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Original Research

GESDAV

Prevalence of formaldehyde in indoor air of gross anatomy laboratory and cadaver storage room of a medical college

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ABSTRACT

Aim: Concentration of formaldehyde (FA) which is used to preserve cadavers for dissection in medical colleges was monitored in indoor air including at the breathing level in dissection classes during a 2-week study in a gross anatomy laboratory and also in the cadaver storage room in a Medical College in India in 2012. **Materials and Methods:** Air samples were collected for 30 min and 3 h to commensurate with World Health Organization (WHO) standard (short-term exposure limit) value of FA (30-min) and dissection class of 3 h duration respectively. **Results:** FA concentration ranged from 0.11 to 1.07 mg/m^3 in the cadaver storage room and 0.06-1.12 mg/m^3 in the gross anatomy laboratory. In samples taken at 5 ft height at the breathing level, FA concentration ranged from 0.32 to 0.86 mg/m^3. **Conclusions:** Most of the observed FA levels were found to be above the prescribed FA guideline values laid down by organizations such as OSHA, ACGIH, WHO, Japan Ministry of Health, Labor, and Welfare and, therefore, could be considered as harmful for students' and teachers' health. FA concentrations reported from a few medical facilities in other countries are comparable, implying that some uniform management and control strategies for FA could be contemplated to reduce risks of FA exposure to students and teachers which are discussed in this paper.

KEY WORDS: Air pollution, aldehyde, health, occupation, student, ventilation

INTRODUCTION

In medical colleges, formaldehyde (FA; also called formalin) has been used for years as an essential component of embalming solution used in cadavers. Medical students, during their dissection course, are exposed to FA [1] and reported to suffer from various physical symptoms like burning eyes, lacrimation, irritation of airways, dermatitis, etc. [2-6] Students are reported to develop chemical hypersensitivity during cadaver dissection [5,7]. Formalin has attracted attention as a health hazard for students and instructors as formalin concentrations in air of gross anatomy laboratories are often higher than permissible limits [1]. Vohra [8] has found that both the indoor FA concentrations and personal FA exposure levels were higher near dissecting tables than away during dissection sessions.

Ministry of Health, Labor, and Welfare in Japan prescribed 0.08 and 0.25 ppm FA as the upper limits in domestic and specified workplaces, respectively [9,10]. The Ministry of Education, Culture, Sports, Science, and Technology in Japan had issued an administrative directive regarding "improvement of the environment of gross anatomy dissection for medical and dental students" in April 2001, requiring that national, prefectural, municipal, and private medical and dental universities take measures to reduce FA levels in the dissection room [11]. The indoor FA guideline values prescribed by various organizations have been compiled by National Research Council of Canada [12].

There is very little scientific literature on indoor FA concentration in medical colleges of a large country like India, and so the potential health risk to FA in medical colleges in India is relatively unknown. In 2011, India had the highest number of medical colleges in the world [13]. The number of existing medical colleges in India as approved by Medical Council of India (MCI) was 301 and 11 new ones were established during 2009-10 [14]. MCI contemplates increasing student intake also in medical colleges [13,15]. Therefore, medical student population under likely FA exposure risk is going to increase significantly.

This study was undertaken to monitor uncontrolled FA concentration in cadaver storage room and gross anatomy laboratory during dissection in a medical college in India to understand likely exposure to workers, teachers, and students during official working hours. The tested null hypothesis of the work was: FA concentration in the studied locations are not more than international guidelines or standards on indoor FA, and people are not exposed to potentially harmful concentrations of FA at this college.

MATERIALS AND METHODS

Background of Study Location

The study was conducted in a gross anatomy laboratory and cadaver storage room in a medical college in India in 2012. The gross anatomy laboratory was of 28 m × 11 m × 4.5 m in size (volume of 1386 m^3) with 16 cadaver dissection tables. The room was ventilated by windows that opened in an adjoining open courtyards. Cadavers for dissection are stored in FA tanks (1.3 m × 2 m) in a cadaver storage room (11 m × 4 m × 4.5 m) located opposite the dissection room, separated by a corridor [Figure 1]. The storage room is ventilated by two exhaust fans fitted on the wall about 4 m above the floor. The tanks are kept covered always except during loading and unloading of cadavers.

Cadaver Embalming and Dissection

Embalming fluid for dissection contains FA as the principal component mixed with water in the proportion of 3:1 with a little amount of glycerin and alcohol as additives. During the dissection, FA vapor is emitted from opened up organs, resulting in FA exposure. During the study, 16 cadavers were placed over the fixed tables, and each cadaver was allotted to 12 students and the instructor. Cadaver dissection involved removal of skin from the entire body followed by dissection of superficial and deep layers of the body.

Air Sampling Locations

Indoor FA was monitored in (i) cadaver storage room where cadavers used in dissection classes are preserved in FA tanks. The workers access this room only during handling and delivery of cadavers. Indoor air was monitored twice at two sampling points, one in the passage, and another at middle of the tanks [Figure 1], (ii) gross anatomy laboratory, where dissection practical classes are run for 3 h at least thrice in a week. There are chances of FA exposure from the FA steeped bodies directly and when bodies and organs are opened up, allowing the FA imbibed in the muscles and organs to release. The FA sampling instruments were placed at four positions (point A, B, C, D) in this dissection hall approximately 3 feet above floor near. Another six locations were used (BZ 1-6) near the dissection tables for monitoring FA concentrations at average height of students. For dissection hall, two types of sample timings were chosen, (i) Time-weighted average (TWA-3 h) to commensurate 3-h dissection classes. A total of 8, 28, and 12 number of air samples was collected, respectively, at the cadaver storage, dissection laboratory, and breathing level, respectively (ii) Another short-term exposure limit (STEL-30 min) sampling for 30 min was carried out (total 8 samples) in the dissection room to match World Health Organization (WHO) indoor FA standard of 30 min [12]. A summary sampling scheme is presented in Table 1.

FA Sampling and Analysis

Indoor air was sampled at a flow rate of 0.8-1 L/min by a portable gas sampler (Polltech Instruments, Mumbai) in high-performance liquid chromatography grade water. The samples were subsequently analyzed for FA content [16]. This method can detect FA in the range 11-23,000 ppm (US EPA) which was suitable for concentrations found. The observed FA concentration values were compared with (i) WHO (STEL-30 min) value: 0.1 mg/m^3 (ii) ACGIH (TLV) value: 0.4 mg/m^3 (iii) OSHA PEL (8-h TWA) value: 0.9 mg/m^3 (iv) Japan Ministry of Health, Labor, and Welfare (IAQ guideline) value: 0.1 mg/m^3. To compare measured 3-h TWA values with 8-h TWA guideline value of OSHA, the observe 3-h TWA concentration values were converted to 8-h TWA concentration values.

Determination of Laboratory Ventilation

Active air change per hour (ACH) was determined in the anatomy laboratory by tracer decay method [17,18]. Carbon monoxide (CO) was released as the tracer in the empty laboratory during weekly holidays to avoid human exposure to CO, and its temporal decline was monitored to calculate ACH [19]. The tracer was analyzed by a CO analyzer (Model 11M, Environment SA, France).

ACH was calculated for two room configurations: (i) All windows/doors closed and (ii) all windows/doors fully open. Concentrations of CO were converted to their natural logarithm values and were plotted against time in hours and ACH was calculated as the slope of the straight line through the natural logarithm of CO concentration plotted against time [17,18]).

Room ventilation was calculated by the established formula:

$$Q = A \times V \qquad (1)$$

Where,

Q = Absolute ventilation of the room (m^3/h or ft^3/h)

A = ACH (1/h)

V = Volume of the room in m^3 or ft^3

RESULTS AND DISCUSSIONS

FA Concentration in Cadaver Storage Room

FA concentration in the cadaver storage room ranged from 0.11 mg/m^3 to 1.07 mg/m^3. Lowest and highest FA concentrations were observed under with and without exhaust fan conditions, respectively. FA was monitored under the business as usual closed-tank condition as the covers of the tanks were removed for a few minutes only at the beginning and end of the week when bodies are removed or loaded in the tanks. Since, the room is accessed only during cadaver handling, there is negligible personal exposure to FA. All the observed FA concentrations with and without exhaust conditions were above the indoor air quality guidelines of Ministry of Health, Labor, and Welfare in Japan. Several of the observations were higher than ACGIH TLV value; all concentration values were below the OSHA PEL value [Figure 2]. The results indicated that the indoor air quality in the cadaver storage room in terms of FA concentration was mostly beyond the prescribed safe limits for humans.

FA Concentration in Gross Anatomy Laboratory

Indoor FA concentrations in the gross anatomy laboratory ranged from as low as 0.06 to 1.11 mg/m^3 at sampling points scattered over the large dissection hall. FA concentrations on Monday, when the bodies are replaced on tables from the storage tanks, were generally higher than other weekdays except on first Friday, when the bodies were dissected, releasing FA [Figure 3]. FA concentrations on second Monday were much higher than first Monday, as the heavily dissected bodies on first Friday imbibed substantial FA during storage which got released on second Monday. As the week progressed, FA concentrations came down to lower levels. The concentrations on Friday increased due to extensive opening up of the cadavers and increased release FA from inner tissues and organs.

The day of a week had a role to play in regulating indoor FA concentration as FA release from the bodies depended on: (i)

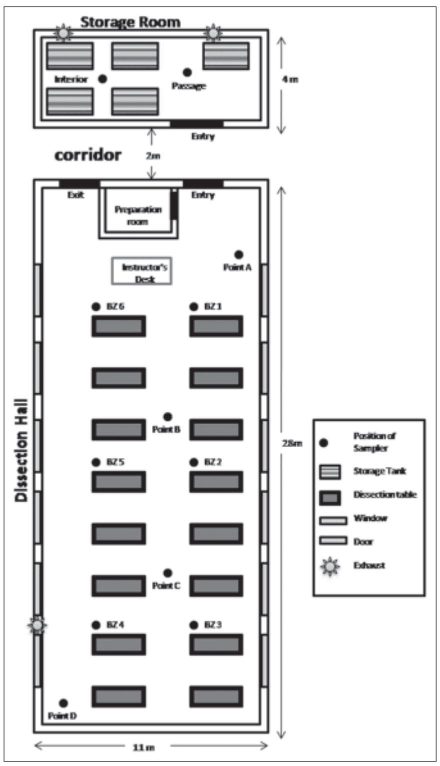

Figure 1: The plan of gross anatomy laboratory (dissection room) and cadaver storage room (storage room) with the selected air sampling locations (BZ: Breathing level sampling; Point: Indoor air sampling)

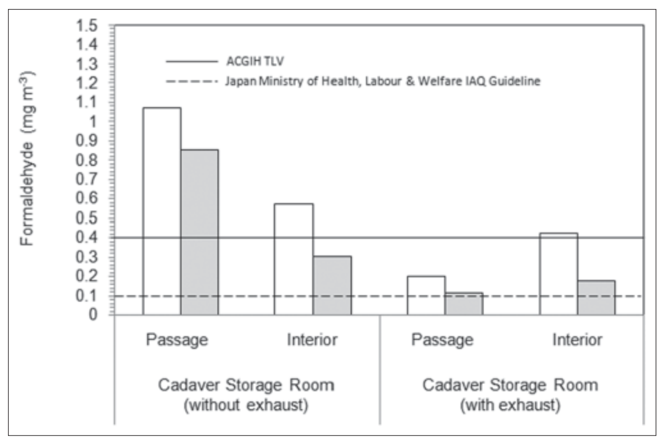

Figure 2: Indoor concentration of formaldehyde in cadaver storage room with respect to various indoor air quality guidelines

Table 1: Summary of indoor air sampling

Sampling site	Sampling point	Number of sampling point[a]	Sampling duration	Number of samples	Remark
Cadaver storage room	In between cadaver storage tanks	01	3 h	04	Time integrated (3-h) sampling with and without exhaust fans
Cadaver storage room	Outside cadaver storage tank zone	01	3 h	04	Time integrated (3-h) sampling with and without exhaust fans
Gross anatomy laboratory	Aisle and corners of the hall; at about 2 ft height	04	3 h	28	3-h TWA (equivalent to class duration of 3-h) FA concentrations at various locations in the dissection hall
Gross anatomy laboratory	At about 5 ft height over dissection tables	06	0.5 h	12	To determine breathing level FA concentrations
Gross anatomy laboratory	Aisle and corners of the hall; at 4 ft height	04	0.5 h	08	30-min sampling for comparison to indoor FA standard of WHO

[a]Please refer to Figure 1 for sampling locations. FA: Formaldehyde, WHO: World Health Organization

Loading of FA steeped bodies from storage tanks onto the dissection tables allowing the superficial FA to release at the start of week, (ii) the dissection of inner organs resulted in release of imbibed FA during the week, (iii) re-entry of dissected cadavers to FA storage tanks, leading to higher imbibition of FA by opened up organs. Hence, the expected pattern of FA emissions in a week could be presumed, and safety precautions may be planned in advance. FA concentration was frequently above indoor air quality guidelines of Ministry of Health, Labor, and Welfare in Japan and ACGIH, respectively, but was below OSHA PEL [Figure 3].

In a separate monitoring exercise, indoor FA concentrations were monitored at the same sampling points in gross anatomy laboratory for 30 min to understand compliance of indoor FA levels to the 30-min FA standard of WHO. Indoor 30-min FA concentrations ranged from 0.23 mg/m^3 to 1.31 mg/m^3 and concentrations on Tuesdays were higher than Thursdays, as was earlier observed, and all the observed concentrations were above WHO prescribed standard of 0.1 mg/m^3, indicating a violation of safe indoor air quality in terms of FA concentration [Figure 4].

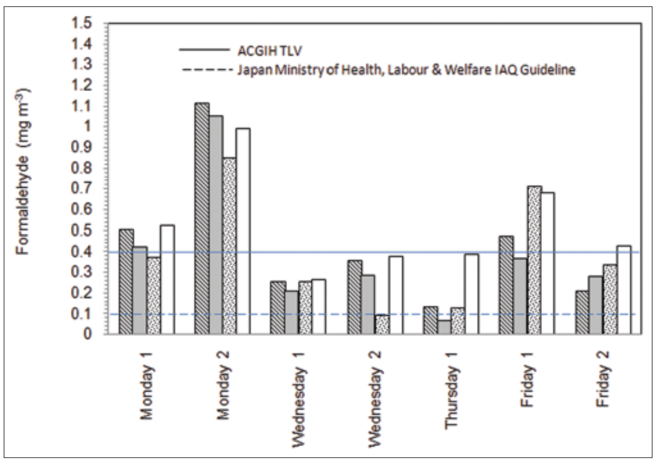

Figure 3: Indoor concentration of formaldehyde in gross anatomy laboratory with respect to various indoor air quality guidelines

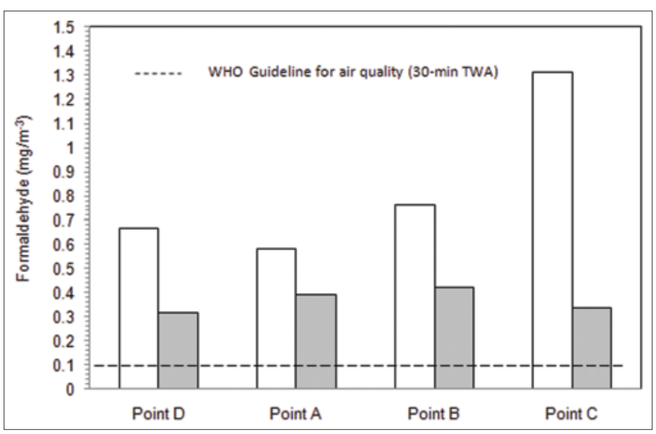

Figure 4: Indoor concentration (30-min time-weighted average [TWA]) of formaldehyde in gross anatomy laboratory with respect to WHO indoor air quality guideline (30-min TWA)

To monitor FA concentration at the breathing levels of students, indoor air samples were collected at 60 cm above cadavers within breathing level of students based on their average height and stooping positions during dissection. FA concentration in the breathing level ranged from 0.32 to 0.86 mg/m^3 during dissection classes [Figure 5]. The range of observed breathing level FA concentrations was lower than those in cadaver storage room and gross anatomy laboratory collected by 3-h and 30-min monitoring schemes. The results also indicated that the medical students and instructors could be exposed to higher than prescribed FA as per the 30-min FA concentration guideline of WHO and also indoor air quality guidelines of Ministry of Health, Labor, and Welfare in Japan. FA concentrations on Tuesdays were above the prescribed ACGIH TLV standard. But, none of the observed FA levels were above the OSHA PEL. The null hypothesis of the experiment is, thus rejected. Similar FA concentrations and indoor conditions might prevail in many medical colleges in India and elsewhere where similar embalming, cadaver storage practices still exist and hence it is pertinent to look into this aspect seriously.

Active air exchange rate in the gross anatomy laboratory was 10.42 ACH under open windows condition and absolute ventilation of same was calculated to be about 28697 m^3/h, which is comparable to standard and acceptable ACH values [20]. But, indoor FA concentrations were still above prescribed safe limits indicating the need to explore local exhaust ventilation for lowering FA levels further.

It is recommended that periodical FA monitoring in dissection laboratories is undertaken in medical colleges to generate required information on possible FA exposure risks to students and instructors since instructors and teachers would end up working under such conditions for very long in their career. As possible solutions, the followings are envisaged: (i) Employing suitable alternatives of FA for cadaver storage and embalmment. Hammer *et al.* [21] reported that Institute of Anatomy at University of Leipzig had successfully attempted conserve human cadavers after embalming with ethanol and glycerin followed by packing in polyethylene foil and storing at 5°C for at least 3 years without decomposition. Such procedures may be undertaken for trial, (ii) Use of ventilated dissection tables [22] have been found to

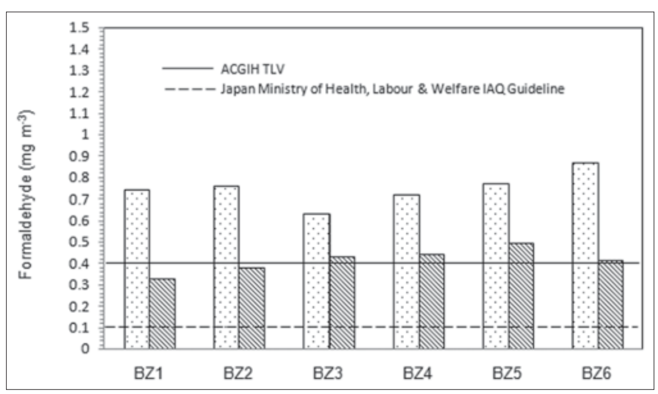

Figure 5: Concentration of formaldehyde within breathing level over cadavers in the gross anatomy laboratory with respect to various indoor air quality guidelines

be effective in reducing exposure to FA in cadaver dissection laboratory, (iii) Air suction duct network on the ceiling at about 3-4 m above floor for exhausting FA from top of dissection tables, (iii) Ohmichi *et al.* [23] have designed and proposed a dissection table fitted with a photocatalytic device for FA decomposition which could be useful in such medical facilities.

CONCLUSIONS

The most important information that emerged from this study is the likely preponderance of unsafe levels of indoor FA in medical dissection laboratories in India and many other countries where such dissection practice is still being followed. Further, the study indicated that in spite of good ventilation, FA concentration levels could reach unsafe levels in such dissection laboratories. Hence, there is a need to look into this issue and undertake corrective measures in medical colleges on case to case basis. Due to lack of information on actual FA levels in these laboratories, precautionary measures may not be even contemplated and hence, health impacts could be substantial. Therefore, such medical practices should be promoted with proper exposure prevention techniques and management. In this study, area sampling was chosen within breathing level of students at immediate vicinity of dissection tables to know general FA concentration to which students got exposed to. In future studies, personal sampling should be undertaken along with area sampling to understand actual personal exposure to FA more precisely.

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