BIOLOGICAL MARKERS FOR FORMALDEHYDE EXPOSURE IN MORTICIAN STUDENTS

REPORT II,

EXTENT OF EXPOSURE

FINAL REPORT

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SUMMARY

One hundred and fifty personal airborne exposure measurements were collected on students at the Cincinnati College of Mortuary Sciences as part of a study to determine the effects of formaldehyde exposure on epithelial cells in the nose and mouth and on circulating lymphocytes. The exposure concentrations were determined using a passive monitoring device (PF-20 STEL monitor). The overall time-weighted average (TWA) airborne formaldehyde concentration was determined to be 1.4 ppm (range 0.15-9.2 ppm) over the exposure period. The average duration of exposure was 125 minutes. Short-term elevations in exposure to formaldehyde were measured with a continuous reading instrument (Interscan Model 4160) with the inlet probe located directly over the embalming table. This instrument detected peak exposures that were 3 to 9 times higher than the corresponding TWA.

Cumulative exposure was determined for 31 students during a 12 week period while embalming. The cumulative exposures ranged from 4 to 82 ppm-hrs. These data will be used in an analysis of biological response to formaldehyde.

DISCLAIMER

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH) or the National Cancer Institute (NCI).

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INTRODUCTION

In the past several years there has been increasing interest in identifying internal markers in the continuum between environmental exposure and development of clinical disease.[1] Field studies are needed to determine if biological changes or damage occur in humans who are exposed to a variety of potentially toxic agents.[2] This study was conducted to determine whether certain internal changes in cellular structure correlate with external measures of exposure to formaldehyde. Human exposure to formaldehyde is of interest to public health because of its widespread presence in both the workplace and in the ambient air and because of the potential of it being a human carcinogen.

This report characterizes the extent of airborne exposure to formaldehyde among a group of mortuary students over an 8-week period. Included are the time-weighted average air concentrations during the embalming period as measured by passive monitors, and the short-term exposures as measured by a continuous reading instrument located near the students as they worked. The results of air samples obtained to measure other agents that are used during the embalming process are also presented. Finally, an estimation of the potential for skin exposure to formaldehyde is included. The results of the biological assays, correlated with the measures of exposure, will be provided in a separate report.

METHODS

TWA Formaldehyde Exposures During Embalmments

This study included 31 students enrolled at the Cincinnati College of Mortuary Science (CCMS) who were performing embalmments, many for the first time, during a laboratory embalming course. During December 6-8, 1989 the blood, nose, and mouth samples were obtained. This was just before the Christmas break and few embalmments were anticipated to be performed at CCMS during this period by any of the students in the study group. On January 4, 1990 the embalming course began and personal monitoring in the CCMS laboratory was begun. This sampling, plus any sampling that could be done by the students during outside embalming activities, continued until the biological samples were again collected on February 27-28.

Airborne exposures to formaldehyde were measured each time the student participants performed an embalmment in the school by having the students attach a passive monitor within their breathing zone. After each embalmment, and just before leaving the embalming laboratory, the passive monitors were removed and sampling was stopped. Used monitors were deposited in a box near the exit of the lab. The used monitors were collected at least every few days at CCMS by NIOSH staff and sent to the vendor for analysis.

Prior to using the PF-20 passive monitor (Air Quality Research, Berkeley, California) to measure the exposure concentrations during each embalming, it was evaluated, both at a NIOSH laboratory and at CCMS during embalmments. Under the conditions expected in the study, the PF-20 monitor performed essentially the same as more established active sampling methods that were compared in the laboratory studies. However, in the field evaluations, there was an average 25% negative bias in the results. The cause of this bias is not precisely known but it was postulated that the bias was due to the slower diffusion rate of non-monomeric species of formaldehyde across the diffusion membrane on the monitor. Further details can be found in Biological Markers for Formaldehyde Exposure in Mortician Students, Report I, "Documentation of Measurement Methodology for Characterizing Extent of Exposure". Accordingly, the measurement data collected using the passive monitors were adjusted by the above bias to reflect the levels that would probably be measured had the more established active sampling methods been used.

NIOSH staff were present initially during each embalming session to familiarize each student with the proper use and recording of pertinent data regarding the personal monitors. However, beginning with the third week, students were required to monitor themselves. Compliance with this requirement was cross-checked with the instructor's record book of each student's laboratory activities. Students entered their activities into the record book so that they could obtain credit for performing each task, as is required to successfully complete the course. The record book is periodically inspected by the laboratory instructor for accuracy. This record was frequently compared with the record of passive monitors obtained from the students throughout the study.

Students who resided or worked at a funeral home during their college enrollment were most likely to have additional exposure. The participating students were asked to measure any exposures to formaldehyde that might occur during embalmments outside of CCMS. Used monitors were to be returned to the CCMS embalming laboratory for regular pick-up by NIOSH staff. Each student was asked to record all outside embalming activities on a separate record sheet and to indicate if a passive monitor was worn.

The study period was regarded as the time between the first sampling of blood, nasal, and oral epithelial cells and the second (post exposure) sampling. The dates these biological samples were collected were December 7-8, 1989 and February 27-28, 1990.

Short-Term (Peak) Exposure Measurement

A continuous reading measurement device was used to record short-term (peak) exposures during embalming operations at CCMS. Teflon tubing was attached to the instrument and the other (inlet) end located in the students' breathing zone directly over the embalming tables (See Figure 1). The instrument used (Interscan Model 4160 SP, Chatsworth, CA) has a rapid response to formaldehyde and was designed to measure between 0.01-20 ppm (see Report I). The monitoring instrument was connected to an external data logging device (Rustrak Ranger, Gulton Co., East Greenwich, R.I.), and the measurement data were later downloaded into a personal computer. Using this system, formaldehyde concentrations were recorded approximately once every 0.6 seconds. After converting the millivolt output into equivalent ppm of formaldehyde, the data files were transformed into graphics using Draw Partner® and Harvard Graphics® (Software Publishing Corp., Mountain View, CA) software programs.

Because the software selected to display the continuous monitoring data was limited to 240 data points from any monitoring session, the original data file had to be reduced accordingly. Thus, concentration values averaged over a time period of 25 to 48 seconds, depending on the total sampling duration, were created for display by the graphics programs. Because of this time integration, instantaneous concentrations were probably higher. However, concentration values averaged over the above time periods were considered acceptable for conveying the magnitude of short-term fluctuations in this study.

Measurement of Glutaraldehyde, Methanol, Isopropyl Alcohol, and Phenol

A study of the material safety data sheets (MSDS) for the embalming solutions used at CCMS indicated that many contained other potentially toxic compounds besides formaldehyde. The primary compounds in these solutions that had relatively high volatility were glutaraldehyde, methanol, isopropyl alcohol, and phenol. NIOSH air sampling methods 2531, 2000, 1400, and 3502, respectively, were used to determine the concentrations of these compounds in air. To check

on the storage stability of shipped samples and on analytical accuracy, laboratory liquid spiked samples for methanol and glutaraldehyde were submitted with the field collected samples. Both personal and area samples for these compounds were collected.

Extent of Skin Exposure

In addition to exposure to formaldehyde through inhalation, it is possible that exposure to the skin, with subsequent absorption, may occur.

Permeation of "surgeons" latex rubber gloves by formaldehyde has been shown to occur. [3] Such gloves are routinely worn by students embalming at CCMS. With a breakthrough time of only 1 to 15 minutes, the permeation rates of formaldehyde through these gloves was found to be between 0.1 to 1 ug/cm^2/minute when challenged with a 9% aqueous solution. The surface area of two standard human hands is 820 cm^2. [4] Thus, if contact of a gloved hand with formaldehyde-containing solutions were to occur, the potential for skin contact and absorption could be substantial.

Formaldehyde (10% v/v in a pH 7.4 buffered solution) has been shown to penetrate human skin.[5,6] Using excised human skin, formaldehyde was found to penetrate the 2 mm skin thickness in about an hour and the rate of passage increased until equilibrium was reached at about 12 hours. The rate of penetration at equilibrium was 16.7 ug/cm^2/hr. The amount of formaldehyde found in the skin itself was approximately 100 ug/cm^2 after 0.5 hours of exposure. As should be expected at higher concentrations, a concentrated solution of formaldehyde (35%) was found to have a penetration rate of 319 ug.cm^2/hr.[6]

Unfortunately, quantitatively estimating the extent of skin contact and the resulting internal biological significance of such exposure is presently very difficult because of incomplete information. The first limitation is the difficulty of estimating the actual frequency and duration of contact of a gloved hand with formaldehyde solutions. The concentration of formaldehyde in liquids and wet surfaces touched by the students most likely varies considerably, but is not known. It is suspected that most of the surfaces contained low concentrations of formaldehyde, since most embalming solutions are prepared with less than 5% formaldehyde. This is important since the rate of breakthrough through a glove material and the skin is a function of the challenge concentration. If only the contact points of the hand (i.e. fingers and palms) are involved, as little as 200 cm^2 of surface area might be exposed. Furthermore, students typically wear double gloves, and were often

observed discarding the outer gloves which were replaced with fresh gloves. This practice would provide added protection against skin contact.

EXPOSURE CRITERIA

The National Institute for Occupational Safety and Health (NIOSH) has recommended that formaldehyde be handled in the workplace as a potential occupational carcinogen. Safe levels of exposure to carcinogens have not been demonstrated, but the probability of developing cancer should be reduced by decreasing exposure. As a prudent public health measure, exposure to formaldehyde should be reduced to the lowest feasible limit.[7] At the time of this writing, the Occupational Safety and Health Administration (OSHA) has specified a Permissible Exposure Limit (PEL) on airborne formaldehyde of 1 ppm as an 8-hour TWA, and an "Action Level" that is one-half of the PEL. OSHA also specifies a short term limit of 2 ppm (average) for a 15 minute period. If measurements indicate concentrations of formaldehyde that are above the Action Level or the STEL, periodic monitoring and medical surveillance are required by the employer.[8]

RESULTS

A total of 238 embalming experiences were achieved by 31 student participants during the study period between December 8 to February 28 (Table 1). One hundred and seventy nine of these embalmments occurred at the CCMS laboratory while the remainder (59) took place at private funeral homes. Personal monitoring of exposures during embalmments that occurred at CCMS was about 90% complete during the air monitoring period that lasted from January 4 to February 27. The occurrence of embalmments was verified by the instructors' records. Of the 153 embalmments the students participated in at the school during the air monitoring period, personal air samples were obtained on all but 16 cases. If the laboratory assistant's embalming activities are not included, personal sampling results were obtained on more than 92% of the embalmment activities. In these instances where samples were not taken, the exposure was estimated by taking the mean of the results obtained from monitors worn by other students during that particular embalming. If no other students were wearing a monitor, the exposure was estimated from the average concentration and duration for the type of embalming performed. During the winter break, an additional 26 embalmments were performed at CCMS by eight students, which were not sampled. Fifteen of

these 26 embalmments were performed by one student (#13). Exposures during this period were estimated by using the average exposure monitored for this type of case during the monitoring period.

During the study period, 11 of the 31 participants engaged in embalming activities outside of CCMS, which amounted to a total of 59 cases. Only five of the participants collected a total of eight personal air samples during these outside embalmments. This extent of sampling was less than anticipated, although every opportunity to encourage the students to sample was taken. One student reported up to 12 embalming experiences that were outside CCMS during the study.

During the study period, the average number of embalmments for the group as a whole was 7.6. The fewest number of embalmments performed by a student was two, while the laboratory assistant (#13) had 23 embalmments during the period. If the laboratory assistant is not included, the average number of embalmments was 6.7.

During the 90 days just prior to the study, 22 of 31 students in the study had engaged in some type of embalmment activity. Using an arbitrary classification criterion of 1:3 for the number of embalmments performed before and during the study, 18 students met or exceeded that number of prior embalmments. Thus, less than half of the entire group had little or no recent exposure to formaldehyde as a result of embalming activities.

Mean Formaldehyde Exposures During Embalmments

In Table 2 the exposure concentrations measured at CCMS for each individual are provided in chronological order. Included is information on the type of case being embalmed, the table number the embalmment occurred on at CCMS (Figure 1), and the duration of the sampling period. This table also provides the actual measured air concentration during the sampling period as well as the adjusted measurement that is obtained if the measured result is increased by 25 percent, due to the negative bias inherent in this method. The last two columns indicate the episodic airborne exposure and the cumulative exposure in ppm-hours, respectively. An episodic airborne exposure constitutes the exposure received by an individual through inhalation during one embalming event.

Table 3 provides a summary of the distribution of cases embalmed at CCMS and the magnitude of exposure to formaldehyde by each type of case during the air monitoring period. Cases are classified into four categories: 1) normal; 2) anatomical; 3) autopsied; and 4) other. Normal cases can involve simply infusing the embalming fluid under pressure through the axillary artery, but may include femoral and carotid arteries as well, and direct hypo-injecting the extremities and torso using a cannula. Embalming solutions typically are made from a mixture of formaldehyde, methanol, and unidentified esters and other compounds. The final solution may contain between 1-3.5% formaldehyde. Anatomical cases require a second injection of a special embalming fluid which can preserve the corpse for several years while in storage at a local medical college. This second injection of aqueous solution contains 6% phenol, 4% methanol, 5.5% glycerin, and 32% ethanol. The hands and feet are covered with a gel containing a more highly concentrated formaldehyde. Autopsied cases typically involve additional hypo-injection using a cannula since the arteries are severed from the thoracic area. There is also considerably more leakage of the embalming fluid from severed blood vessels. A dry material containing para-formaldehyde (called hardening agent) is applied to the open thoracic area. A fourth category was reserved for atypical cases which included mangled or decomposed bodies, as well as small infants.

As can be seen from the distribution of cases, anatomical and autopsied cases are almost equivalent in number and account for over 70% of all cases embalmed. This distribution of cases is expected to be considerably different from the experience at most funeral homes where most cases would fall into the normal category. The descriptive statistics shown by type of case do not contain results identified as outliers which possibly resulted from splashes, etc., and one occurrence where the student wore one monitor during two consecutive embalmings.

In total, 137 personal exposure concentrations were determined during embalmments performed at CCMS during the 8-week monitoring period. The average adjusted air concentration was 1.3 ppm, with concentrations ranging from 0.15-4.3 ppm over the exposure episode. Three of the sampling results were identified as high outliers by Grubb's Test and were substituted with values obtained from other students who wore a monitor during that embalming or else the average exposure for that type of case was used. One time, a student wore a single monitor during two consecutive embalmings and the individual exposures could not be determined.[9] It is quite conceivable that high measurements could have occurred as a result of embalming fluid spray contacting the monitoring device.

The distribution of formaldehyde exposure for each type of case is also shown in Table 3. Exposures are divided into 1 ppm segments over the range measured. This presentation of data shows that the highest exposures to formaldehyde were encountered when autopsied cases were embalmed (1.4 ppm), followed by anatomical (1.3 ppm), and finally normal cases (0.9 ppm). The type 4 cases, which include all atypical types of situations, are not shown in the frequency tabulation due to their small number and diverse circumstances.

Analyzing the exposure data by table on which the embalming was performed, it is shown in Table 3 that exposures in the isolation room are higher than those occurring in the larger room (Figure 1). Embalmments in the isolation room are typically performed with the door closed, while a much greater area exists in the outside room for formaldehyde to diffuse into. This, given essentially equal forced air ventilation in both rooms, may be the primary reason for the difference in average concentration in the two rooms. Exposures around Table 1 and 2 were equivalent. All the personal exposure data could not be used in this analysis since it was not always certain on which table a student had worked.

Table 4 lists, by participant, the results of samples collected outside of the CCMS laboratory. Only eight such measurements were taken. By comparison, 59 outside embalmments were reported to have occurred during the study period in which the participants were involved. When only a single or few samples were collected by a student and additional embalmments were reported which were not monitored, the values obtained from the monitored embalmments were used to estimate the unmeasured exposures. In order to estimate exposures at funeral homes where no measurement data were available, typical concentrations reported in the literature were used. Average exposures during embalmments, as suggested by surveys of funeral homes, are about 1 ppm.[10,11] These values were multiplied by the exposure durations provided in the outside activity records submitted by the students to determine the ppm-hours of exposure for that episode.

Table 5 tabulates the cumulative ppm-hours of exposure to formaldehyde for each student during the study period. These exposures are from both embalmments at CCMS and elsewhere. The total cumulative ppm-hours of exposure is the sum of these two sources of exposure. Individual totals ranged from a low of about 4 to 34 ppm-hours of exposure (an 8.5-fold difference), if the laboratory assistant who had 82 ppm-hours of exposure is not included.

Because the oral and nasal epithelial cells are estimated to have a turnover rate of not more than 25 days, exposures during the last 28 days of the study are presented by day of occurrence. The strength of association between the recency of exposure and biological effect upon the oral and nasal epithelial cells could then be assessed. These results, in ppm-hours of exposure to formaldehyde, are shown in Table 6. The range of exposures during this period was wide, ranging from less than one to more than 24 ppm-hours.

Short-Term (Peak) Exposures

The results of continuously measured formaldehyde concentrations over the embalming tables are displayed in Figures 2-12. These are shown as examples of the many embalmings performed during the survey period. In all cases, except those shown in Figures 2 and 5, more than one body was being embalmed at a time. This accentuates the formaldehyde concentrations that exist in the laboratory since the activities performed on one table will impact to some extent the concentrations of formaldehyde in the entire laboratory. This also complicates the relationship between activities performed on the table being monitored and the air concentrations measured at that point in time. However, the concentration fluctuations are apparent from these figures and the major activities corresponding to those fluctuations are presented in each graph. The time-weighted average concentrations of all values measured during the embalming period are also shown.

A quick inspection of the graphs indicates that both TWA and peak concentrations differ widely from case to case. This is probably due primarily to differing work practices employed by the individual students, the amount of leakage occurring, the speed at which the students worked, the concentration and amount of embalming solution used, and the condition of the corpse (e.g., lacerations could increase leakage).

Examples of how activities can influence the formaldehyde concentrations abound in the figures. For example, in Figure 2, applying formaldehyde gel to the extremities elevated exposure. In Figure 3, leaving the viscera bags open after adding embalming solutions elevated exposure. Such exposure need not happen as indicated by comparison to Figures 6, 11 and 12.

Generally, concentration levels began to rise appreciably when arterial infusions began. Hypo-injection using a cannula was also associated with elevated exposure. The use of a disinfectant spray containing formaldehyde (Dis-spray®)

usually elevated airborne formaldehyde concentrations. In Figure 12, the liberal use of this spray to clean the embalming table elevated the airborne formaldehyde concentration more than 7-fold above the time-weighted average. Obviously, accidents - such as a detachment of the embalming solution hose from the arterial infusion attachment, the results of which are shown in Figure 11 - should be avoided.

These limited data suggest that there is no typical exposure pattern during an embalming, especially under these circumstances where students are in a learning environment. A variety of activities are associated with short-term elevated exposures. Peak exposures during any one of these cases were 3 to 9 times higher than the corresponding TWA.

The extent of agreement between the continuous reading instrument and the personal sampling results obtained at that same time is indicated in nine sets in Table 7. These are the only samples that could be linked to personal monitors during the exposure survey. The TWA reading of the continuous reading instrument is comparable to the TWA results of the passive monitors. Where several students were monitored, the results of all were presented. Prior to monitoring exposure, this instrument was factory calibrated, and its accuracy was compared against two NIOSH methods and the passive monitors (See Report I). Generally, good agreement was obtained when comparing the data shown in Figures 2 through 12 with the personal monitoring data. Slightly lower readings from the Interscan unit are possibly due to the proximity of the overhead fresh air vent to the monitor inlet that was over the tables.

Measurement of Glutaraldehyde, Methanol, Isopropyl Alcohol, and Phenol

The liquid spiked samples submitted for glutaraldehyde, phenol, methanol, and isopropanol were all within the expected range and precision, indicating no obvious problem with storage or analysis of such samples.

Of a total of 16 air samples collected for glutaraldehyde, none contained detectable analyte. The least amount detectable in these samples would be approximately 0.15 ppm. By comparison, the OSHA PEL is 0.2 ppm as a ceiling concentration.[12] NIOSH has not specified any exposure criteria for glutaraldehyde.[13]

Eight area air samples were collected for phenol on separate occasions. Some of these samples were collected during the preparation of anatomical cases where the second injection contained phenol. None of these air samples contained

detectable analyte. The least amount detectable in these samples was approximately 0.1 ppm. The OSHA permissible exposure limit (PEL) is 5 ppm as an 8-hour TWA.[12] The NIOSH recommended exposure limit (REL) is 5 ppm during a 10-hour period and 15 ppm for a 15-minute period.[13] Ten area and personal air samples for isopropyl alcohol (IPA) were collected. The concentrations measured ranged from non-detectable to 12 ppm. The least detectable limit amount in air was about 0.4 ppm. Most sample results contained 1-4 ppm of IPA. The OSHA PEL for IPA is 400 ppm as an 8-hour TWA and 500 as a short-term exposure limit (STEL).[12] The NIOSH REL is 400 ppm for 10-hours and 800 ppm over a 15-minute period.[13]

Seven area air samples were collected for methyl alcohol. All results were below the least detectable amount limit of about 0.8 ppm. The OSHA PEL is 200 ppm as an 8-hour TWA and 250 ppm as a STEL.[12] The NIOSH REL is 200 ppm for 10-hours and 800 ppm over a 15-minute period.[13]

Since the above sample results were obtained early in this investigation and most contained quantities below the limit of detection, additional samples were not taken.

The vapor pressures published for the above compounds are as follows: glutaraldehyde, 17 mm at 20°C; phenol, 1 mm at 40°C; IPA, 33 mm at 20°C; methanol, 100 mm at 21°C. By comparison, pure formaldehyde has a vapor pressure of 664 mm Hg at minus 22°C.[14] However, pure formaldehyde is extremely unstable and dilute formaldehyde in aqueous solution has an approximate vapor pressure of only 1 mm Hg at room temperature (~ 22°C).[14] Formaldehyde solutions (formalin) actually contains less than 0.1% formaldehyde, the remainder being mostly methylene glycol and polyoxymethylene glycols, among other things.[14] Based on the above vapor pressures, and the stated presence of compounds such as methanol in the embalming solutions, one would expect the presence of these other compounds in the air to be much greater. However, complex interactions between these compounds are known to occur. Methanol, when combined in solution with formaldehyde, forms hemiacetals (CH_3O-$(CH_2O)_n$-H). Such a combination acts as a stabilizer to prevent the polymerization of monomeric formaldehyde into polyoxymethylene glycols (HO-$(CH_2O)_n$-H) (the polymers where $n>12$ are referred to as paraformaldehyde) which would precipitate out of solution. Thus, in these solutions, both formaldehyde and methanol are not appreciably present as free parent compound and the rate at which they would evaporate into the air could be dramatically affected.

Extent of Skin Exposure

Assuming a worst case situation (gloves worn for a full two hours without changing, full hand exposure to embalming solution [- 9% formaldehyde], and continuous exposure), it can be calculated that up to 98.4 milligrams of formaldehyde might pass into the hands of an individual (1 ug/cm^2/min x 820 cm^2 (2 hands)
x 120 minutes). In contrast, inhalation dose during a typical embalmment at CCMS would contribute at most only 4.8 milligrams (1.6 mg/m^3 x 2 hours x 1.5 m^3/hr. x 100% absorption). However, because of the many mitigating circumstances presented earlier, it is viewed as unlikely that the extent of absorption is this high. Any attempt to estimate actual absorption would be very crude. Presently, it is preferred to wait for the cytogenetic results. If skin exposure was appreciable, it would most likely be observed as a discrepancy between the nasal/mouth epithelial cell results and the circulating lymphocyte cell results, since the circulating cells could have higher indirect exposure to formaldehyde.

DISCUSSION

The goal of this research study was to determine if the extent of individual exposures, as occurred while working at CCMS and private funeral homes during the study period, are associated quantitatively with subtle biological changes. The exposure concentrations measured both at CCMS and at private funeral homes by these students are comparable to the concentrations found in funeral homes elsewhere, as reported in the literature.[10,11] Other researchers also have found that measured airborne exposures to other embalming chemicals are low to nondetectable. Thus, findings resulting from this study should be applicable to a large population of potentially exposed workers. The range of cumulative exposures (i.e. dose) measured during the study period was broad, and should support the detection of a dose-response effect, if one exists at the levels found, in the tests used in this study to measure biological changes.

Because of the present inability of directly measuring skin absorption to formaldehyde, this could be a potential confounder in the interpretation of the biological results. However, skin absorption of formaldehyde would not be expected to affect the epithelial cells in the nose and mouth, and its ability via this route to affect the circulating lymphocytes has not been shown in the literature. A discrepancy between the biological findings from the nose and mouth versus the circulating lymphocytes might perhaps be due to the role skin absorption plays.

Since the OSHA PEL allows up to 8 ppm-hours of exposure in a given day (1 ppm x 8 hours), only two of the measurements taken at CCMS, excluding three outliers, exceeded that level (Table 2). However, the continuous reading data indicates that it is more likely that concentrations measured over a 15-minute period could exceed the 2 ppm 15-minute STEL specified by OSHA. Improving the ventilation design in the embalming laboratory could significantly lower air concentrations of formaldehyde.

RECOMMENDATIONS

Because the level of exposure to formaldehyde in the CCMS embalming laboratory may be such as to exceed both the 8-hour TWA and 15-minute STEL permissible exposure limit, it is recommended that the existing ventilation be modified. This modification could be in the form of increased general ventilation or as local "point source" ventilation.

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Table 1
Participants' Embalming History

Student ID	Embalmments at CCMS			Embalmments Outside CCMS			Total per Student	Emblamings 90 days Prior to Dec.8	
	Dec. 8 - Jan. 3	Jan. 4 - Feb. 28	Total	Dec. 8 - Jan. 3	Jan. 4 - Feb. 28	Total			
1		4	4				4	0	*
2		5	5	2		2	7	0	*
3		5	5				5	0	*
4		4	4				4	4	
5	3	7	10				10	2	*
6		2	2				2	0	*
7		6	6				6	1	*
8		5	5				5	0	*
9		8	8	2	4	6	14	2	*
10		5	5				5	0	*
12		4	4				4	0	*
13	15	14	29				29	85	
14	2	7	9	1	2	3	12	10	
15		2	2	6	6	12	14	30	
16		2	2				2	15	
17	1	2	3				3	10	
18		3	3				3	0	*
19	2	3	5		1	1	6	0	*
20	1	6	7				7	3	
22		5	5	7	3	10	15	20	
23		8	8				8	15	
24	1	6	7				7	3	
25		2	2	11		11	13	25	
27		6	6				6	2	
28		7	7				7	25	
29		4	4	2	1	3	7	5	
30		3	3		3	3	6	3	
31		5	5				5	10	
32		5	5	3		3	8	2	*
34		3	3	4	1	5	8	8	
35	1	5	6				6	5	
n = 33									
Participants' Embalmments:	26	153	179	36	21	59	238	285	

Footnote: * These students had little or no embalming experiences in the 90 days prior to the course at CCMS compared to during the course period using a criterion of a 1:3 minimum ratio.

Table 2
Log of Participants' Embalmments at CCMS Between January 3 and February 28

Subject ID # (n=31)	Date	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm-hrs	Cum. Exp. ppm-hrs
1	1-12	3	1	0.7	0.9	2.20	2.1	
1	1-19	2	1	1.2	1.6	1.42	2.2	
1	1-26	3	1	0.8	1.0	2.25	2.2	
1	2-16	2	1	no sample		?	0.8	7.2
2	1-09	3	1	1.2	1.6	2.03	3.2	
2	1-23	3	1	0.4	0.5	3.25	1.5	
2	2-06	3	1	1.1	1.4	1.50	2.2	
2	2-20	2	1	0.8	1.0	2.13	2.1	
2	2-20	2	1	no sample	1.0	2	2.0	11.0
3	1-08	3	2	no sample	0.8	1.07	2.6	
3	1-10	1	3	1.7	2.1	1.25	2.7	
3	1-17	1	2	0.6	0.7	2.17	1.6	
3	2-07	2	1	1.4	1.8	2.00	3.7	
3	2-21	1	1	0.7	1.0	1.75	1.7	12.2
4	1-04	2	1	0.5	0.7	1.33	0.9	
4	1-11	1	1	0.6	0.7	2.33	1.7	
4	2-01	1	1	0.2	0.3	2.75	0.9	
4	2-08	3	2	0.9	1.2	1.92	2.3	5.7

Table 2 (Continued)

Subject ID # (n=31)	Date (ex.1–4)	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm–hrs		Cum. Exp. ppm–hrs
5	1–06	3	2	1.7	2.2	2..7	4.8		
5	1–08	2	3	1.0	1.2	1.72	2.1		
5	1–13	4	2	0.7	1.0	4.00	3.6		
5	1–20	2	1	0.7	0.9	3.33	2.0		
5	1–20	3	2	0.5	0.6	1.25	1.1		
5	2–03	2	1	0.6	0.7	3.00	2.1		
5	2–12	1	2	0.8	1.0	1.75	1.8		17.8
6	1–08	3	1	1.4	1.9	2.78	5.2		
6	2–12	3	3	2.3	3.0	2.42	7.2		12.4
7	1–10	2	2	0.5	0.7	1.58	1.1		
7	1–17	1	2	0.6	0.8	2.13	1.7		
7	1–17	1	1	0.6	0.8	2.15	1.7		
7	1–24	3	1	0.3	0.4	2.42	1.1		
7	2–14	2	1	1.6	2.1	1.00	2.1		
7	2–21	3	2	0.4	0.6	1.85	1.0		8.6
8	1–04	2	2	0.6	0.7	1.35	1.0		
8	1–16	1	1	0.9	1.2	1.75	2.1		
8	1–25	2	2	1.0	1.3	1.35	1.7		
8	2–01	1	1	0.7	0.9	2.92	2.7		
8	2–08	2	1	0.7	0.9	1.08	1.0		8.5
9	1–10	2	1	0.6	0.7	2.23	1.6		
9	1–13	4	2	0.2	0.3	4.00	1.1		
9	1–17	1	2	0.6	0.6	2.25	0.0		
9	1–24	3	2	1.2	1.5	3.50	5.3	**	
9	1–31	3	1	1.5	1.9	2.67	5.1		
9	2–21	3	2	2.3	2.9	1.83	5.3		
9	2–28	2	1	no sample			1.4		
9	2–07	2	1	1.0	1.3	2.00	2.5		21.0

Table 2 (Continued)

Subject ID # (n=31)	Date (ex.1–4)	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm-hrs	Cum. Exp. ppm-hrs
10	1–17	1	1	0.7	0.9	1.98	1.8	
10	1–24	3	1	0.9	1.1	2.42	2.7	
10	1–31	3	1	1.5	1.9	2.72	5.2	
10	2–14	2	1	2.9	3.7	1.75	6.5	
10	2–21	2	1	1.5	1.9	2.33	4.5	22.1
12	1–04	2	2	0.6	0.7	1.20	0.9	
12	1–11	1	1	0.6	0.8	2.63	2.0	
12	1–25	2	2	1.3	1.7	1.35	2.3	
12	2–08	2	1	0.5	0.7	2.00	1.4	6.6
13	1–09	3	2	no sample	1.3	4	5.2	
13	1–09	3	1	1.5	1.9	2.90	5.6	
13	1–11	2	2	1.3	1.6	2.78	4.5	
13	1–11	2	2	no sample	0.8	2.5	1.9	
13	1–13	4	2	0.8	1.0	4.00	4.0	
13	1–18	1	1	0.5	0.6	2.00	1.2	
13	1–23	3	2	1.3	1.6	3.00	4.9	
13	2–01	1	1	0.4	0.6	2.75	1.5	
13	2–06	1	2	0.9	1.1	2.25	2.5	
13	2–08	3	2	no sample	1.0	2	2.0	
13	2–10	1		6.4	8.3	1.50	12.44*a	
13	2–16	2	2	no sample	1.0	2	2.0	
13	2–20	4		0.8	1.0	2.50	2.6	
13	2–27	2	1	0.7	0.9	1.42	1.3	40.8

Table 2 (Continued)

Subject ID # (n=31)	Date (ex.1-4)	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm-hrs	Cum. Exp. ppm-hrs
14	1-23	3	1	no sample	0.8	3	3.3	
14	1-23	1	3	no sample	0.8	1	0.8	
14	1-27	2	1	0.7	0.9	2.00	1.8	
14	1-30	2	1	0.7	0.9	2.00	1.7	
14	2-07	2	1	1.2	1.5	2.00	3.1	
14	2-13	2	1	0.4	0.5	1.50	0.8	
14	2-20	3	3	1.5	1.9	2.42	4.6	15.9
15	1-08	3	1	0.9	1.1	2.70	3.0	
15	2-12	3	1	0.8	1.0	1.83	1.9	4.9
16	1-08	3	1	0.6	0.8	2.60	2.1	
16	2-12	3	1	1.1	1.5	1.50	2.2	4.3
17	2-05	1	3	1.0	1.3	3.42	4.3	
17	2-12	3	3	2.8	3.6	2.25	8.2	12.5
18	1-08	3	1	0.8	1.1	2.62	2.8	
18	2-12	3	1	1.5	1.9	1.50	2.8	
18	2-12	3	1	0.6	0.8	1.92	1.6	7.2
19	1-08	2	3	1.6	2.0	1.80	3.6	
19	1-15	1	1	1.2	1.6	1.08	1.7	
19	2-12	1	2	0.8	1.0	1.83	1.9	7.3
20	1-09	2	2	0.9	1.2	1.50	1.8	
20	1-23	3	2	3.0	3.8	2.67	10.3	
20	1-30	2	1	1.4	1.8	1.67	3.1	
20	2-06	3	1	2.8	3.6	1.83	6.5	
20	2-07	2	2	3.4	4.3	1.50	6.5	
20	2-13	2	1	1.7	2.2	1.25	2.7	30.8

Table 2 (Continued)

Subject ID # (n=31)	Date (ex.1–4)	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm–hrs	Cum. Exp. ppm–hrs
22	1–04	2	2	0.7	0.8	1.40	1.2	
22	1–11	1	1	0.7	0.8	2.50	2.1	
22	1–12	4	1	0.8	1.0	2.92	2.8	
22	1–25	3	1	0.7	0.9	1.42	1.3	
22	2–08	2	1	0.8	1.0	1.17	1.2	8.6
23	1–11	1	1	0.5	0.7	2.48	1.6	
23	1–18	1	1	0.8	1.1	1.92	2.1	
23	1–20	1	1	0.9	1.1	1.00	1.1	
23	1–20	3	1	0.5	0.6	3.33	2.0	
23	1–25	2	2	1.4	1.8	1.42	2.6	
23	2–01	1	1	0.3	0.4	2.57	1.1	
23	2–08	3	2	0.5	0.7	2.25	1.6	
23	2–24	2	1	2.5	3.2	0.58	1.9	14.0
24	1–05	1	1	0.1	0.2	1.67	0.3	
24	1–12	3	1	1.0	1.3	1.50	2.0	
24	1–26	3	1	0.8	1.0	2.25	2.2	
24	2–09	1	1	0.7	0.8	1.17	1.0	
24	2–16	2	3	no sample	1.4	2	2.8	
24	2–23	3	2	0.8	1.1	2.75	2.9	11.2
25	1–08	3	2	1.1	1.4	1.83	2.6	
25	2–12	1	2	no sample	1.0	1.8	1.8	4.4
27	1–09	3	1	0.7	0.9	2.83	2.5	
27	1–23	3	1	0.8	1.0	3.27	3.2	
27	2–06	3	1	2.6	3.3	1.83	6.1	
27	2–13	2	1	0.9	1.1	1.00	1.1	
27	2–20	2	1	no sample	2.3	2.5	5.6	
27	2–20	2	1	2.0	2.5	2.30	5.8	24.3

Table 2 (Continued)

Subject ID # (n=31)	Date (ex.1-4)	Type Embal. 1=normal 2=anatom. 3=autops. 4=other	Table # (1,2,3)	Pas.Monit. TWA Conc.	Adjusted TWA Conc.	Duration (hours)	Episodic ppm-hrs	Cum. Exp. ppm-hrs
35	1-04	2	2	0.4	0.6	1.67	0.9	
35	1-11	2	2	0.9	1.1	2.83	3.1	
35	1-11	2	2	no sample	0.8	2.5	1.9	
35	1-25	2	2	0.6	0.8	1.42	1.1	
35	2-08	2	1	1.0	1.3	1.00	1.3	6.4

* Sample was identified as an outlier by Grubb's test and was not used in the exposure analysis. Rather, the average of other students' measurements were substituted.

a. 1.5 ppm-hours was substituted.

b. 3.3 ppm-hours was substituted.

c. 2 ppm-hours was substituted.

** Sample represents two embalmings.

Table 3
Distribution of Embalmings at CCMS by Type of Case and by Exposure Concentration

Type of Case Monitored

Case[1] Type	Percent of Total
1	21.4
2	35.7
3	36.4
4	6.4
	100.0

Overall Results

	Measured Concentrations	Adjusted Concentrations
Average Conc. =	1.0 ppm	Average 1.3 ppm
Range =	0.1–4.3 ppm	Range = 0.15–4.3 ppm

Average Duration = 125 minutes; range 35 minutes to 4 hours

Exposure Distribution by Case Type

Exposure Distribution by Case Type 1
Average = 0.9 ppm; range 0.2–2.1

(ppm range)	(No. of Cases)	(ppm range)	(No. of Cases)
0–1.00	26	0–1.00	19
1.01–2.00	4	1.01–2.00	9
2.01–3.00	0	2.01–3.00	1

Exposure Distribution by Case Type 2
Average = 1.3 ppm; range 0.5–4.3

0–1.00	31	0–1.00	23
1.01–2.00	14	1.01–2.00	17
2.01–3.00	2	2.01–3.00	5
		3.01–4.00	2
4.01–5.00	1	4.01–5.00	1

Exposure Distribution by Case Type 3
Average = 1.4 ppm: range 0.4–3.8

0–1.00	24	0–1.00	16
1.01–2.00	19	1.01–2	25
2.01–3.00	6	2.01–3	4
		3.01–4	4

Average Exposure by Table Embalmment Occurred

Table 1	1.3 (N=80)
Table 2	1.3 (N=43)
Table 3	2.1 (N=10)

Footnote:
1) Case Types include 1=normal; 2=anatomical; 3=autopsied; and 4=other
2) Measured Concentrations were increased by 25% (See text for details).

Table 4
Exposure Measurements During Embalmings Outside CCMS

Subject Number	Date	Type of Case	Duration (minutes)	Monitor Number	Measured Conc. (ppm)	Adjusted Conc. (ppm)
9	1–07	1	15	60569	2.49	3.21
9	1–18	1	59	60696	0.85	1.10
9	2–03	1	75	60556	0.65	0.84
14	1–15	1	120	60626	0.68	0.88
14	2–07	1	15	60629	2.57	3.32
19	1–11	1	75	60586	1.43	1.84
22	2–03	1	110	60606	0.53	0.68
34	2–24	1	90	60587	0.45	0.58

Table 5
Cumulative Formaldehyde Exposure Per Student During Study Period
December 7 to February 27

Student ID#	1	2	3	4	5	6	7	8	9	10
# Embalmings at CCMS	4	5	5	4	10	2	6	5	8	5
Avg. ppm *	1.17	1.03	1.42	0.73	1.09	2.43	0.89	1	1.45	1.92
Range ppm *	0.9-1.6	0.5-1.6	0.8-2.1	0.3-1.2	0.6-2.2	1.9-3.0	0.4-2.1	0.7-1.3	0.3-3.2	0.9-3.7
Cum. Exp.(ppm-hrs)	7.2	11.0	12.2	5.7	26.4	12.4	8.7	8.5	21.0	22.1
# Exp. outside CCMS	0	2		0	0	0	0	0	6	0
Actual Measurements	--	No	--	--	--	--	--	--	3	--
Estimated ppm		1.0							1.0	
Estimated ppm-hrs.		3.0							5.0	
Total ppm-hrs	7.2	14.0	12.2	5.7	26.4	12.4	8.7	8.5	26.0	22.1

Student ID#	12	13	14	15	16	17	18	19	20	22
# Embalmings at CCMS	4	29	9	2	2	3	3	5	7	5
Avg. ppm	0.97	1.89	1.29	1.07	1.14	2.44	1.26	1.62	2.56	0.88
Range ppm	0.7-1.7	0.6-8.3	0.5-3.3	1-1.1	0.8-1.5	1.3-3.6	0.8-1.9	1-2	1-4.3	0.7-1
Cum. Exp.(ppm-hrs)	6.6	82	21.7	4.9	4.3	15.3	7.2	13.1	33.6	8.6
# Exp. outside CCMS	0	0	3	12	0	0	0	1	0	10
Actual Measurements	--	--	2	No	--	--	--	1	--	1
Estimated ppm			0.9	1.0				1.8		0.7
Estimated ppm-hrs.			3.4	12.0				2.3		7.6
Total ppm-hrs	6.6	82.0	25.1	16.9	4.3	15.3	7.2	15.4	33.6	16.2

Student ID#	23	24	25	27	28	29	30	31	32	34	35
# Embalmings at CCMS	8	7	2	6	7	4	3	5	5	3	6
Avg. ppm	1.21	0.88	1.42	1.59	0.94	3.55	1.47	1.81	1.33	2.52	0.93
Range ppm	0.4-3.2	0.2-1.3	--	0.7-3.3	0.3-2.4	1.4-9.2	1.1-2.2	0.6-5.3	0.7-1.7	0.6-6.1	0.6-1.3
Cum. Exp.(ppm-hrs)	14	14	4.4	24.3	19.4	14.8	6.2	14.6	16.5	9.1	9.4
# Exp. outside CCMS	0	0	11	0	0	3	3	0	3	5	0
Actual Measurements	--	--	No	--	--	No	No	--	No	1	--
Estimated ppm			0.5-1.0			1.0	1.0		1.0	0.6	
Estimated ppm-hrs.			6.3			1.6	3.0		4.5	4.4	
Total ppm-hrs	14.0	14.0	10.7	24.3	19.4	16.4	9.2	14.6	21.0	13.5	9.4

* Includes both measured and, where no measurement was taken, estimates based on the average exposure for that type of or by using samples taken nearby, if available.

Table 6
28-Day Exposure Matrix for Buccal Cell End Points – All Embalmments

Student	Date																											Total
	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/16	2/17	2/18	2/19	2/20	2/21	2/22	2/23	2/24	2/25	2/26	2/27	2/28	ppm-hr
1																0.8													0.8
2						2.2														4.1									6.3
3			0.8				3.7														1.7								5.9
4	0.9							2.3																					3.1
5			2.1									1.8			0.5														4.4
6												7.2																	7.2
7														2							1								3
8	2.8							1																					3.8
9			[1.1]				2.5					[0.9]									5.3							1.4	11.2
10														6.6							4.5								11.1
12								1.4																					1.4
13	1.5					2.5		2		12.4						2				2.6							1.3		24.3
14							3.9						0.8							4.6									9.3
15												1.9																	1.9
16												2.2																	2.2
17					4.3							8.2																	12.5
18												4.4																	4.4
19												1.9																	1.9
20						6.5	6.5						2.7																15.8
22			[1.3]					1.2																					2.5
23	1.1							1.6																1.9					4.6
24									1							2.8							2.9						6.7
25												1.8																	1.8
27						6.1							1.2							5.8									13.1
28														1.5		4					6.1								11.6
29					6.5		2.3					2.7																	11.5
30												2.2												1.3					3.5
31														5.3							2								7.3
32													1.6							4.7									6.3
34										2.5														[0.9]					3.4
35								1.3																					1.3

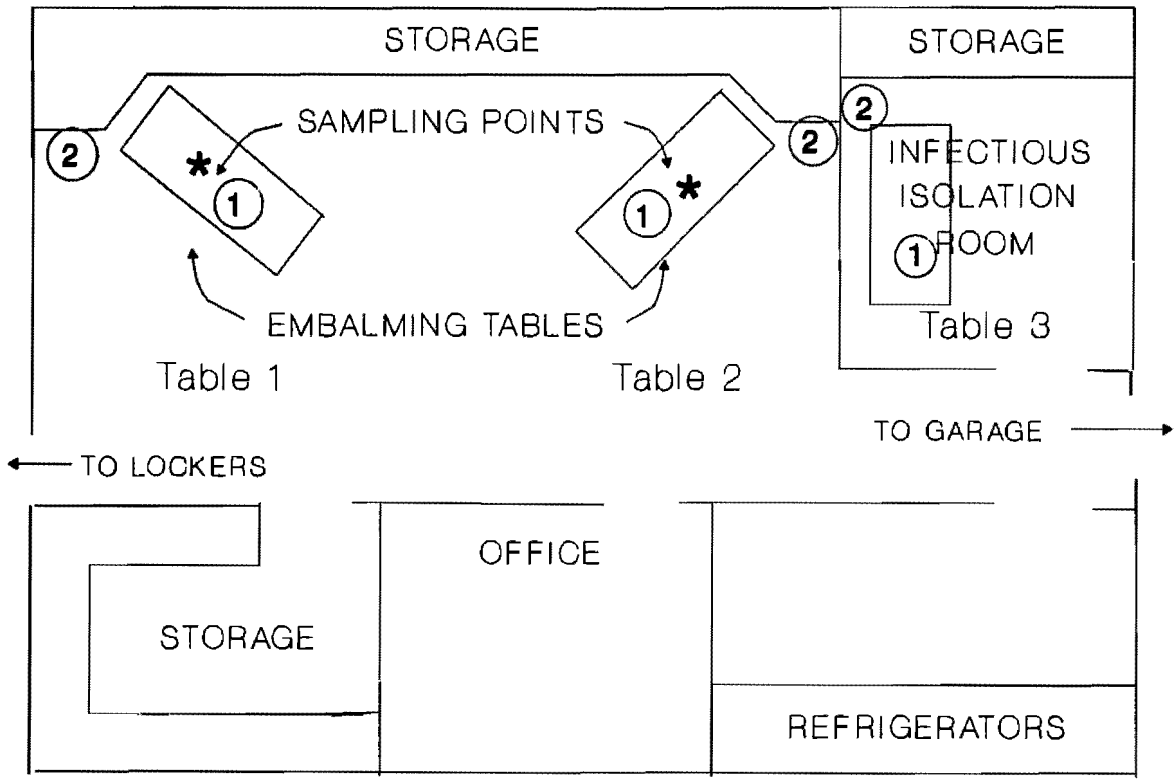
values in brackets indicate outside exposures, both measured and estimated.

Table 7
Comparison of Continuous Reading Instrument Time-Weighted Average Concentration to Personal Passive Monitoring Results

Case #	3	5	7	9	15	27	79	83	89
Table #	1	1	2	2	1	1	2	2	1
Concentration (ppm) Instrument	0.5	0.17	0.9	1.4	0.8	1.0	0.9	0.7	0.4
Concentration (ppm) Passive Monitor	0.7	0.15	1.1, 1.4	1.2	0.7, 0.7, 0.8, 0.8	0.8, 0.8, 0.8	1.9	0.6, 0.9, 2.4, 2.9	0.7, 0.7, 0.9
Concentration (ppm) Adjacent Table						0.8, 0.9, 0.9	1, 2.5		
Direction of Bias	-	0	-	+	0	+	-	-	-

Figure 1

CCMS EMBALMING LABORATORY

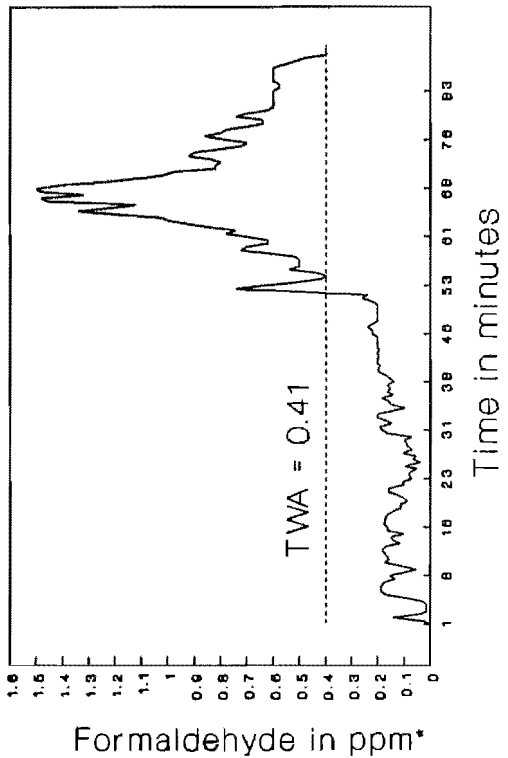


1 = Fresh air ventilation 2 = Exhaust air ventilation

Figure 2

Continuous Exposure Monitoring

Case 408 -- Anatomical



Removed body

Applied gel to hands and feet

Began hypoing legs

Began 2nd injection

Started injection at axillary

Prepared embalming solutions

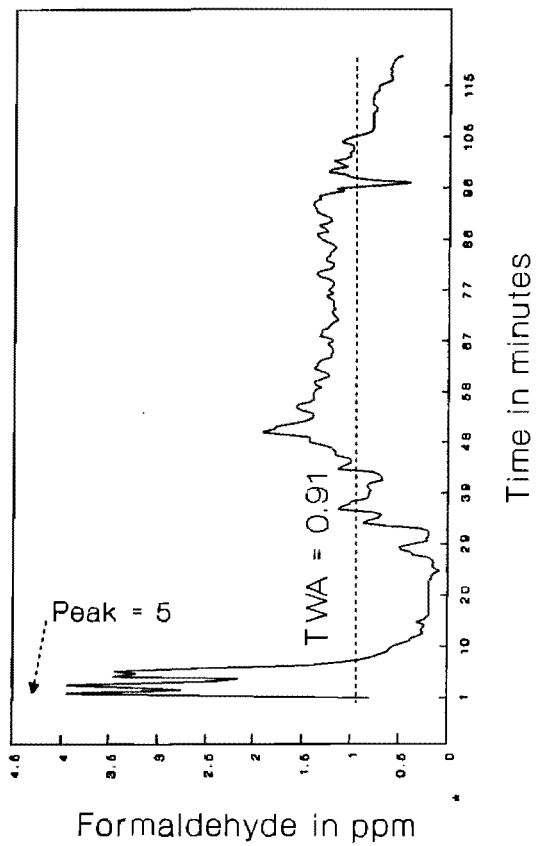
Note: Only one anatomical case was prepared.

* Monitoring data was averaged over 30 second periods.

Figure 3

Continuous Exposure Monitoring

Cases 409 & 410 -- Autopsies



Began restitching torsos

Applied hardening agent

Hypoed side walls

Injected axillaries, notable leakage

Began injecting femorals

Injected heads, massive leakage

Prepared embalming solutions

Unstitched torsos

Added HAR to viscera bags

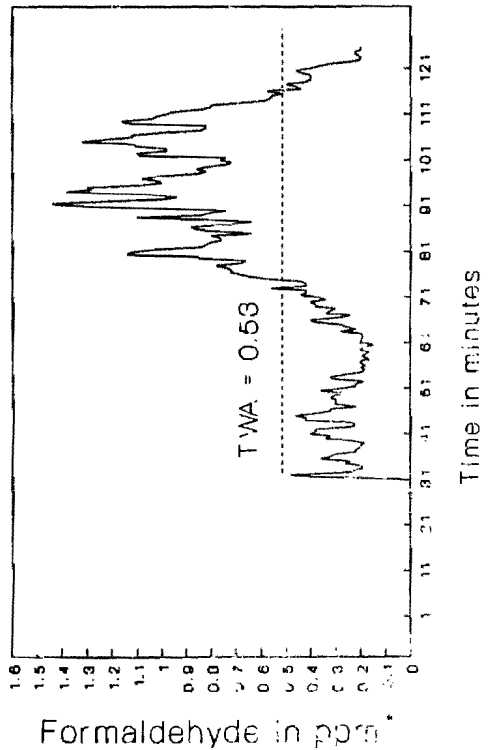
Note: Two autopsies being prepared simultaneously

* Monitoring data averaged over 80 sec.

Figure 4

Continuous Exposure Monitoring

Case 3--Anatomical



Removed bodies

Second injections made

Started injecting axillary

Dis-spray used on heads

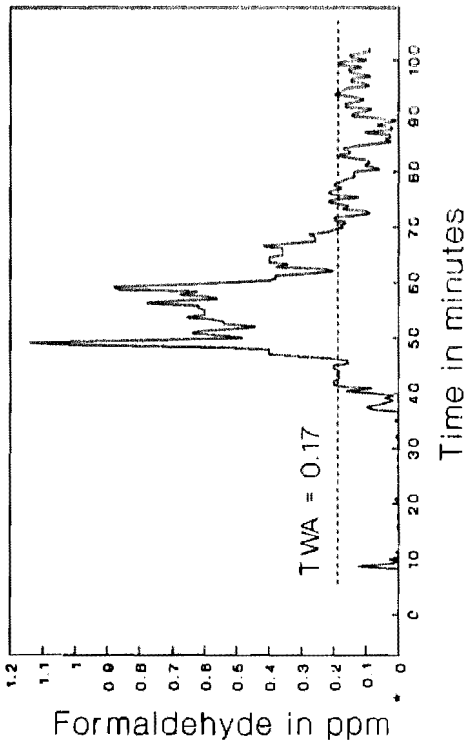
Note: Two anatomical cases were being prepared simultaneously.

* Measurement data plotted as 30 second averages.

Figure 5

Continuous Exposure Monitoring

Case 5 -- Normal



Removed body from laboratory

Cleaned fluid reservoir, used Dis-spray

Hypoing legs

Started injecting femoral

Started injecting axillary

Prepared embalming solution

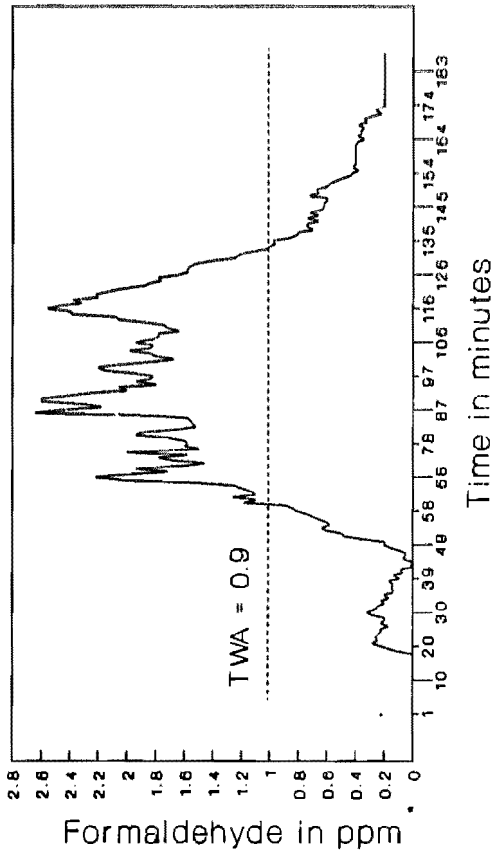
Note: One normal case embalmed.

* Monitoring data plotted as 25 second averages.

Figure 6

Continuous Exposure Monitoring

Case 7 -- Autopsy



Removed body

Replaced viscera bag

Hypoing side walls
Injected corotid

Used hardening agent

Started injecting axillary

Started injecting femorals

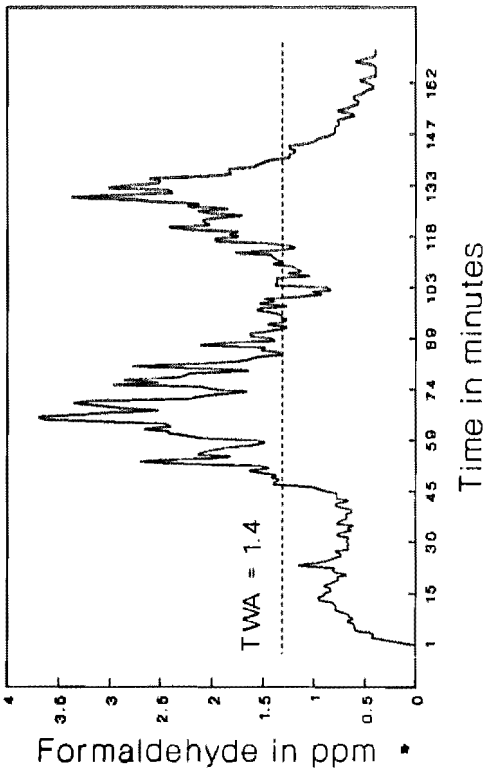
Treat viscera in bag

Note: Two autopsies processed simultaneously.
Monitoring data plotted as 48 second averages.

Figure 7

Continuous Exposure Monitoring

Cases 9 & 10 -- Anatomical & Autopsy



Applied hardening agent

Started hypoing sidewalls of autopsy

Started injecting femoral, autopsy

Injected axillary on anatomical
Prepared embalming solutions

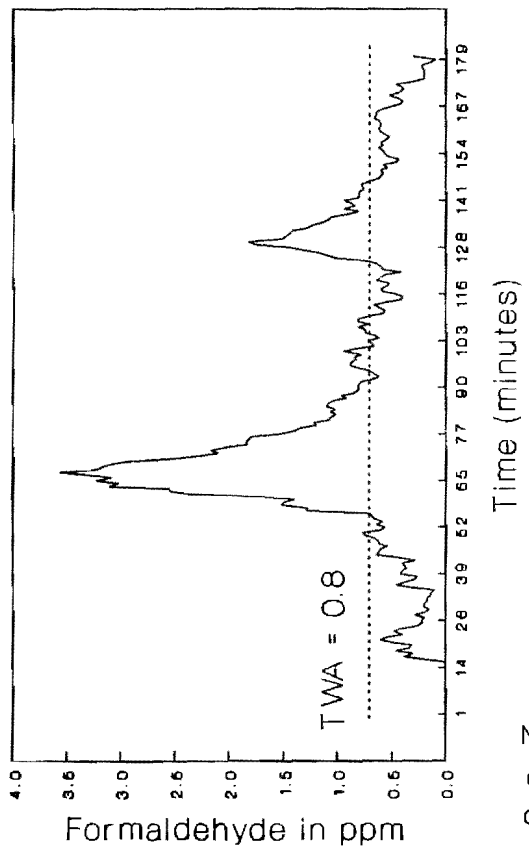
Note: Monitored over anatomical but autopsied case being processed on adjacent table.

* Data plotted as 40 second averages

Figure 8

Continuous Exposure Monitoring

Case 15 --Normal



Remove first body from lab

Started injecting second body

Started hypoing legs

Began injecting axillary

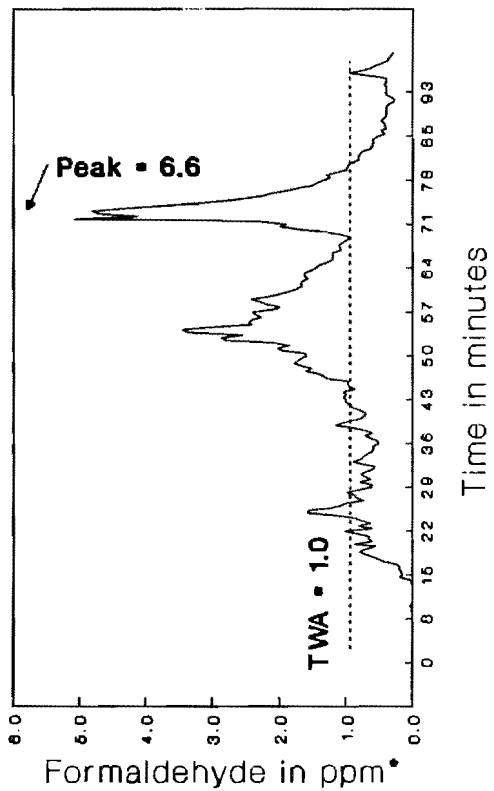
Sprayed Dis-spray around head
Sprayed Dis-spray around head

Note: Sampling was over a large normal case, slightly decomposed. Two additional cases were being embalmed on adjacent table, an anatomical and normal, respect.

Figure 9

Continuous Exposure Monitoring

Cases 27 & 28 -- Both Normal



Hypoing legs

Aspirated stomach

Started injection at axillary

Prepared embalming solutions

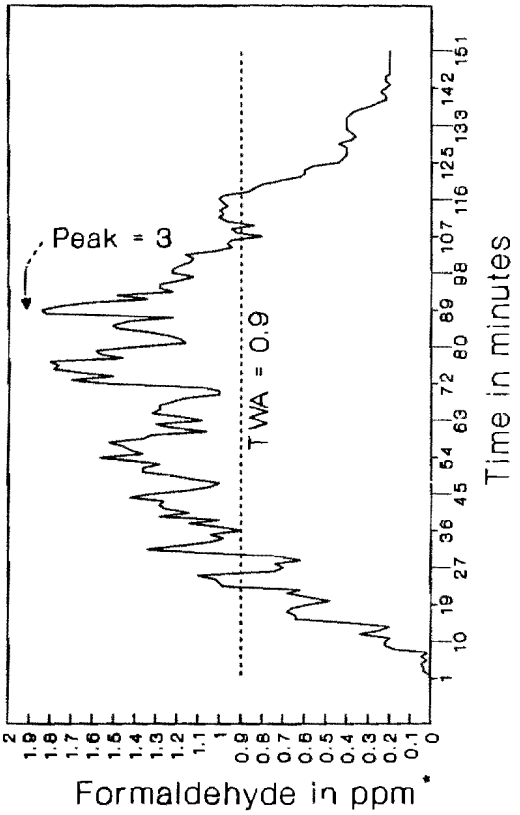
Note: Monitored over case 27.
Other normal case was similar

* Monitoring data plotted as 25 second averages

Figure 10

Continuous Exposure Monitoring

Cases 79, 77, 78 -- Autopsy & Two Anatomicals



Removed body

Aspirated & replaced viscera bag
Hardening agent applied
Hypoing side walls
Injected head

Started injecting axillary

Started injecting femoral

Treated viscera bag

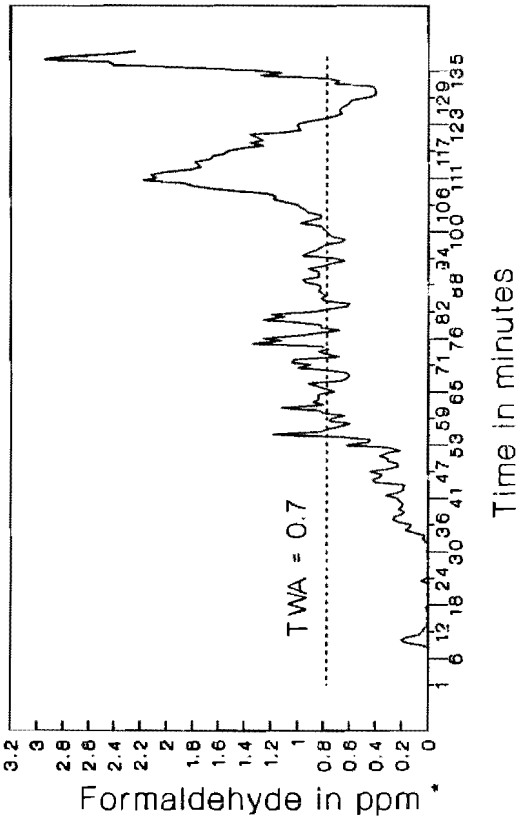
Note: Monitored autopsy, while two anatomical cases were consecutively processed on adjacent table.

* Monitoring data plotted as 53 second averages

Figure 11

Continuous Exposure Monitoring

Cases 83, 82 & 76 -- Autopsy & Two Anatomicals



Removed anatomical case
Applied Hexaphene gel to hands & to feet

Fluid hose blew off of clamp

Started injecting anatomical case
Removed autopsy case

Added hardening agent to autopsy

Began injecting axillary

Began injecting femoral
Mixed embalming fluids

Treated viscera bag with HAR

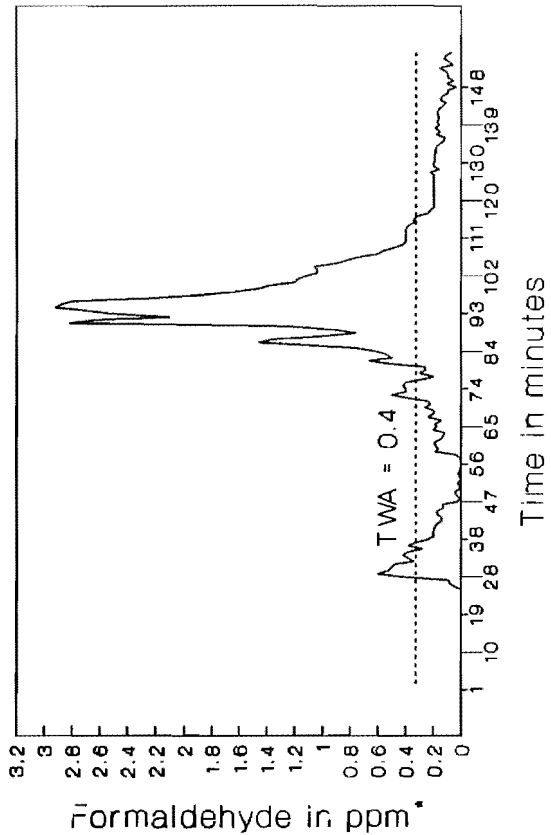
Note: An autopsy case was treated, followed by two anatomical cases on an adjacent table.

* Monitoring data was plotted as 35 second averages.

Figure 12

Continuous Exposure Monitoring

Cases 89 & 90 -- Anatomical & Autopsy



Sprayed table with Dis-spray
Applied Postene gel to hands & feet
Began second injection on anatomical

Began injecting axillary on anatomical

Prepared viscera for autopsy

Note: Anatomical case was monitored.
The autopsy case was of a small infant.

* Monitoring data was plotted as 46 second averages.