปฏิบัติงานในส่วนของการสอนวิชามหกายวิภาคศาสตร์ เจ้าหน้าที่ดองศพ เจ้าหน้าที่ฉีดยาศพ การชันสูตรและการเตรียมห้องเรียนมหกายวิภาคศาสตร์ และจากการศึกษาความเสี่ยงต่อการเกิดมะเร็งตลอดช่วงชีวิตตามคำแนะนำของ US EPA พบว่าบุคลากรเกือบทุกรายมีโอกาสเป็นมะเร็งในช่วงชีวิตได้ ยกเว้นในกลุ่มผู้ปฏิบัติในงานส่องกล้องตัวอย่างปรสิตและเตรียมตัวอย่างปรสิต พบว่ามีความเสี่ยงที่ยอมรับได้ โดยสรุป ในบุคลากรทางการแพทย์ที่มีการสัมผัสฟอร์มาลดีไฮด์ควรได้รับการควบคุมการสัมผัสฟอร์มาลดีไฮด์และได้รับการเฝ้าระวังทางการแพทย์ด้วยการตรวจสุขภาพตามความเสี่ยงทุกปีอย่างเหมาะสม

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Cancer risk assessment of personnel occupationally exposed to formaldehyde in a medical school

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Abstract

Formaldehyde, a well-known human carcinogen in IARC Group 1, is used in various industries, with hospitals being one of the places that widely utilize it. Several medical staff members were exposed to a high concentration of formaldehyde. Therefore, this study aims to evaluate concentrations of formaldehyde exposure and cancer risk in medical staff. In this study, data were collected using the NIOSH 2016 method, applying personal sampling to medical staff during working hours for each job task. Then, this data was utilized to calculate cancer risk. Based on a sample size of 77 samples, the average formaldehyde concentration from the personal sampler was 0.0286 ppm, with the highest formaldehyde exposure being 0.0518 ppm during the teaching of gross anatomy and the lowest exposure being 0.0066 ppm in microscopic parasitology. The formaldehyde concentration was classified into high and low-exposure groups, where the high-exposure group included formaldehyde concentrations above 0.016 ppm. This group encompassed tasks such as teaching gross anatomy, embalming, injecting formaldehyde into cadavers, autopsy, and preparing gross anatomy class. The estimated lifetime cancer risk, as per US EPA guidelines, found that almost all medical staff had a potential cancer risk, except in microscopic and preparing parasitology, where the risk was deemed acceptable. In conclusion, medical staff exposed to formaldehyde should receive proper protection from exposure and undergo medical surveillance through annual physical examinations according to the risk.

Keywords: formaldehyde; carcinogen; cancer risk assessment; medical staffs

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Introduction

Formaldehyde is a colorless aqueous solution with a pungent, irritating odor, being a gas at room temperature. Formaldehyde is widely present in both indoor and outdoor environments. Formaldehyde is widely used as a tissue preservative or embalming cadavers in pathologic anatomy laboratories in hospitals.[1–4]

The toxic effects of formaldehyde are mainly from inhalation, direct contact through skin or eyes, and food containing formaldehyde. The acute result of exposure can be irritating to many organ systems such as the respiratory system through eye contact, skin contact, or the GI tract. The most common acute effect found in formaldehyde is irritation to the upper airway.[3,5] The international agency for cancer research classified formaldehyde as a carcinogenic agent in humans (group 1) because sufficient epidemiological evidence found that it causes nasopharyngeal cancer in humans.[2,6]

Several safety and occupational health organizations have announced occupational exposure limits to formaldehyde. The American Conference of Governmental Industrial Hygienists (ACGIH) suggests 0.1 ppm as a ceiling level. The National Institute for Occupational Safety and Health (NIOSH) sets a short-term exposure limit of 0.1 ppm, and a time-weighted average of up to 10 hours at 0.016 ppm. The Occupational Safety and Health Administration (OSHA) suggests that the workplace's permissible exposure limit is 0.75 ppm, measured as an 8-hour time-weighted average with a short-term exposure limit of 2 ppm.[4,5,7]

There are 788 factories in Thailand that use formaldehyde. The number of employees who work with formaldehyde is 36,824. In hospitals, formaldehyde is used in autopsy rooms, pathological rooms, anatomical rooms, and operation rooms.[7] Hospitals are one of the places that widely use formaldehyde. Many healthcare workers, teachers, and medical students may be exposed to a high concentration of formaldehyde. Studies in Thailand evaluating the concentrations of formaldehyde exposure in medical students during anatomy lab by using area sampling found that they have an increased risk of cancer if they are exposed to the same concentration for more than five years.[8] Studies of cancer risk assessment of formaldehyde exposure among autopsy staffs have shown that the average exposure was 0.034 mg/m^3 and the average cancer risk was 1.97×10^{-4} which is considered unacceptable by 1.0×10^{-6}.[9] Studies about occupational exposure and cancer risk assessment in pathology departments with staff exposed to formaldehyde in low levels but have prolonged exposure each day after many years show that these workers have a cancer risk ranged from 9.52×10^{-5} to 1.53×10^{-3}, which is greater than the WHO acceptable cancer risk level.[10] But, in the study of formaldehyde exposure and cancer risk in students[11] in Thailand that were exposed to formaldehyde levels of 0.155 ppm

for one year and two years show that the risk of cancer is 2.16×10^{-7} and 4.31×10^{-7} respectively.

There are a total of 110 employees at Srinagarind Hospital: 13 work in the forensic department, 47 in the anatomical department, 50 in the pathological department. In 2018, formaldehyde levels were measured from personal sampling and analysis by using the NIOSH method 2541. The range of occupational exposure was <0.001-0.982 ppm in which some jobs were exposed to formaldehyde levels lower than the NIOSH recommended exposure limit (0.016 ppm). In the previous study, some departments evaluated cancer risk by area sampling, the results show that there are some jobs[12] with no risk of cancer. This study uses personal sampling to precisely assess exposure levels and has found that workers might have an increased risk of cancer because they have worked in these conditions for many years.

Objectives

The current study aimed to assess formaldehyde exposure of the workers in Srinagarind hospital, Khon Kaen University (KKU) by collecting from personal sampling for the precise value and estimating the cancer risk of all job tasks.

Material and Methods

Sample monitoring

This descriptive study was conducted at Srinagarind Hospital, Khon Kaen University (KKU), and the study was done in the workers who occupationally exposed to formaldehyde in working process more than 15 minutes. In each job, the job description was recorded, and personal exposure assessment was collected with active air pumping (SKC – PCXR8) using cartridges (Supelco LpDNPH tubes). Following the NIOSH standard method 2016[13] by attaching a personal pump with a cartridge at the collar (breathing zone) of the worker over working time. The flow rate was controlled to 0.03 to 0.125 L/min to limit the volume of samples to 15 L/sample. When the sampling collection was complete, the sampling tubes were placed in a zip-lock bag and maintained at the temperature specified by the standard method until it arrived at the laboratory for analysis.

Formaldehyde concentration analysis

For sample preparation, acetonitrile (HPLC grade) was used to extract formaldehyde from the sampling tube. The extracted solution was analyzed by Shimadzu High Performance Liquid Chromatography (HPLC). The amount of formaldehyde was compared with a calibration curve where the calibration method involved first standardizing a formaldehyde solution that was 37% aqueous, and then diluting the solution to a total of six different concentrations at 0.04, 0.10, 0.20, 0.40, 0.80, 1.0 µg/sample. The estimated limit of detection (LOD) for this method is 0.07 µg/sample and the working range is 0.012 to 2.0 ppm. The end result is an equation that can be used to determine the concentration of the sample based on the region of the HPLC graph that lies below the peak. The equation

is y = 149724x + 6387.4, R^2 = 0.9922 and it may be found here (y is the area under the peak; X is the mass of formaldehyde). After that, the concentration is converted to parts per million (ppm).

Risk for cancer assessment

Risk for lifetime cancer risk was calculated following US EPA guidelines.[14]

risk = IUR x EC

IUR for inhalation unit risk in formaldehyde is $1.3x10^{-5}$ (ug/m^3), EC for exposure concentration in the air (ug/m^3). The exposure concentration was calculated by:

EC = (CA × ET × EF × ED) / AT

EC (ug/m^3) = exposure concentration.

CA (ug/m^3) = contaminant concentration in air. This study uses an 8-hr TWA for each job.

ET (hours/day) = exposure time.

EF (days/year) = exposure frequency. This study uses 219 days/year.

ED (years) = exposure duration.

AT (lifetime in years x 365 days/year x 24 hours/day) the average lifetime for participants in this study is 77 years.[15]

Study populations

Referring to the previous study,[16] the SD value in method A is 0.35; the SD value in method B is 0.32; the multiple correlation coefficient is 0.952. This study needs 5% of significance level, a power of 80%, and ratio of sample sizes B: A is 1. To detect difference is 0.15. all these values are calculated in the Winpeppi program version 11.65. The required sample size of this study is 79.

All 79 workers that worked with formaldehyde for more than 15 minutes per day were divided into eight job tasks.

Statistical analysis

Data analysis was performed by using the Stata program. For personal concentration sampling was determine the descriptive analysis in mean, standard deviation, geometric mean, and geometric standard deviation. The geometric mean concentration of each job task was calculated to lifetime cancer risk.

Results

A total of 79 sample sets were collected by using a personal pump. Only 77 samples were included in the analysis because some of the sampling pumps used for method 2016 had technical errors in data collection and laboratory assessments were excluded. In all sample was collected in eight difference job tasks. The working process is described in Table 1.

Table 1 Job description and characteristics of sampling location

Job task	Age (years) (mean±SD)	Sample amount	Descript/details	Minimum working period (hour/day)	Area (m^2)	Volume (m^3)	Ventilation system
Injected formaldehyde in cadaver	51±6.95	4	Formaldehyde solution is injected into vessel in the groin area of the corpse. The workers use the pumper to push the solution into the body. The workers will be exposed to formaldehyde in this process by breathing or spilling on the skin.	1	25	87.5	Mechanical ventilation (fan)
Embalming	44±9.74	12	The cadavers are injected with formaldehyde in the body and then are soaked in a bath filled with embalming solution. The embalming solution consists of formaldehyde solution.	2	96	336	Mechanical ventilation (fan)
Prepare sample for pathology	42±1.41	8	The tissues that were soaked in formalin from the operation room are brought to the new container and cut into slight (small?) pieces.	2	28	98	Local exhaust ventilation
Prepare sample for parasitology	32±6.36	9	The process is receiving specimens from other hospital departments to prepare for microscopy with a formaldehyde solution.	2	14.6	51.1	Local exhaust ventilation
Microscopic for parasitology	52±7.07	12	Receive specimen from preparing process to microscopes. The workers expose to formaldehyde vapor from specimen slide.	1	15	52.5	Local exhaust ventilation
Autopsy	51±6.95	12	Performing an examination to determine the cause of death. After finishing the autopsy, the technician will pour formalin solution in the body cavity and close.	2	30	105	Natural ventilation
Teaching gross anatomy class	42±10.62	15	Dissection of cadavers and teaching of medical students. Each class uses eight to twelve cadavers, but the other cadavers are still covered by plastic covers. The teachers are exposed to formaldehyde by walking around the gross anatomy room and getting close to cadavers during dissection.	3	180	630	Local exhaust ventilation
Prepare gross anatomy class	44±9.74	7	Preparing cadavers before class, including locating and laying out the cadavers for student groups and removing the cadaver covers. The workers are exposed to formaldehyde vapor in the room and after removing the cadaver cover. Each table has local exhaust ventilation.	1	180	630	Local exhaust ventilation

The internal area of the workplace was also collected. The largest working area is the gross anatomy room where the teaching and lab preparation occurs in the same place, while the parasitology preparation room is the smallest. The amount of samples in each job task is different. Workers in parasitology and pathology work every workday so the sample that were collected will higher than the workers in other jobs. The amount of sample is dependent on occasion of case or class.

Formaldehyde exposure concentration

Personal sampling was done during working hours, and the results showed that the average formaldehyde concentration was 0.0286 ppm (based on a sample size of 77 samples). The highest formaldehyde exposure that was collected by personal sampling was 0.157 ppm from teaching gross anatomy. The lowest formaldehyde exposure was 0.0017 ppm in microscopic parasitology. The worker exposure is related to the activities that take place during working hours; it was anticipated that the formaldehyde concentration at these positions would be high or low in the research, such as with the prolonged exposure to formaldehyde vapor during dissection, the ventilation system in the gross anatomy room, and the surroundings (Table 2).

Because of the activity involved in the tasks, this study found that some tasks, such as embalming cadavers, teaching gross anatomy, and preparing cadavers, provided a higher concentration of formaldehyde than others. There is some evidence of formaldehyde exposure ranging above 0.016 ppm that induced cytogenetic change in human nasal mucosa[17], and the results of the personal sampling were used to classify workers' levels of exposure into high and low exposure groups. According to this limit, workers are considered to be in the high exposure group if their exposure to formaldehyde is above 0.016 ppm. Workers who have an exposure to formaldehyde that is below 0.016 are considered to be part of the low exposure category. The high exposure groups include teaching gross anatomy class, embalming, injecting formaldehyde into cadavers, autopsy, and preparing gross anatomy class. The low exposure groups include pathology sample preparation, parasitology specimen preparation, and microscopic examination of parasitology specimens.

Table 2 Formaldehyde exposure collected from personal sampling

Job description	Amount of sample	8-hr TWA Exposure Concentration (ppm) Mean±SD	8-hr TWA GM±GSD
Teaching gross anatomy class	15	0.0609±0.0385	0.0518±0.2503
Embalming	12	0.0380±0.0317	0.0253±0.4371
Autopsy	12	0.0257±0.0232	0.0142±0.5756
Injected formaldehyde in cadaver	4	0.0243±0.0258	0.0126±0.5022
Prepare gross anatomy class	6	0.0196±0.0162	0.0119±0.5591
Pathology	7	0.0150±0.0101	0.0124±0.2802
Prepare sample for parasitology	9	0.0136±0.0154	0.0064±0.5808
Microscopic for parasitology	12	0.0071±0.003	0.0066±0.1482

Carcinogenicity risk assessment

This study used the exposure result from personal sampling to estimate the lifetime cancer risk by following US EPA guidelines. The risk was classified into three levels: a *definite* risk (more than $1x10^{-4}$), a *probable* risk (between $1x10^{-4}$ to $1x10^{-5}$) and a *possible* risk (between $1x10^{-5}$ to $1x10^{-6}$)[9].

It is important to use the EC equation that most closely shows the exposure pattern and duration while working in The CA are calculated by mean of exposure in each job task. Exposure time is calculated as the shortest time of exposure in each job. Exposure duration was calculated from years of service. The result of cancer risk shows in Table 3 that teaching gross anatomy class had a probable risk of 66.67% and a possible risk of 33.33%. The embalming job had a probable risk of 50% and all workers in preparing pathology samples had a possible risk for cancer. The workers in autopsy, formaldehyde injection, preparing gross anatomy class, and preparing samples for parasitology and microscopic jobs had probable and possible risk of cancer at 83.3%, 50%, 66.7%, 55.6% and 33.3% respectively.

Table 3 Lifetime cancer risk

Job	8-hr TWA Exposure (ppm)	Concentration in air (ug/m^3)	Exposure concentration (ppm)	Risk cancer (min,max)	Worker in probable and possible risk in each job (%)
All	0.0157	19.2796	0.3213	4.177×10^{-6} (0.077×10^{-6}, 4.2879×10^{-5})	59 workers (76.6)
Teaching gross anatomy class	0.0518	63.6104	1.0881	1.4145×10^{-5} (5.535×10^{-6}, 4.2879×10^{-5})	15 workers (100)
Embalming	0.0253	31.0684	0.5178	6.731×10^{-6} (1.783×10^{-6}, 2.8411×10^{-5})	12 workers (100)
Autopsy	0.0142	17.4376	0.3977	5.170×10^{-6} (0.606×10^{-6}, 2.5692×10^{-5})	10 workers (83.3)
Injecting formaldehyde into cadavers	0.0126	15.4728	0.1764	2.294×10^{-6} (0.498×10^{-6}, 1.0471×10^{-5})	2 workers (50)
Prepare gross anatomy class	0.0119	14.6132	0.1218	1.583×10^{-6} (0.231×10^{-6}, 5.950×10^{-6})	4 workers (66.7)
Prepare sample for pathology	0.0124	15.2272	0.2538	3.299×10^{-6} (1.776×10^{-6}, 8.370×10^{-6})	7 workers (100)
Prepare sample for parasitology	0.0064	7.8592	0.0620	0.807×10^{-6} (0.077×10^{-6}, 6.142×10^{-6})	5 workers (55.6)
Microscopic for parasitology	0.0066	8.1048	0.0711	0.924×10^{-6} (0.571×10^{-6}, 2.116×10^{-6})	4 workers (33.3)

Discussion

This study collected 79 samples from eight job tasks and 77 samples were analyzed. The result was divided into high exposure and low exposure groups. The formaldehyde exposure for each job was related to job descriptions. Teaching gross anatomy had the highest level of exposure due to being exposed to a large amount of formaldehyde vapor and a long duration of exposure per day. Other exposure groups also work with large volumes of formaldehyde. Low exposure groups work with small amounts of formaldehyde and work under local exhaust. The findings of this study imply that workers who are exposed to formaldehyde while on the job should have an exposure assessment conducted using personal sampling collection. It seems that the primary route of exposure to formaldehyde would be through the vaporization of formaldehyde coming from the source and the worker's exposure by breathing. Therefore, this result is able to reveal the precise level of formaldehyde

exposure that the employees were exposed to. In this study, the exposure concentration in each job was lower than previous studies[12] that were collected by area sampling because the source of formaldehyde was not located close enough to the employees, or that the workers were required to leave their workstations, but the area sampling assessment tool remained in the same spot while working. The result is also lower than the study in Myanmar[18] that was collected by personal sampling because the wall fan ventilation system may be a more significant contributor in the differences in formaldehyde levels than the specifics of the workstation. Differences in an area of work, room temperature, humidity, and local exhaust ventilation can affect concentration that is collected by area sampling. Increasing temperature may increase the transportation of chemicals in the air and, in lower humidity conditions, may decrease transportation.

The action level of formaldehyde from OSHA is 0.375 ppm. The average exposure of all job tasks did not exceed the action level. The highest concentration was 0.1570 ppm for workers while teaching anatomy class, while the lowest concentration was 0.0017 ppm in workers working with microscopic for parasitology specimens. However, all jobs have an unacceptable cancer risk for workers especially in high exposure groups and almost all workers have a probable risk or possible risk. The result of cancer risk assessment shows that even if the formaldehyde exposure does not exceed the recommended standard, it still has a cancer risk in workers who are working in low level formaldehyde exposure jobs. Following the hierarchy of control, formaldehyde exposure should be reduced as much as possible.

Conclusion

In conclusion, this study found that the formaldehyde exposure level under the conditions in all jobs in this study had a possible lifetime risk for cancer even if the formaldehyde exposure does not exceed the permissible exposure limit and action level. So, workers that are exposed to formaldehyde should undergo medical surveillance annually for early detection of cancer. They should receive more protection and work under safer conditions. For future studies, medical staff in hospitals have a risk for cancer from formaldehyde exposure. This study and previous studies have shown the same results in Thailand, but the case report or cohort study is still limited, so the data from medical surveillance for cancer may be useful for future study.

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