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Original Research Article

Formaldehyde tracking in a histopathology laboratory in a medical college

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ABSTRACT

Background: Formalin 10% is a fixative agent used in pathology laboratories. Formaldehyde released from formalin is a strong irritant and a carcinogen. The lab personnel are exposed to 10% formalin preserved surgical and post-mortem tissue samples during the visual examination and grossing. The present study aims to assess the exposure to formaldehyde in a histopathology laboratory unit as well as the effectiveness of existing engineering/ventilation systems.
Methods: This is a cross-sectional study. Formalin levels were measured using portable air quality/pollution meter which measures formaldehyde (HCHO) in terms of mg/m^3 in the morning, noon, and evening in different areas for one month. Areas of rooms and ventilation were mapped. The level of formalin was noted before, during, and after the grossing procedure and compared with the reference values given in the Occupational Safety and Health Administration (OSHA) and World Health Organisation (WHO).
Results: Formaldehyde concentration ranged from 0.005 to 0.48 ppm (parts per million) in the grossing room and 0.002-0.010 ppm in the museum. Formaldehyde levels were highest in the morning and during grossing without using exhaust/ventilation and the levels reached minimum value within 15-20 minutes of switching on the existing control methods (exhaust fan of grossing station and opening of window panes).
Conclusions: Formalin from the histology laboratories cannot be removed entirely but can be reduced sufficiently to lessen the risks to health by educating lab personnel and adopting appropriate control techniques.

Keywords: Formaldehyde, Histopathology laboratory, Portable pollution meter

INTRODUCTION

Formaldehyde (FA) is a colourless, strong irritant, flammable one-carbon chemical.[1] FA is the stock-in-trade of the pathology laboratory. It plays a major role in tissue fixation, in withstanding treatment with various reagents, preventing decomposition of tissue, and keeps it in a life-like manner.[2] International Agency for Research on Cancer in 2004 classified formaldehyde as a human carcinogen.[3] Lab personnel are exposed to FA vapours released from formalin during grossing and tissue processing. There is very little scientific literature on FA concentration in histopathology labs in India. The present study aimed to assess the exposure to formaldehyde in a histopathology laboratory and to know the effectiveness of the existing ventilation systems.

METHODS

This is a cross-sectional study conducted in the Department of Pathology at S. S. Institute of Medical Sciences & Research Centre, Davangere for a period of 1

month from June 2022 to July 2022 after obtaining Ethical Clearance certificate with reference number IERB 525-2022. FA levels in the air were measured using a portable air quality/pollution meter (Figure 1) which is detected by the electrochemistry sensing technology and gives the measure in terms of mg/m^3. It detects FA in the range of 0-1.999mg/m^3.[4] Conversion factor: 1 ppm (parts per million) = 1.23 mg/m^3.[5]

Figure 1 (A & B): portable air quality/pollution meter.

Study place

The FA levels were assessed in the museum, grossing room, tissue processing area, and reporting room in the Department of Pathology at our medical college. The breathing zone of workers was used for personal sampling and air in the environment was used in the reporting, museum and storage rooms for sampling. 319 specimens, all bottles covered with lids, were stored in the storage room and 520 in the grossing room, and a total of 1009 in the museum for the exhibit. The levels were assessed during different time zones of the day i.e., morning, noon, and evening in areas of interest for one month using the above method. The level of FA was noted before, during, and after the grossing procedure with and without the use of exhaust fan and compared.

The grossing room was 456.87 square feet (sq. ft.) in size and is very well ventilated with four large windows with an area of 312 sq. ft. It has two exhaust fans fitted 5.8 ft above the floor which opens into an outside open area. The storage room is adjacent to the grossing room ventilated by one window and of size 223.13 sq. ft. Outside the grossing room is the tissue processing area of 685 sq. ft. size with two windows, of the same measurements, and a door. The reporting room has four windows and a door and the museum is equipped with 21 windows and two doors and the size of the room is 2459.06 sq. feet (Table 1). The observed data were compared with the following reference values as described in (Table 2).

Table 1: Layout with measurements (in square feet).

Areas of interest	Dimensions in square feet (sq. ft.)	Number of windows	Number of doors
Grossing room	456.87	4	1
Storage room	223.13	1	1
Museum	4574.3	21	2
Tissue processing area	685	2	1
Reporting room	2459.06	4	1

Table 2: Threshold limit values for formaldehyde by various organizations.

Organisations	Values (ppm)	Type	Remarks
National Institute for Occupational Safety and Health (NIOSH) (Yahyaei et al [6]).	0.016	Ceiling Limit	Recommended standard
World Health Organisation (WHO) and Japan Ministry of Health, Labor, and Welfare (JMHLW) (Ogawa et al[7])	0.08	Ceiling Limit	Recommended standard
Occupational Safety and Health Administration (OSHA) (OSHA regulations 1910.1048) [8]	0.75 2 0.5	TWA[a] concentration, PEL[b] STEL[c] Action level	Legal standard
American Conference of Governmental Industrial Hygienists (ACGIH) (Ohmichi et al [9])	0.3	Ceiling limit	Recommended standard

[a]TWA-Time-Weighted Average; [b]PEL-Permissible Exposure Limit; [c]STEL-Short-Term Exposure Level

RESULTS

In the grossing room and storage area, the highest FA concentration in the morning was 0.014 mg/m^3 (0.011 ppm) and the lowest was found to be 0.006 mg/m^3 (0.005 ppm) after employing the control measures. In the morning, the highest FA levels were 0.005 mg/m^3 (0.004 ppm), 0.010 mg/m^3 (0.01 ppm) and 0.011 mg/m^3 (0.009 ppm) in reporting room, museum and tissue processing area respectively. In the afternoon, levels were reduced to

0.000 mg/m^3 in the reporting room and tissue processing area. The levels reduced to 0.002 mg/m^3 (0.002 ppm) in the museum. Levels in the afternoon and evening were similar. In the grossing room, the FA level was found to be 0.014 mg/m^3 (0.011 ppm) before grossing, 0.48 mg/m^3 (0.39 ppm) during grossing without the use of exhausts, and the levels reached 0.006 mg/m3 (0.005 ppm) in 15-20 minutes after switching on the exhaust (Table 3).

Table 3: Formaldehyde concentration in different areas of study.

Areas of study	Formaldehyde concentration (ppm)	
	Morning	Afternoon and evening
Grossing room	0.011-0.014	Before grossing-0.011-0.014(afternoon) During grossing (without exhaust) – 0.39-0.48 With exhaust -0.005-0.008
Storage room	0.008-0.011	0.002-0.006
Reporting room	0.002-0.004	0.000
Tissue processing area	0.005-0.009	0.000
Museum	0.007-0.010	0.002-0.004

Before using the existing control methods, FA levels in all the study locations was less than the recommended levels of WHO, JMHLW, NIOSH and ACGIH and OSHA PEL except in the grossing room where levels were higher than the recommended level of OSHA PEL and less than levels recommended by other organisations (Figure 2).

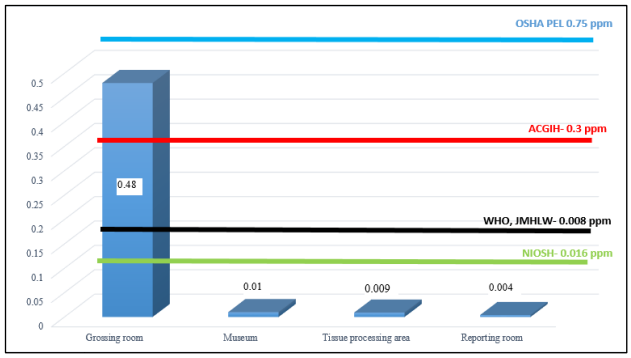

Figure 2: Indoor concentration of FA in different areas with respect to various indoor air quality guidelines without control measures. The levels of FA exceeded the standard levels of all except OSHA's.

After using existing ventilation/engineering methods, lab personnel in the Department of Pathology were not exposed to formaldehyde levels greater than the levels recommended by OSHA, WHO, ACGIH, JMHLW, or NIOSH levels (Figure 3).

The exposure rate (E) was calculated using the following formula:[6]

$$E = FxDxM / W$$

Where; E-Weekly exposure to formaldehyde (ppm); F-Exposures frequency in the time period of a week (12 hours in our case); D-Average time of exposure to formaldehye (12 hours in our case); M-Concentration of exposure to formaldehyde; W-Average work hours worked per week (48 hours in our case).

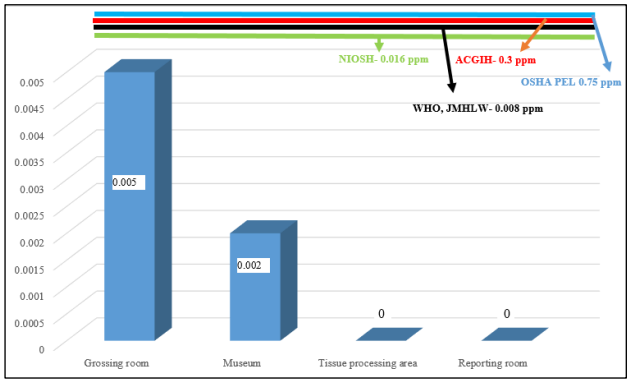

Figure 3: Indoor concentration of FA in different areas with respect to various indoor air quality guidelines with exhaust/control measures. The levels of FA were within the recommended standard levels of all organisations.

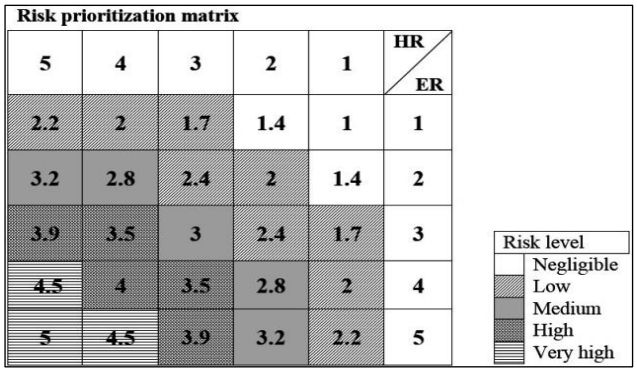

Figure 4: Risk prioritization matrix.

Exposure index is determined by taking the proportion of E and OSHA (PEL) and the risk of exposure rate is obtained using risk ranking matrix (Manpower 2005) (Figure 4).

The exposure rate to the histopathological samples before grossing procedure was started was 0.04, during grossing without using the safety measures was 1.44 and after using the safety measures was 0.018. Thus, the risk of exposure rate was negligible in all scenarios.

DISCUSSION

As the most common aldehyde in the environment, formaldehyde (HCHO), which is an oxidation product of methyl alcohol, has a natural background concentration of <1mg/m^3.[10] A solution containing 37% formaldehyde and 10-15% methanol is commercially available where methanol inhibits polymerisation and prevents paraformaldehyde formation. 10% formalin (4% formaldehyde) is used as a fixative in medical laboratories.[11] Other than histopathology labs, FA is used in the production of resins, paints, carpeting and construction materials.[12] Environmental sources of FA consist of motor vehicle exhaust, engine exhaust, tobacco smoke, incinerators.[13]

Adverse health effects of FA exposure are:

Acute health effects: Exposure to 0.5 to 2.0 ppm level of formaldehyde first causes tingling sensation and irritation to eyes, nose, and throat.[10,14] OSHA concluded that the odor threshold is 0.8-1 ppm.[15] Contact of formalin with skin causes white discoloration, contact dermatitis, drying, crackling, scaling, erythema multiforme. It causes permanent corneal clouding and loss of vision.[10,15,16] Due to adaptation to formalin fumes, the exposed personnel show decreased sensitivity for smell perception making him susceptible to adverse health effects if proper control measures are not taken. 25-30 ppm of FA levels causes pneumonia, work-related bronchial asthma and pulmonary edema.[10]

Chronic health effects: FA exposure could pose a threat to human reproductive system causing abnormal menstruation, abnormal sperm and infertility and abortions.[17] Exposure to FA can lead to sinonasal cancer, lung cancer, breast cancer, and nasopharyngeal cancer.[16,18] Studies also suggest genotoxic effect of FA in blood lymphocytes leading to leukemia.[19] Concentration up to 100 ppm is fatal.[10]

To protect subjects from acute and chronic health effects of formaldehyde, legal standards, or recommended standards are established by multiple organizations. These are shown in (Table 4).

To prevent the adverse health effects, the general ventilation requirements of histopathology labs recommended is to be well ventilated to provide at least six-room air changes per hour and the lab should be under negative pressure.[22]

Table 4: Legal standards or recommended standards and their definitions.

Legal or recommended standards	Definitions
Ceiling limit (Barsan et al[20]).	A limit that should not be exceeded even instantaneously at any time during the workday.
Short-Term Exposure Level (STEL) (Ahmed et al[21]).	It is the concentration to which employees can be continuously exposed for 15 minutes without any adverse health effects and should not be exceeded more than four times in a day.
Time-Weighted Average (TWA) concentration (Ahmed et al[21]).	It is an 8-hour working-day or 40-hour work-week average concentration under which all the employees may be repeatedly exposed to throughout their lifework without any adverse health effects.
Permissible Exposure Limit (PEL) (Ahmed et al[21]).	It is a regulatory limit on the amount or concentration of a substance in the air usually based on TWA or STEL.

In the present study, the containment/control measures utilized were as follows: opening of window panes; introduction of local exhaust ventilation; collection of drain liquid from displayed specimens in closed containers; leak prevention; specimen containers covered with lids

Safety measures included wearing gloves, goggles/face shields.

FA levels were highest while performing grossing without using exhaust fans and the levels reached minimum value within 15-20 minutes of switching on the exhaust fans and opening windows. This is in concordance to the study done by Edward et al.[23] Museum, tissue processing area, and reporting room had minimum formaldehyde concentration even before using the control methods. We observed that the FA concentrations were highest on Monday mornings. This could be due to more samples being processed on Monday compared to other days of the week and due to the accumulation of formalin fumes the day before, as the doors and the windows would be closed on Sundays. This is similar to the study done by Gahukar et al.[1]

In the study by Ogawa et al conducted in a hospital pathology laboratory, they utilized hardware and software interventions in addition to already established ventilation

systems and used a Japanese work environment measure system and found these techniques were effective in improving the work environment.[7]

In a study by Ahmed HO, air samples were collected using flow pumps and analyzed for formaldehyde using the National Institute for Occupational Safety and Health (NIOSH) method 3500 wherein the colored solution formed by reaction of FA with a chromotropic acid and sulfuric acid is detected by spectrophotometer and compared with the prepared FA standard solution and suggested that use of Personal Protective Equipment (PPE) and local exhaust ventilation system can considerably reduce the adverse health effects.[21] Edwards FP et al conducted the study in the histopathology department and concluded that after 40 minutes of implementing measures such as use of extraction trunks, vents, fans, discarding the fluids in sinks and sluice tanks, FA levels reduced and formaldehyde concentrations were measured using infrared spectroscopy.[23]

The present study was compared with other studies by using the legal standard FA exposure limit recommended by OSHA PEL (0.75 ppm). In the present study, formaldehyde concentrations before using control methods were found to be in concordance with the study done by Ogawa et al and Edwards et al where the concentrations were above the ceiling limit of OSHA and was contrary to the study by Ahmed et al.[7,23,21] In all the studies i.e., Ogawa et al, Ahmed et al, and Edwards et al and the present study, levels reached below 0.75 ppm after implementing interventions (Table 5).[7,21,23]

Table 5: Formaldehyde concentration in histopathology laboratories (grossing room) -comparative studies.

Other studies	Formaldehyde concentration (ppm)	
	Before intervention (Maximum value)	After intervention (minimum value)
Ogawa et al[7]	0.447	0.228
Ahmed et al[21]	0.023	0.001
Edwards et al[23]	13	<2
Present study	0.48	0.011

This study has few limitations. The recommended method of air sampling (use of fume hoods or snorkel exhaust) was not used and the air exchange rate was not measured.

CONCLUSION

The present study indicated that the use of ventilated rooms, grossing station, and proper air suction duct network can reduce FA concentration to safe levels in pathology laboratories. Hence, the use of corrective measures in medical colleges should be undertaken to protect lab personnel from exposure to carcinogenic formalin fumes.

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