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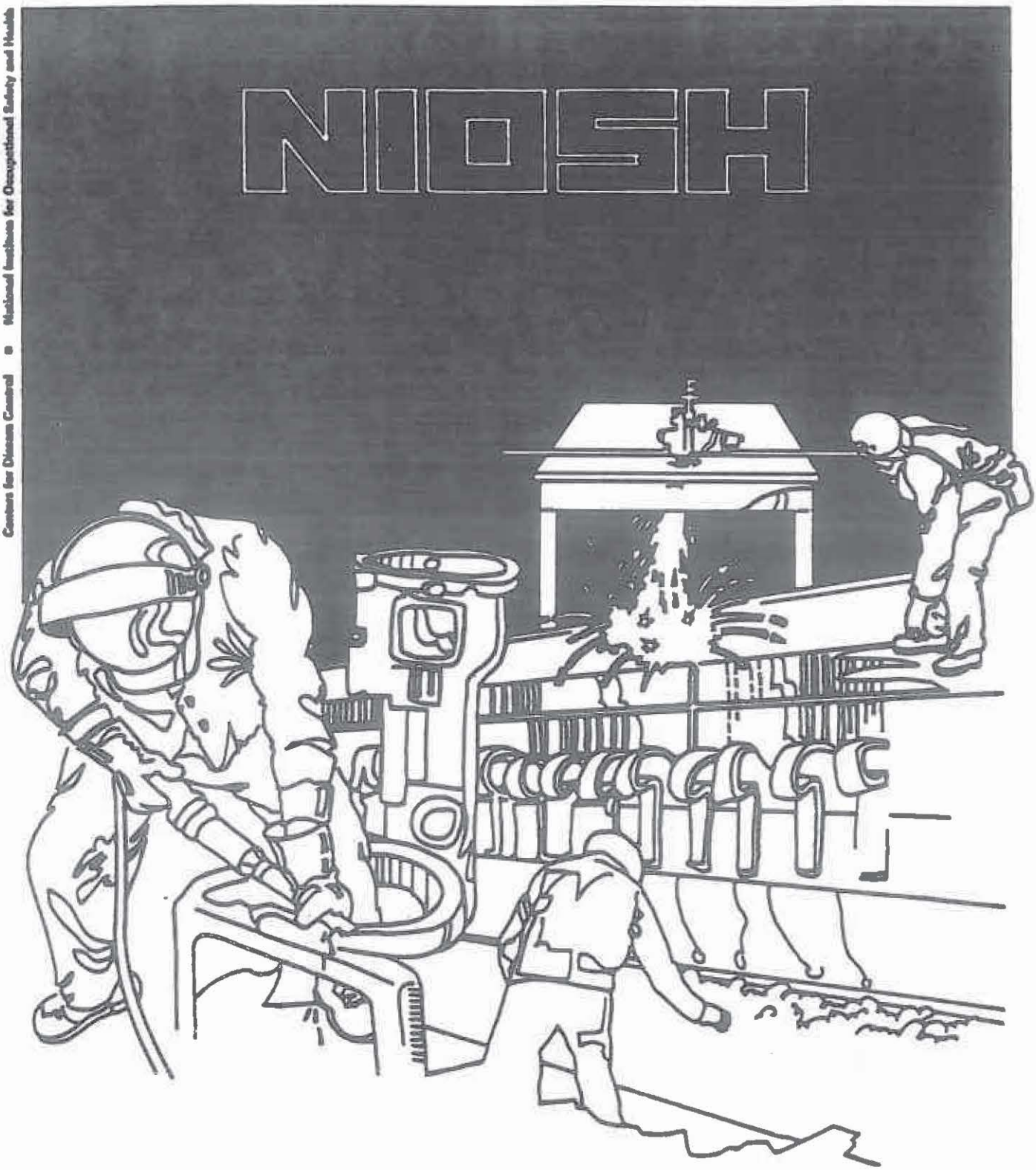

Health Hazard Evaluation Report

HETA 84-098-1497
UNIVERSITY OF PENNSYLVANIA
MEDICAL EDUCATION BUILDING
PHILADELPHIA, PENNSYLVANIA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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AUGUST 1984
UNIVERSITY OF PENNSYLVANIA
MEDICAL EDUCATION BUILDING
PHILADELPHIA, PENNSYLVANIA

NIOSH INVESTIGATORS:
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I. SUMMARY

In December 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate exposures to formaldehyde and phenol among dental students during dissection and examination of embalmed cadavers in a gross anatomy course. Health complaints reported by the students included eye and upper respiratory tract irritation.

On April 2-4, 1984, NIOSH investigators conducted an environmental evaluation of two gross anatomy laboratories used by approximately 100 dental students and instructors each weekday for 4 hours over a 5 week period. To assess exposures, 24 formaldehyde and 24 phenol breathing zone air samples were collected from students and instructors on April 3 and 4. Sampling durations ranged from 1.5 to 3.0 hours. In addition, the ventilation in both labs was evaluated by obtaining air flow measurements at exhaust and supply vents, and by observing air patterns using smoke tubes.

Formaldehyde was detected in all 24 air samples. Concentrations ranged from 0.43 to 2.01 parts per million (ppm). Nine (38%) of the samples exceeded the ceiling limit of 1 ppm currently proposed by the American Conference of Governmental Industrial Hygienists. No exposures exceeded the OSHA standard of 3 ppm as an 8-hour TWA. NIOSH recommends that occupational exposure to formaldehyde be reduced to the lowest level feasible because of its carcinogenic potential. Phenol was also detected in all 24 samples; concentrations ranged from 1.3 to 5.0 ppm during the sampling period, with the highest level equaling the OSHA standard of 5 ppm.

Air flow measurements indicated similar deficiencies in both labs and including: (1) inadequate air exchange rate, 9-10 changes per hour compared to 12 per hour recommended by the Health Resources and Services Administration and (2) movement of air from inside the lab into the corridor which meant that contaminants generated in the labs would enter other non-contaminated areas of the building.

On the basis of the data obtained during this evaluation NIOSH has determined that students and instructors are overexposed to formaldehyde during routine dissection and examination of embalmed cadavers. Recommendations concerning improvements in ventilation are presented in Section VIII of the report.

KEYWORDS: SIC 8221 (Colleges, Universities, and Professional Schools), formaldehyde, phenol, gross anatomy lab, ventilation, irritation

II. INTRODUCTION

On February 10, 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the Director of Environmental Health and Safety at the University of Pennsylvania, Philadelphia, Pennsylvania. The requestor asked NIOSH to assess formaldehyde and phenol exposures of dental students and instructors during dissection of cadavers in a first-year gross anatomy course. Reported health complaints consisted of eye and upper respiratory tract irritation.

Environmental findings were presented to the University of Pennsylvania in a letter report dated August 3, 1984.

III. BACKGROUND

Approximately 100 first-year dental students were enrolled in the 5 week gross anatomy course. Students were grouped into 26 teams of 3-4 students each; 13 teams were assigned to each of two gross anatomy laboratories (labs 202 and 206) located on the second floor of the Medical Education Building. Each team was assigned a cadaver to dissect and study over the 5 week period. Although the course meets from 9am to 1pm (weekdays) most of the students usually complete their exercise well within this time frame. This evaluation was conducted during the third week of the course.

Cadavers were embalmed with approximately 20 liters of an institutionally prepared solution containing 2.29% formaldehyde (6.2% of a 37% formalin solution), 15.2 phenol (16.9% of a 90% phenol solution), 37.5% ethylene glycol, and 45.0% water, by volume. The cadavers are normally stored at least 12-14 months prior to use in the lab.

The cadavers were kept in the labs on stainless steel tables for the duration of the course. To minimize tissue dessication and mold growth the cadavers, when not in use, were wrapped in cloths soaked in a solution containing 5% phenol (by volume), ethylene glycol and water, and covered with plastic.

IV. METHODS AND MATERIALS

A. Environmental

On April 3 and 4, NIOSH investigators collected breathing zone air samples from students and instructors to assess their exposures to formaldehyde and phenol vapors. A total of 24 air samples were collected over the 2-day period, 20 from students and 4 from instructors. All students/instructors participating in the NIOSH monitoring had samples taken simultaneously for formaldehyde and phenol.

Formaldehyde vapors were collected on Supelco ORBO-22 sorbent tubes containing 2-(benzylamino)ethanol-coated Chromsorb 102 resin. These tubes were attached to the students/instructors collar and connected via flexible tubing to a battery operated sampling pump calibrated at a flowrate of 0.080 liters per minute (lpm). Samples were analyzed by gas chromatography according to NIOSH Method 2502[1] (formerly NIOSH Method P&CAM 354). The limit of detection of the analysis was 2.0 micrograms (ug) per sample.

Phenol vapors were collected by bubbling air into midget impingers containing 15 milliliters of 0.1N sodium hydroxide solution. The impingers were positioned in the breathing zone and connected via flexible tubing to sampling pumps operating at 1.0 lpm. The samples were analyzed by gas chromatography according to NIOSH Method 3502[2] (formerly NIOSH P&CAM S330). The analytical limit of detection for the analysis was 10 ug per sample.

B. Ventilation

To assess general ventilation, air flow measurements were taken at each exhaust and supply vent in labs 202 and 206. Since study/storage rooms adjoining each of the two labs had supply air vents which provided an additional source of air to the labs, air flow measurements were taken in these rooms also but only for those in lab 202. Measurements could not be taken in similar rooms in lab 206 because they were inaccessible during this study.

Ventilation measurements were made using a Shortridge Model CFM-83 Flowhood. In a few situations where the use of the flowhood was limited by its size a Kurz Velometer was instead used. Direction of air movement was observed using smoke generated from smoke tubes.

In addition, psychrometric measurements were taken each day using a battery operated psychrometer.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet only those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

B. Formaldehyde

The health effects of formaldehyde can result from acute or chronic exposure. The effects of acute exposure are primarily mucous membrane irritation (burning, tearing eyes, nose and throat irritation). These symptoms can occur as low as about 0.1 parts per million (ppm).[3] Dermatitis associated with formaldehyde vapor, solutions or formaldehyde containing resins has been documented.[3,4] Formaldehyde is a primary skin irritant but may also cause allergic dermatitis at concentrations below those likely to cause primary irritant effects.

Allergic effects include skin sensitization and possibly, asthma or asthma-like symptoms.[5,6] There is considerable evidence that formaldehyde can produce skin sensitization in man, especially in persons occupationaly exposed through skin contact.[7] Eczematous contact dermatitis, when acute, is characterized by redness, swelling, vesiculation, and oozing with itching. In the chronic form, affected areas of the skin may become dry, thickened, and fissured.[8]

A recent study conducted by the Chemical Industry Institute of Toxicology (CIIT) in which rats and mice exposed to formaldehyde vapors developed nasal cancer has raised concerns about its carcinogenic potential in humans.[4]

The Federal (OSHA) Standard for formaldehyde exposure is 3 ppm as an 8-hour TWA, with a ceiling level of 5 ppm, and an acceptable maximium peak level of 10 ppm for 30 minutes.[9] This standard was based on the prevention of irritation effects, not on the carcinogenic potential. On the basis of the CIIT study ACGIH and NIOSH currently recommend that formaldehyde be treated as a potential human carcinogen. ACGIH currently proposes a TLV of 1 ppm as a ceiling limit.[10] NIOSH recommends that exposures be reduced to the lowest feasible level.[3]

C. Phenol

Phenol is toxic by inhalation, ingestion, and skin absorption, and is a strong tissue irritant. The usual symptoms exhibited by exposure to phenol include irritation of the eyes and respiratory tract, erosion of the skin, eczema, digestive disturbances, dark discoloration of the urine, emaciation, nephritis, gangrene, and jaundice.[11] Phenol also acts as a local anesthetic, so that burns from it may not be felt until serious damage has occurred. It may cause kidney and liver damage if exposures are excessive and for a prolonged and repeated basis. There is no conclusive evidence showing that phenol has carcinogenic, mutagenic, or teratogenic properties.[11]

The OSHA standard for phenol is 5 ppm averaged over an 8-hour work shift.[9] NIOSH currently recommends 5.2 ppm averaged over a 10-hour work shift with a short-term (15 minute) exposure limit of 15.6 ppm.[11]

D. Ventilation

The Health Resources and Services Administration (HRSA) and the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) have published guidelines concerning general ventilation requirements for hospitals and medical facilities.[12,13] Although these organizations do not include ventilation criteria specifically for gross anatomy laboratories they do, however, provide them for autopsy rooms, which are considered relevant for purposes of this evaluation.

According to HRSA guidelines[12] general ventilation in autopsy rooms should provide a minimum of 12 air changes per hour. They base this requirement primarily on comfort, as well as asepsis and odor control. The ventilation should also provide for movement of air into the lab from surrounding areas, i.e., the lab should be under negative pressure. Because of potential buildup of odors and/or contaminants, HRSA recommends that the air should not be recirculated but rather exhausted directly outdoors (away from air intakes).

To achieve acceptable indoor air quality the American Society of Heating, Refigeration and Air Conditioning Engineers (ASHRAE) recommends in their 62-1981 Standard[13] that autopsy rooms be ventilated in terms of fresh (outside) air requirements on an occupancy basis rather than on an air exchange rate basis. They recommend that outdoor air be supplied to autopsy rooms at a rate of 100 CFM per person and that none of the air be recirculated for other uses in the building.

VI. RESULTS AND DISCUSSION

A. Environmental

Formaldehyde and phenol air sampling results are presented in Table 1. Formaldehyde was detected in all twenty-four air samples with exposure concentrations ranging from 0.43 to 2.01 ppm. Nine (38%) of the samples exceeded the proposed ACGIH ceiling limit of 1 ppm. None of the samples exceeded the OSHA standard of 3 ppm.

Phenol was also detected in all of the air samples (Table 1). Breathing zone concentrations ranged from 1.3 to 5.0 ppm, the highest level meeting the OSHA standard. (One sample was not included in the data analysis because of suspected tampering). However, when averaged over an 8-hour period, exposures would not have exceeded half of the Standard assuming zero exposure the rest of the day.

When grouping exposures by lab, students and instructors in lab 202 were exposed to significantly higher levels of formaldehyde and phenol than their counterparts in lab 206. Formaldehyde exposures for individuals in lab 202 averaged 1.09 ppm (range 0.52 to 2.01 ppm) while exposures for those in lab 206 averaged 0.76 ppm (range 0.43 to 1.52 ppm) ($t = 4.112$, $p<0.0005$). Similarly, phenol exposures levels for persons in lab 202 averaged 2.86 ppm (range: 1.5 to 5.0 ppm) while their counterparts in lab 206 were exposed to an average level of 2.17 ppm (range 1.3 to 3.2 ppm) ($t = 2.600$, $p<0.01$). It is not readily apparent why individuals in lab 202 were exposed to higher contaminant levels. Although various factors such as work practices, location of students in the lab, size/adipose tissue content/general condition of cadavers, environmental conditions, etc., could have contributed to the differences in exposures it does not appear that differences in ventilation, temperature, or humidity were responsible for these differences (see "Ventilation" below). Also, this data does not support the contention by students and faculty that lab 206 is the worse of the two labs. It could be that individuals in lab 206 were more sensitive to the irritative effects of formaldehyde.

On the average, students were exposed to higher levels of formaldehyde (0.97 ppm vs 0.68 ppm) and phenol (2.53 ppm vs 2.25 ppm) than the instructors. This difference, however, was not statistically significant.

B. Ventilation

Gross anatomy labs 202 and 206 are identical in terms of physical dimensions and ventilation; both labs are essentially mirror images of each other (see Figure 1). Each lab measures 80'(L) X 33'(W) X 13'(H). General ventilation (100% fresh air) was provided via 10 supply air vents, each located about 2-3 feet below ceiling level and equally distributed throughout the lab. Air is also provided to the lab via air vents in each of the adjoining study/storage rooms. Air was removed from each lab by 7 exhaust air vents including one canopy-type hood. All of these exhaust vents were located along the corridor wall at near-ceiling or floor level. There was no local ventilation in the labs.

According to in-house ventilation design specifications (see Table 2) the total amount of air supplied to each lab should be 7150 CFM. The amount exhausted was designed at 7800-7900 CFM (assuming the use of actual flowrates for the E7 hoods since the information

was not provided in the design specifications). Because actual flowrates were consistently lower than those provided in the design specifications (Table 2), the total exhaust volumetric flowrate of 7800-7900 CFM should be considered a minimum range. According to these figures, both labs were designed to be under negative pressure and to provide 13-14 air changes per hour (based on 34,320 $feet^3$ lab space), or about 130 CFM outdoor air per person (assuming 55 persons per lab). It is interesting to note that the in-house design specifications are more stringent than either the HRSA or ASHRAE guidelines.

Air flow measurements, presented in Table 2, show that the actual flowrate in all exhaust/supply vents in both labs were below in-house design specifications as well as HRSA and ASHRAE guidelines. The total amount of air supplied to labs 202 and 206 was 5000 and 4950 CFM, respectively, or approximately 70% of design specifications. The amount of air exhausted from labs 202 and 206 was measured at 4650 and 4450 CFM, respectively, or about 60% of the design figures. According to our measurements the ventilation system was providing 8-9 air changes per hour or about 90-96 CFM fresh air per person, and was maintaining the labs under positive pressure, a finding which was corroborated by observations of air (smoke) movement from the lab into the corridor.

Psychrometric measurements indicated that the temperature and relative humidity (RH) were very similar in both labs at the selected time intervals measurements were taken (Table 3). The temperature in labs 202 and 206 ranged from 66 to 69°F and from 67 to 70°F, respectively, while the RH ranged from 76 to 69% and from 47 to 65%, respectively.

C. Personal Protective Equipment

Aside from cloth lab coats, disposable polyvinyl chloride (PVC) surgical gloves (worn on both hands) were the only other protective equipment used by students and faculty. According to the permeation data provided by the manufacturer this type of glove provides good protection against formaldehyde and phenol.

VII. CONCLUSIONS

The results of the investigation show that students and instructors are exposed to formaldehyde at levels capable of producing symptoms of eye and upper respiratory tract irritation. These symptoms, reported by students, are consistent with the acute health effects reported in the literature for formaldehyde. Although there is no way of determining whether students or faculty are at an increased risk of developing cancer at the levels measured (0.43 to 2.01 ppm), the presence of symptoms and the fact that formaldehyde is a suspect human carcinogen underlie the need for improvements in the ventilation system.

Although the highest phenol exposures met the OSHA standard, when extrapolated over an 8-hour period, exposures would have been less than half of the 5.0 ppm standard, assuming zero exposure for the remainder of the day. Even though the 8-hour TWA was not exceeded phenol levels should be further reduced. Percutaneous exposure appeared to be minimal since appropriate gloves were worn.

VIII. RECOMMENDATIONS

1. The University of Pennsylvania's Anatomy Department should investigate the possibility of reducing the concentration of formaldehyde and phenol in the embalming solution. Discussions with anatomy lab directors in other medical schools indicated that they are currently using commercially available embalming solutions containing as little as 0.62% formaldehyde and 13.2% phenol. When compared to the embalming solution currently used by University of Pennsylvania this represents a 73% and 13% reduction in the formaldehyde and phenol content, respectively.

2. Ventilation in both labs should be increased to provide the levels specified in the in-house design specifications for the supply and exhaust air components. The ventilation in lab 202 may need to be set at a higher air exchange rate initially than lab 206 based on the fact that exposures in lab 202 were higher. Air monitoring should then be conducted to determine whether increased ventilation is effective in reducing formaldehyde and phenol exposures. Further increases in ventilation may be necessary.

IX. REFERENCES

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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1. University of Pennsylvania
2. NIOSH Region III
3. OSHA, Region III

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Formaldehyde and Phenol Exposures of Dental Students and Instructors

University of Pennsylvania
Medical Education Building, Gross Anatomy Labs
HETA 84-098

April 3-4, 1984

Date	Location	Sample Description	Sampling Time (min)	Formaldehyde Sample Volume (liters)	Phenol Sample Volume (liters)	Environmental Concentration (ppm) Formaldehyde	Phenol
4-3-84	lab 202	student, table 1	134	10.3	134	1.03	4.1
4-3-84	lab 202	student, table 3	143	10.3	143	0.64	2.9
4-4-84	lab 202	student, table 3	183	13.0	183	1.07	1.7
4-4-84	lab 202	student, table 4	138	10.5	138	0.62	2.1
4-3-84	lab 202	student, table 5	129	9.9	129	1.24	2.8
4-4-84	lab 202	student, table 5	122	10.8	122	1.29	2.1
4-3-84	lab 202	student, table 7	146	10.8	146	1.82	5.0
4-4-84	lab 202	student, table 10	134	9.5	134	1.55	2.9
4-4-84	lab 202	student, table 11	126	8.5	126	0.65	3.9
4-4-84	lab 202	student, table 13	149	11.8	149	2.01	3.7
4-3-84	lab 206	student, table 14	151	11.2	151	0.43	1.4
4-4-84	lab 206	student, table 15	168	12.5	168	0.72	12.8*
4-3-84	lab 206	student, table 17	88	6.2	88	0.52	2.0
4-4-84	lab 206	student, table 19	151	11.6	151	0.78	1.3
4-3-84	lab 206	student, table 20	134	10.4	134	0.55	2.1
4-3-84	lab 206	student, table 22	98	7.6	98	0.43	1.8
4-4-84	lab 206	student, table 22	176	12.1	176	1.22	2.5
4-3-84	lab 206	student, table 23	139	10.8	139	1.52	3.2
4-3-84	lab 206	student, table 25	144	11.5	144	0.79	2.2
4-4-84	lab 206	student, table 26	145	11.2	145	0.58	1.5
4-3-84	lab 202	instructor, variable	144	11.3	144	0.65	1.5
4-4-84	lab 202	instructor, variable	145	10.9	145	0.52	1.6
4-3-84	lab 206	instructor, variable	142	10.8	142	0.61	3.1
4-4-84	lab 206	instructor, variable	138	11.3	138	0.94	2.8
		Evaluation Criteria:				**	5.0

* Sample questionable, impinger solution was cloudy after sampling period. Result will not be included in data summary.

** NIOSH recommends that exposures be reduced as low as feasible since formaldehyde is a potential human carcinogen. (See Section V B)

Table 2
Ventilation Measurements in Labs 202 and 206, as Compared to Design Specifications

University of Pennsylvania
Medical Education Building, Gross Anatomy Lab
HETA 84-098
April 3, 1984

Exhaust Air Measurements					
	Design CFM		Measured CFM		
Exhaust Vent[1]	Lab 202	Lab 206	Lab 202	Lab 206	
E1	1090	1090	330	480	
E2	1090	1090	960	600	
E3	1200	1200	340	260	
E4	1200	1200	850	720	
E5	890	890	250	400	
E6	890	890	450	440	
E7	not available assume 1450	not available assume 1550	1450	1550	
TOTAL	7800	7900	4650	4450	

Supply Air Measurements					
	Design CFM		Measured CFM		
Supply Vent[1]	Lab 202	Lab 206	Lab 202	Lab 206	
S1	770	770	600	600	
S2	770	770	520	610	
S3	600	600	420	450	
S4	600	600	400	430	
S5	600	600	440	450	
S6	600	600	420	430	
S7	600	600	400	380	
S8	600	600	430	360	
S9	600	600	420	380	
S10	600	600	460	360	
S11	100	100	30	not measured because study and storage rooms were inaccessible. Assume total CFM to be same as counterparts (S11-S16) in Lab 202, i.e., about 490 CFM	
S12	180	180	120		
S13	180	180	120		
S14	180	180	120		
S15	80	80	25		
S16	100	100	70		
TOTAL	7150	7150	∿ 5000	∿ 4950	

1. Locations of vents are indicated in Figure 1.

Table 3
Psychrometric Measurements

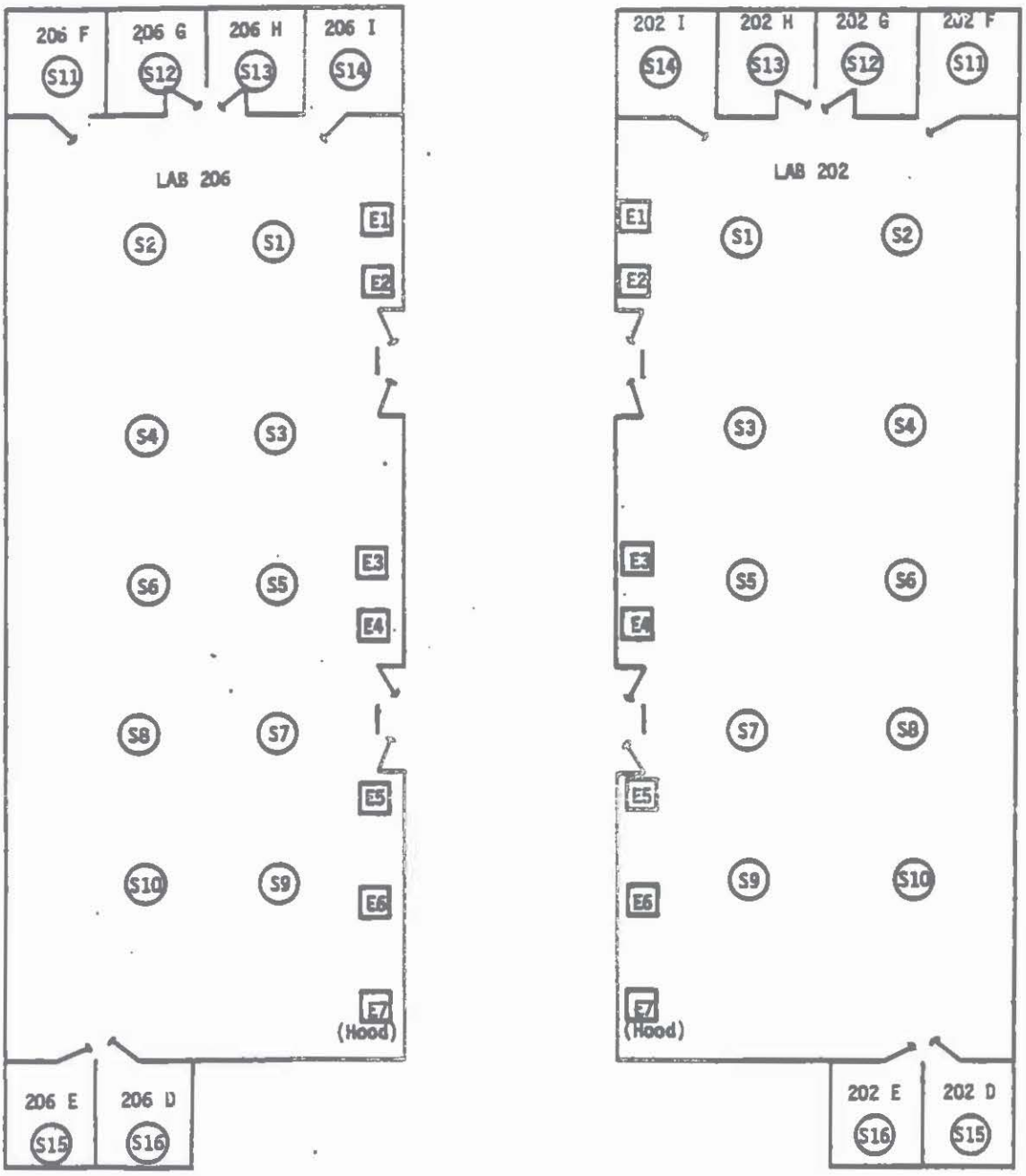
University of Pennsylvania
Medical Education Building, Gross Anatomy Labs
HETA 84-098

April 3-4, 1984

Date	Lab	Time	Dry Bulb/Wet Blub (°F) (°F)	Relative Humidity %
4-3-84	202	10:40am	68/50	52
4-3-84	202	4:45pm	69/48	46
4-4-84	202	9:35am	67/53	60
4-4-84	202	12:00noon	66/53	63
4-4-84	202	2:50pm	67/57	69
4-3-84	206	10:45am	70/51.5	51
4-3-84	206	4:55pm	70/49	47
4-4-84	206	9:40am	68.5/54	59
4-4-84	206	12:10pm	69/55	60
4-4-84	206	2:55pm	67.5/56	65

Figure 1
Schematic Indicating Locations of Supply and Exhaust Vents
in Labs 202 and 206

University of Pennsylvania
Medical Education Building, Gross Anatomy Labs
HETA 84-098



S = Supply Vent
E = Exhaust Vent
Note: drawing may not be to scale