A Thesis

entitled

Formaldehyde Exposures in a University Anatomy Laboratory

by

Kyle William Winkler

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Occupational Health

___________________________________________
Dr. Sheryl Milz, Committee Chair

___________________________________________
Dr. Michael Valigosky, Committee Member

___________________________________________
Dr. Carlos Baptista, Committee Member

___________________________________________
Dr. Patricia Komuniecki, Dean
College of Graduate Studies

The University of Toledo

June 2011
Air sampling studies were conducted within a university anatomical laboratory during the embalmment of a cadaver in order to determine if dangerous concentrations of formaldehyde existed. Three air sampling studies were conducted in the anatomical laboratory on three separate days that a cadaver was being embalmed. Samples were collected and analyzed using the Occupational Safety and Health Administration (OSHA) Sampling and Analytical Methods: Method 52. Each air sampling study sampled for short term exposure limit (STEL) and time weighted mean (TWA) breathing zone formaldehyde concentrations as well as area TWA formaldehyde concentrations. A personal aldehyde monitor was also used in each air sampling study to sample for breathing zone formaldehyde concentrations. Measured TWA mean exposures to formaldehyde ranged from 0.15-1.3 parts per million (ppm), STEL formaldehyde exposures ranged from 0.019-0.64 ppm, and eight-hour TWAs ranged from 0.03 to 3.6 ppm. All 8-hour TWA formaldehyde concentrations sampled in the anatomy laboratory during an embalmment were less than the permissible exposure limit (PEL) required by OSHA.
Acknowledgments

This thesis would not have been possible without the support and encouragement from my family and friends. They have provided me the strength to push on through difficult times in my lifetime and I cannot express how grateful I am to have them in my life. I have also benefited greatly from the teachings I have received from Dr. Michael Valigosky. Dr. Valigosky first introduced me to the field of Occupational Health and sparked my interest to pursue this field as a career. I am extremely thankful that he shared his vast knowledge and experience with me and I will utilize what he has taught me to better myself as a professional throughout my career.
# Table of Contents

Abstract.................................................................................................................................ii

Acknowledgements.................................................................................................................iii

Contents......................................................................................................................................iv

List of Tables..............................................................................................................................vi

List of Figures............................................................................................................................vii

List of Abbreviations................................................................................................................viii

1 Introduction...............................................................................................................................1

1.1 Statement of Problem...........................................................................................................2

1.2 Purpose and Significance.....................................................................................................3

1.3 Hypotheses..........................................................................................................................3

2 Literature Review.....................................................................................................................4

2.1 Properties of Formaldehyde...............................................................................................4

2.2 Health Effects of Formaldehyde.........................................................................................5

2.3 Exposure Limits of Formaldehyde.....................................................................................6

2.4 Exposure in Anatomy Laboratories....................................................................................7

2.5 Exposure During Embalming...............................................................................................7

2.6 Formaldehyde and Embalming Fluid..................................................................................8

2.7 Ventilation and Formaldehyde Exposure...........................................................................9

2.8 Monitoring Formaldehyde in Anatomy Laboratories.........................................................11

3 Material & Methods .................................................................................................................15

3.1 Overview..............................................................................................................................15

3.2 Location...............................................................................................................................16
List of Tables

4-1 Ventilation measurements in anatomical laboratory.................................27
4-2 Formaldehyde concentrations from all air sampling studies........................28
4-3 Eight-hour TWA formaldehyde concentrations from all air sampling studies....29
List of Figures

3-1 Autopsy Table in Anatomical Laboratory Embalmment Room.............................17
3-2 Electronic micromanometer with connected flow hood.................................19
3-3 SKC Airchek 52 Air Sampler Pump..............................................................20
3-4 Sensidyne Gilibrator 2 Primary Flow Calibrator..............................................20
List of Abbreviations

ACGIH….American Conference of Governmental Industrial Hygienists
EPA……..Environmental Protection Agency
mg/m$^3$ ……Milligrams per cubic meter of air
NIOSH…..National Institute for Occupational Safety and Health
OSHA…….Occupational Safety and Health Administration
ppm………Parts per million
STEL……..Short term exposure limit
TWA……..Time-weighted average
Chapter 1

Introduction

Formaldehyde is a widely used chemical that can be used in numerous environments (Agency for Toxic Substances and Disease Registry, 1999). Formaldehyde can be utilized for synthesizing industrial applications, acting as a disinfectant, production of fertilizers, and can be put into glues that hold wooden cabinetry together. It is also commonly used in embalming fluid in anatomical laboratories, funeral homes, and morgues because of formaldehyde’s ability to preserve tissues.

Formaldehyde at room temperature is an odorless and colorless gas that possesses a distinct scent (Varela, 1995). It is infinitely soluble in water, allowing it to absorb readily in the upper respiratory tract, and is flammable as both a liquid and a gas. Formaldehyde is a sensitizing agent that has the ability to cause an immune system response upon first exposure to the chemical. Acute exposures are known to irritate the mucous membranes of the nose, eyes, and throat causing symptoms such as coughing, sneezing, wheezing, nausea, and lacrimation. The respiratory tract is also susceptible to adverse health effects upon formaldehyde exposures. Chronic exposures have shown to produce skin conditions such as dermatitis and respiratory issues similar to asthma. Concentrations of 100 parts per million (ppm) are immediately dangerous to life and
health, which is defined in OSHA regulation 1910.134(b) as “an atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual’s ability to escape from a dangerous atmosphere.”

Studies have been done in the past measuring concentrations of formaldehyde in the air in anatomical laboratories. However, little data is available monitoring the concentration of formaldehyde in the air during the embalmment process of a cadaver in an anatomical laboratory.

1.1 Statement of Problem

A study conducted by the United States Environmental Protection Agency (EPA) has shown that formaldehyde is carcinogenic when inhaled by humans. The study shows that there is sufficient evidence of a causal relationship between formaldehyde exposure and cancers of the upper respiratory tract. Common sources of formaldehyde exposure include tobacco smoke, combustion sources, glues, and pressed wood products. Although studies have been conducted in the past determining formaldehyde exposures in anatomical laboratories, little data exists for exposures to employees who embalm cadavers for medical purposes in anatomical laboratories. Employees may be exposed to dangerous levels of formaldehyde during the embalming process thus increasing their risk for producing adverse health effects. This study was strategically conducted to collect a number of air samples utilizing chemical sorbent tubes and personal aldehyde monitors during the entire process of embalming a cadaver to determine if dangerous levels of formaldehyde exposures were existing to both the employee and the surrounding environment in the anatomical laboratory.
1.2 Purpose and Significance

The purpose of this study was to conduct an industrial hygiene air sampling study in order to determine if the concentration of formaldehyde present in the air during the embalming of a cadaver in an anatomical laboratory were exceeded the permissible exposure limit recommended by OSHA. The significance of this study was to provide data relevant to formaldehyde exposures during the embalming process in an anatomical laboratory for other occupational safety and health professionals to compare to possible future studies similar to this study.

1.3 Hypotheses

1. The 8-hour time-weighted average formaldehyde concentrations will not exceed the current permissible exposure limit or the short term exposure limit recommendations from by the Occupational Safety and Health Administration

2. The highest mean formaldehyde concentrations will come from the personal aldehyde monitors.

3. The lowest mean formaldehyde concentrations will come from the area time-weighted samples.
Chapter 2

Literature Review

2.1 Properties of Formaldehyde

Formaldehyde is a naturally occurring substance found in the environment that is comprised of oxygen, carbon, and hydrogen (OSHA, 2010). Its chemical formula is HCHO. Formaldehyde is a colorless and odorless gas that is extensively used for its tissue embalming properties, which is why it is commonly found in anatomy laboratories and funeral homes (Viegas et al, 2010). Formaldehyde is volatile organic compound that is flammable and extremely soluble in water. The term “formalin” describes aqueous solutions that usually contain both formaldehyde and an alcohol stabilizer. Formaldehyde that is in a solid state is known as “paraformaldehyde.” The odor threshold of formaldehyde is around 1 parts per million. Formaldehyde is a powerful disinfectant and biocide, as it can kill most bacteria and fungi and is also used as a preservative in some vaccines. Besides its use in anatomy laboratories, formaldehyde is used in a variety of work environments such as the woodworking, manufacturing, construction, and chemical industries (Tang et al, 2009).
2.2 Health Effects of Formaldehyde

Formaldehyde can cause skin and respiratory irritations along with other adverse symptoms to individuals who are exposed to this chemical. Potential health effects include sore throat, coughing, shortness of breath, headache, vomiting, blurred vision, and diarrhea (Tang et al., 2009). Formaldehyde has also been known to cause contact dermatitis both as an irritant and an allergen. Irritant contact dermatitis occurs when too much formaldehyde has been exposed to the skin. Symptoms of irritant contact dermatitis to formaldehyde can include redness and scaling of the skin. Allergic contact dermatitis occurs when skin comes in contact with formaldehyde and produces an immune system response, potentially causing redness or itching of the skin.

A study done by Kryzanowski et al. (1990) focused on the relationship between chronic respiratory symptoms and pulmonary function to formaldehyde concentrations in homes. In this study 298 children and 613 adults were sampled. The results from the study showed that children who had medically diagnosed asthma and chronic bronchitis were more predominant in homes that had higher formaldehyde levels (0.06 -0.12 ppm). The study also displayed that peak expiratory flow (PEV) decreased linearly with increasing concentrations of formaldehyde in the homes. The same relationships were not seen in the adults studied. These results suggest that chronic short-term exposures to formaldehyde in children can cause bronchial obstructions to occur.

Workforce members were studied to determine if low-level exposures to formaldehyde would cause adverse symptoms to arise (Main and Hogan, 1983). The workforce was split into two groups. One group of 21 individuals who were being
exposed to formaldehyde concentrations ranging from 0.12 – 1.6 ppm were compared to a second group of 18 individuals who were not exposed to any formaldehyde vapors. All members were then asked to fill out a questionnaire to describe if any symptoms were present after their shift was completed. Eye and throat irritations, headaches, and fatigue were significantly more common among the exposed group of workers. Other symptoms that were described by the exposed group included chest tightness, shortness of breath, and nasal irritations were noted. The results from this study indicate that adverse health effects can occur with formaldehyde exposures as low as 0.12 ppm. This study states that the current permissible exposure limit enforced by the Occupational Safety and Health Administration (OSHA) needs to be re-assessed for its adequacy based on their results.

2.3 Exposure Limits of Formaldehyde

Various exposure limits to formaldehyde are recommended by a number of regulatory agencies. OSHA has currently set the 8-hour time-weighted average (TWA) permissible exposure limit (PEL) for formaldehyde at 0.75 ppm and the short-term exposure limit (STEL) to 0.2 ppm while the American Conference of Government Industrial Hygienists (ACGIH) has set a threshold limit value – ceiling (TLV-C) of 0.3 ppm (ACGIH, 2007). An 8-hour TWA is the average exposure concentration over the course of an 8-hour workday. A short term exposure limit is defined by ACGIH as the concentration to which workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible damage, or narcosis. A TLV-C is the concentration that should not be exceeded during any part of the working exposure.
2.4 Exposure in Anatomy Laboratories

A study done by Akbar-Khanzadeh et al. (1994) conducted air monitoring within the breathing zones of 54 medical students and instructors who were working with cadavers. The cadavers were embalmed with a 36% formaldehyde-containing embalming fluid. Air sampling took place during 9 days of laboratory work. The students worked in the anatomy laboratory from 1.20 – 3.12 hours per day with a mean of 2.3 hours. Results showed that sampled formaldehyde concentration ranged from 0.07 – 2.94 ppm with a mean of 1.24 ppm while 8-hour TWAs ranged from 0.09 – 0.95 ppm with a mean of 0.17 ppm, respectively. Results also indicated that 30 subjects complained of eye irritation, 25 of nose irritation, and 10 of throat irritation after acute exposures to formaldehyde. While only 3 percent of subjects were subjected to 8-hour TWAs over the recommended exposure limit for formaldehyde by OSHA, adverse health effects were still present.

2.5 Exposure during Embalming

Formaldehyde exposure to embalmers within the funeral industry in the province of Manitoba, Canada was studied by Korczynski (1994). The study monitored formaldehyde exposure during 36 embalming sessions in 18 different chapels. The National Institute for Occupational Safety and Health (NIOSH) method 3500 was used with personal and area midget impingers monitoring formaldehyde concentrations. Results from the study showed that a majority of the embalmers working in these chapels were exposed to levels higher than the ACGIH threshold limit value-ceiling of 0.3 ppm. Fifteen of the 18 chapels monitored had levels greater than 0.3 ppm. These levels were
not in compliance for both the ACGIH recommendation and the Canadian Workplace Hazardous Materials Information System Legislation standard. Embalmers indicated they experienced symptoms such as irritation to mucous membranes and chest tightness. Improvement of engineering controls, work practices, and personal protective equipment were recommended in the chapels that exceeded 0.3 ppm. Also the addition of downdraft ventilation was added to existing embalming tables.

2.6 Formaldehyde and Embalming Fluid

Formaldehyde was introduced as a fixative for preserving cadavers in 1893 (Fox et al., 1985). Medical schools and funeral homes all over the world continue to use embalming fluids containing formaldehyde as a main fixative. However, the potential health hazards associated with formaldehyde exposure necessitate the need to find ways to lower formaldehyde exposures to individuals working with cadavers (Coleman and Kogan, 1998). A number of studies have been conducted in order to determine formaldehyde exposure to different types of embalming fluids and the concentration of formaldehyde they contain.

A study done by Whitehead and Savoia (2007) researched a number of embalming fluid and solutions in order to reduce formaldehyde levels in embalmed cadavers. In this study, four cadavers were embalmed with four different embalming fluids. Air sampling studies were conducted for each embalming session. Both area and breathing zone samples were taken during air sampling using NIOSH method 2541. This method used XAD-2 chemical sorbent tubes to collect formaldehyde vapors drawn in from personal air sampling pumps. The tubes were then analyzed by a private accredited laboratory to determine formaldehyde concentrations absorbed by the sampling tubes.
Embalming fluid that had leaked out from the cadaver was also sampled for chemical analysis. The results showed that formaldehyde levels can be decreased up to 50 percent if a 2 percent formaldehyde embalming solution is used followed by re-embalming the cadaver with InfuTrace solution. This embalming technique provides the same results as a traditional embalming fluid but requires much more time to preserve the cadaver.

Using a low-formaldehyde, high-salt level embalming fluid was shown in a study that it could reduce formaldehyde exposures compared to that of other embalming fluids (Coleman and Kogan, 1998). This study showed that this type of embalming fluid could produce excellent embalming properties while producing virtually no odor within the anatomy laboratory where the embalming took place. Air sampling results showed that both area and personal levels on the medical students were less than 10 percent of the permitted value of 0.37 ppm in the laboratory.

2.7 Ventilation and Formaldehyde Exposure

Ventilation systems are important in indoor environments because of their ability to produce a fresh air supply and exhaust out potentially contaminated air. These ventilation systems can lower hazardous airborne exposures, such as formaldehyde vapors, by removing the contaminated air out of the area. A number of studies have been conducted that show the effect that ventilation systems have on exposure levels in an indoor environment.

A study done by Gilbert et al. (2008) focused on the relationship between air change rates and indoor concentrations of formaldehyde. A total of 96 homes in Quebec City, Canada were examined for one week in order to calculate the air change rates.
Formaldehyde was sampled in the homes for 24 hours using passive monitors with dinitrophenylhydrazine as an absorbent. Results showed a direct relationship between air changes per hour and formaldehyde concentrations in the homes. This relationship showed that the more air changes per hour the ventilation system produced; the less formaldehyde concentrations were found in the homes. Results from this study also showed that houses that had at least 0.35 air changes per hour were adequate in order to keep household formaldehyde levels less than 50 micrograms per cubic meter. This level is the proposed residential indoor air quality guideline set by Health Canada.

An embalming study using room formaldehyde concentrations and room ventilation in order to calculate formaldehyde emission rates was conducted (Keil et al., 2001). The study took place in a gross anatomy laboratory at a medical school. Air sampling was evaluated on 15 days during a 16 week period. NIOSH method 3500 was used to collect area samples during dissection sessions performed by medical students. The dissection sessions lasted three to four hours per day with air sampling being conducted during the entire time of the sessions. The ventilation system of the laboratory was assessed on three separate days during the 16 week period. A balometer was used to calculate the volumetric flow rate supplied to the laboratory exhausted. A balometer is an instrument with a capture hood that measures airflow from a diffuser (ACGIH, 1995). Each supply diffuser was measured three times with the balometer and the measurements were then averaged. The exhaust air flow speed was determined using a thermoanemometer. A thermoanemometer is an instrument used to measure air flow speed (ACGIH, 1995). The area of the exhaust grill was divided into eight equal areas, with an air flow measurement taken from each area. The average of the eight readings
was calculated to be the exhaust flow rate. Results from the study showed that the average daily area concentrations of formaldehyde in the laboratory ranged from 0.52 – 1.48 ppm with an average of ventilation rate of 9.8 air changes per hour. The average formaldehyde emission rate from all sources in the laboratory was 148 milligrams per minute. These results showed that formaldehyde levels were above the OSHA action level of 0.5 ppm and also had readings that were above the permissible exposure limit. It was recommended that a local exhaust ventilation system be installed in the laboratory along with modifications to the laboratory’s exhaust and supply air-intake locations be completed.

2.8 Monitoring Formaldehyde in Anatomy Laboratories

Numerous studies have been conducted that air monitored for formaldehyde vapors in anatomy laboratories during dissections or embalming processes. During these processes, formaldehyde vapors can be emitted from the embalming fluid in cadavers (Ohmichi et al., 2006). The emission of these vapors can therefore expose individuals who are working with the cadavers, potentially causing adverse health effects to occur. A study done by Ohmichi et al. (2006) focused on determining the personal exposure levels to formaldehyde that medical students and instructors were being exposed to as well as the indoor air concentration of formaldehyde in the laboratory during dissections. The study took place in a dissection laboratory in a medical school. Air samples were collected from the students’ breathing zones during three separate dissection courses by using a diffusive sampling device. The results showed that the average 8-hour TWA for the students ranged from 0.81 – 0.92 ppm, all of which are above the OHSA PEL of 0.75 ppm. Control methods, such as personal protective equipment, administrative controls,
or engineering controls were recommended to be put into place in order to prevent future overexposures from occurring.

A study that focused on determining formaldehyde concentrations and adverse health effects on medical students was completed in a gross anatomy laboratory (Chia et al, 1992). The students were in the laboratory for an average of 2.5 hours, twice a week. The results were under the permissible exposure limit set by OSHA, with a mean concentration of 0.50 ppm for area samples and 0.74 for personal samples. Even though the exposure to formaldehyde was under the permissible exposure limit, 150 students complained of adverse health effects including throat irritation, eye irritation, and dry mouth. The results from this study indicate adverse health effects can become prominent in exposures less than 1.0 ppm. It is recommended that OSHA should reassess its current 8-hour TWA PEL of 0.75 ppm in order to prevent adverse health effects from taking place.

A group of 86 medical (50 exposed group, 36 control group) students were studied in an anatomy laboratory in order to determine the changes in respiratory function within one to three hours of exposure to formaldehyde (Akbar-Khanzadeh and Mlynek, 1997). Forced vital capacity, forced expiratory volume in one second, forced expiratory volume in three seconds, and forced expiratory flow were respiratory changes that were measured. Personal breathing zone and area samples were collected according to the NIOSH method 3500. Results showed that breathing zone formaldehyde concentrations ranged from 0.30 – 4.45 ppm with a mean of 1.88 ppm while area samples ranged from 0.59 – 1.72 ppm with a mean of 0.97 ppm, respectively. Out of the exposed group of students, 82 percent reported nose irritation and 76 percent reported eye irritation. Skin
irritation was found to be low in the exposed group (12 percent). This is most likely because of the availability of protective gloves and the students commonly practicing double gloving techniques when handling cadavers. There were no meaningful relationships between formaldehyde exposure and acute respiratory changes.

Students enrolled into an associate’s or bachelor’s degree program at a college of mortuary science were studied for formaldehyde exposures and cytogenetic effects during embalmment of cadavers (Suruda et al., 1993). The study monitored the group of students once a day for 85 days. Exposures to formaldehyde were collected by passive monitoring devices (PF-20 short-term exposure limit monitor, Air Quality Research, Berkeley, CA). A NIOSH staff member was present for the first two weeks of the study in order to show the students how to properly use the monitoring devices. The 29 subjects monitored for the study completed 144 embalmings, with the average time period to complete an embalmment being 125 minutes. The 8-hour TWA for a student on a day when embalmings were performed ranged from 0.10 – 0.96 ppm, with a mean of 0.33 ppm. Even though 8-hour TWAs were within the recommendations of OSHA, peak levels of short-term (15 minute periods) formaldehyde exposures were seen to reach concentrations of 6.6 ppm. This is over three times the STEL of 0.2 ppm recommended by OSHA. These peaks were believed to be caused by embalming fluid leaking when injected into vessels and body cavities or faulty tubing.

A study completed by Kim et al. (1999) sampled a group of Korean medical students to determine formaldehyde exposure levels during cadaver dissections in an anatomy laboratory as well as the prevalence rates of formaldehyde-specific Immunoglobulin (Ig) E or IgG antibodies and comparing them to symptoms associated
with formaldehyde exposure. The group of 167 medical students who had previous exposures to formaldehyde were studied along with 67 medical students who had no previous exposure. NIOSH method 3500 was used to collect area samples at 48 locations within the laboratory. Air sampling pumps were calibrated to a rate of 1.1 – 1.2 liters per minute for sample times of either 60 or 120 minutes. The students were also given a questionnaire with listed responses about any symptoms that they experienced during the dissection as well as a health questionnaire about their medical histories. Results showed that formaldehyde concentrations within the laboratory ranged from 0.16 – 9.16 ppm. The questionnaire revealed that 92.8 percent of the students complained of eye soreness, 51.5 percent headaches, 26.3 percent sore throat, and 25.1 percent shortness of breath. These results showed that the students sampled were being exposed to formaldehyde concentrations higher than the university’s recommended limits during dissection practices. Most of the medical students studied complained of irritative symptoms when performing dissections in the laboratory.
Chapter 3

Materials and Methods

3.1 Overview

Industrial hygiene air sampling procedures for formaldehyde exposures were conducted at a university anatomical laboratory in Ohio during the process of embalming a cadaver. The laboratory’s ventilation system and dimensions were calculated prior to air sampling. The Occupational Safety and Health Administration (OSHA) Sampling and Analytical Methods: Acrolein and/or Formaldehyde, 52 was selected as a standard for the sampling method for determining airborne formaldehyde concentrations. This method directs known volumes of air to be drawn through sorbent tubes that contain XAD-2 adsorbent that has been coated with 2-(hydroxymethyl)piperidine. The sorbent tubes are then desorbed with toluene and are then analyzed by the use of gas chromatography using a nitrogen selective detector. Air sampling pumps were calibrated and chemical sorbent tubes were used based on the recommendations made by the sampling method. Air sampling began by setting up the pumps and placing the personal aldehyde monitor on the employee who was conducting the embalmment. The two air sampling pumps used for breathing zone samples were placed on the employee with the tygon tubes that direct the air from the environment through the chemical sorbent tubes were placed within the
employee’s breathing zone and remained there until the embalmment was completed. The pump sampling for the short term exposure limit (STEL) concentration was run for 15 minutes while the pumps sampling for the time-weighted average (TWA) concentrations were run throughout the embalmment, which lasted 211 minutes on average for the three embalming procedures that were studied.

3.2 Location

Formaldehyde sampling took place within a university anatomical laboratory in Ohio. The floor plan and layout of the anatomical laboratory area can be seen in Appendix A. The anatomical laboratory has a designated room where embalmment of cadavers takes place. This room is where air sampling for formaldehyde exposures was conducted. The dimensions of the embalming room are 12.5 feet x 21 feet x 9 feet giving the anatomical laboratory a volume of 2,362.5 cubic feet. Three doors in this area lead to other areas of the laboratory. The embalmment room contained an embalming table (Mopec Model Number CE100, Oak Park, Michigan), cabinets for storage, a sink, and a ventilation system. The dimensions of the embalming table are 100 inches long, 30 inches wide and 37 inches high. The embalming table was located on the south side of the embalming room. Cabinetry lined the north side of the room from the door leading to a satellite office down to where the north and east walls connected. The sink was located on the east wall next to the exhaust duct. The supply duct was located on the west side of the room on the ceiling with the exhaust duct connecting directly into the autopsy table on the east side and running up into the ceiling. Figure 3-1 depicts where the embalming table is in the anatomical laboratory.
3.3 Laboratory Ventilation System

The ventilation system of the embalmment room was assessed before air sampling procedures began. Using an electronic micromanometer (Shortridge Instruments, Scottsdale, AZ) with attached flow hood, three supply air flow rates (cubic feet per minute) were recorded. Measurements were taken by holding the flow hood tightly up against the supply duct. The air velocity was then determined by the micromanometer located at the bottom of the flow hood and was displayed on the instruments screen panel. Figure 3-2 shows the micromanometer and flow hood used in this study. The mean velocity of the three readings was referred to as the laboratory’s supply air velocity. To
calculate the air changes per hour, the following equation was used:

\[ N = \frac{(60 \times Q)}{V} \]

where \( N \) is the number of air changes per hour, \( Q \) is the volumetric flow rate of air in cubic feet per minute, and \( V \) is the volume of the room.

A duct traverse for the rectangular exhaust duct was used to calculate exhaust air velocity. A log-Tchebycheff method was used for determining where the measuring points along the duct would be taken. The duct traverse created for this study can be seen in Appendix F. Taking the size and location of the exhaust duct into consideration, thirty air velocity measurements were taken using the electronic micromanometer. Averaging the thirty velocities produced the exhaust air velocity of the laboratory. Using the air flow velocities in the embalming room and the volume of the room, the air changes per hour of the laboratory were calculated.
3.4 Sampling Equipment

Airchek 52 Air Sampler Pumps (SKC, Eighty Four, PA) were used as Low-Flow pumps to draw any formaldehyde vapors through the chemical sorbent tubes. Figure 3-3 shows an example of the air sampler pump used in this study. The sorbent tubes (SKC, Eighty Four, PA) used in this study contained XAD-2 adsorbent which had been coated with 2-(hydroxymethyl) piperidine. A Gillian (Sensidyne, Clearwater, FL) Gilibrator 2 Primary Flow Calibrator was used to calibrate the air sampler pumps to ± 5% of the sampling rate recommended by the OSHA analytical method, which was 0.2 liters per minute for STEL was sampling and 0.1 liters per minute for TWA sampling. Figure 3-4 depicts the Gilibrator 2 Primary Flow Calibrator. Two air sampling pumps used for breathing zone sampling were placed on the employee with the tygon tubes that direct the
air from the environment through the chemical sorbent tubes within the employee’s breathing zone. Tygon tubing was used to connect sorbent tubes to the air sampler pumps as well as to the primary flow calibrator. The sampling train for the pre-calibration consisted of the air sampling pump, chemical sorbent tube, and primary flow calibrator, respectively, with tygon tubing connecting the pump to the chemical sorbent tube and the chemical sorbent tube to the primary flow calibrator. Along with the use of air sampler pumps, personal aldehyde monitors (Assay Technology, Livermore, CA) were utilized as a passive monitor during the studies. The personal aldehyde monitors are devices that can monitor chemical exposures to personnel or areas. The badges contain a media that uses the principle of diffusion to capture chemical vapors.

Figure 3-3: SKC Airchek 52 Air Sampler Pump
3.5 Sampling Areas and Times

Air sampling was conducted at the university anatomical laboratory for three embalming procedures. Three air sampling pumps with chemical sorbent tubes and a personal aldehyde monitor were used for all air sampling studies. Two of the air sampling pumps and the personal aldehyde monitor were used to sample breathing zone formaldehyde concentrations of the employee performing the embalmment, while the remaining air sampling pump was used to collect area samples around the embalming table.

The first air sampling pump was used to sample the short-term exposure limit formaldehyde concentrations was run for one period of fifteen minutes for all air sampling studies. The STEL sampling period was conducted at the time when exposure to formaldehyde vapors was thought to be greatest. This period was at the beginning of
the embalming process when the embalming fluid was being prepared and poured into a storage container.

The second air sampling pump used to sample breathing zone TWA formaldehyde concentrations. This pump was run throughout the duration of the embalming process. The embalming processes lasted 250 minutes for the first study, 102 minutes for the second study and 280 minutes for the third study.

The air sampling pump used to sample area TWA formaldehyde concentrations was run throughout the entirety of all three air sampling studies. The embalming processes lasted 250 minutes for the first study, 102 minutes for the second study and 280 minutes for the third study. This pump was placed on a table allowing the chemical sorbent tubes to be four feet off the ground at the head of the embalming table.

The personal aldehyde monitor was placed on the shirt collar of the employee within the employee’s breathing zone and remained there throughout the embalming procedure for all air sampling studies. The embalming processes lasted 250 minutes for the first study, 102 minutes for the second study and 280 minutes for the third study.

3.6 Sampling Procedures and Data Collection

3.6.1 Pre-Calibration of Sampling Pumps

Air sampling pumps were pre-calibrated with XAD-2 adsorbent tubes in the train. The air sampling pump sampling the STEL concentrations was pre-calibrated to 0.2 liters per minute, as stated in the OSHA analytical method. The air sampling pumps sampling the breathing zone TWA concentrations were pre-calibrated to 0.1 liters per minute using a Gilibrator 2 Primary Flow Calibrator. Measurements needed to be within ±5% of the
calibration rate. Three trial runs were conducted with each measurement being recorded. The mean of the three measurements was used to determine the pre-calibration flow rate.

3.6.2 Sample Collection

Sample collection began by setting up all air sampling pumps and personal aldehyde monitors. The personal aldehyde monitor was pinned to the employee’s shirt collar. The two air sampling pumps sampling STEL and TWA formaldehyde concentrations were placed in the employee’s pockets with the chemical absorbent tubes attached to the employee’s collar. The third air sampling pump was placed four feet off the ground one foot away from the head of the embalming table where the cadaver was placed. All three air sampling pumps were then turned on, by pressing down the power button on each pump, when the employee began embalming the cadaver.

When the embalming was completed, all of the sampling pumps were turned off by pressing the power button on each pump. The pumps were then post-calibrated using the same procedure as the pre-calibration. The sorbent tubes were collected from each air sampling pump after the embalmentation was completed by removing them from the tygon tubing and placing caps on both open ends of the sorbent tube to prevent contamination. The tubes were then stored in a refrigerator at 34°F Fahrenheit until they were shipped to an accredited private laboratory for analysis. The chemical sorbent tubes were shipped in an insulated container filled with ice packs in order to keep the tubes at a constant cold temperature. The personal aldehyde monitor was also collected at the end of the embalmentation and was directly shipped to a private laboratory for analysis. The following procedure was conducted to retrieve samples during the air sampling studies:
1. Air sampling pumps were pre-calibrated to OSHA Analytical Method 52 recommendations using a Gilian Gilibrator 2 Primary Flow Calibrator.

2. The chemical sorbent tubes were placed in tygon tubing that connected to the air sampling pumps in a direction that allowed contaminated air to move through the absorbent material within the tube.

3. Two air sampling pumps were placed within the employee’s breathing zone and one air sampling pump placed at head of embalming table before the embalmment process began.

4. The personal aldehyde monitor was placed within the employee’s breathing zone before the embalmment process began.

5. Air sampling pumps were turned on and personal aldehyde monitor was uncapped once the embalmment began.

6. After the embalming was completed, the air sampling pumps were turned off and removed.

7. The personal aldehyde monitor was removed and recapped.

8. Air sampling pumps were post-calibrated to OSHA Analytical Method 52 recommendations using a Gilian Gilibrator 2 Primary Flow Calibrator.

9. The chemical sorbent tubes were capped to prevent contamination and were placed into a refrigerator at 34⁰ Fahrenheit until the samples were ready to be shipped to an accredited private laboratory for analysis along with the personal aldehyde monitor.
3.6.3 Post-Calibration of Sampling Pumps

Air sampling pumps were post-calibrated after each embalming process was completed. The exact sampling train and procedure used to pre-calibrate the air sampling pumps was also used for post-calibration. Three trial runs were collected and averaged to determine the post-calibration flow rate. The pre- and post-calibrations were then averaged together to calculate the mean flow rate of the air sampling pump. This mean flow rate was then multiplied by the number of minutes that the air sampling pump ran in order to determine the total air volume drawn through by the pump during the air sampling study. A ± 5% limit from the pre-calibration value compared to the post-calibration value was used in order to assure the air flow did not change too much during the sampling period.

3.6.4 Blanks

Field blanks were used for each air sampling study to act as controls. The blanks were collected just as the actual samples were; however, the pumps that contained the blank tubes were not turned on during the study thus drawing no air through the blank tube.

3.7 Converting Results

After the results were retrieved from the accredited laboratory, the concentrations had to be converted from mg/m$^3$ to ppm, as seen in the formula below. This was done by multiplying 24.45 and the formaldehyde concentration given in mg/m$^3$ and then dividing this number by the gram molecular weight of formaldehyde (30.03 grams/mole).

\[
\frac{24.45 \times (TLV \text{ in mg/m}^3)}{(\text{gram molecular weight of substance})}
\]

(ACGIH, 2007)
Chapter 4

Results

4.1 Overview

Air sampling studies took place at a university anatomical laboratory on three separate days on June 15, June 24, and June 30 in 2010 after a new embalming table was installed on June 11, 2010 in the anatomical laboratory. Laboratory dimensions, ventilation rates, personal and area formaldehyde vapor concentrations were collected in the study. The short-term exposure limits (STEL) and time-weighted means (TWA) of formaldehyde vapor concentrations were calculated as well. The highest sample concentration of formaldehyde vapors was 0.62 parts per million which was the STEL, personal sample taken during the June 30 study. The lowest sample concentration of formaldehyde vapors was 0.019 parts per million which was the STEL personal sample taken during the June 15 study.

4.2 Ventilation and Dimensions of Laboratory

Measurement of the laboratory’s dimensions and ventilation took place on June 11, 2010; four days prior to the air sampling study done on June 15. The laboratory had a width of 21 feet, a length of 12.5 feet, a height of 8 feet, and a volume of 2,100 ft³. The exhaust duct depth, width, length to first duct bend, and diameter, supply air flow, and air
changers per hour were all measured in the anatomical laboratory. Table 4-1 summarizes all ventilation measurements calculated during this study. This table shows all the measurements of the duct work in the laboratory as well as all of the air velocity readings taken by the micromanometer. When the data is put into the equation,

\[ N = \frac{60 \times 450 \text{ fpm}}{2,100 \text{ ft}^3} \]

the air change per hour was calculated as 12.9.

Table 4-1: Ventilation measurements in anatomical laboratory.

<table>
<thead>
<tr>
<th>Description</th>
<th>Measurement/Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Duct Length</td>
<td>12.75”</td>
</tr>
<tr>
<td>Exhaust Duct Width</td>
<td>23”</td>
</tr>
<tr>
<td>Exhaust Duct Diameter</td>
<td>26.298”</td>
</tr>
<tr>
<td>Supply Air Flow Readings</td>
<td>285 cubic feet per minute</td>
</tr>
<tr>
<td></td>
<td>284 cubic feet per minute</td>
</tr>
<tr>
<td></td>
<td>287 cubic feet per minute</td>
</tr>
<tr>
<td>Supply Air Flow Mean</td>
<td>285.33 cubic feet per minute</td>
</tr>
<tr>
<td>Exhaust Air Flow</td>
<td>450 cubic feet per minute</td>
</tr>
<tr>
<td>Air Changes Per Hour</td>
<td>12.9</td>
</tr>
</tbody>
</table>

### 4.3 Formaldehyde Concentrations

The mean 8-hour TWA of formaldehyde exposure for all three studies was 0.19 ppm. The mean area TWA formaldehyde concentration was 0.25 ppm and ranged from 0.15 – 0.34 ppm. The mean breathing zone TWA samples formaldehyde concentration was 0.59 ppm, ranging from 0.29 – 1.3 ppm and the mean STEL breathing zone samples was 0.37 ppm ranging from 0.019 – 0.64 ppm. All results are shown in table 4-2.
Table 4-2: Formaldehyde concentrations from all air sampling studies.

<table>
<thead>
<tr>
<th>Sampling Type</th>
<th>Formaldehyde Concentrations June 15, 2010</th>
<th>Formaldehyde Concentrations June 24, 2010</th>
<th>Formaldehyde Concentrations June 30, 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/m³</td>
<td>ppm</td>
<td>mg/m³</td>
</tr>
<tr>
<td>STEL – Breathing Zone</td>
<td>0.024</td>
<td>0.019</td>
<td>0.57</td>
</tr>
<tr>
<td>TWA – Breathing Zone</td>
<td>0.31</td>
<td>0.25</td>
<td>0.59</td>
</tr>
<tr>
<td>TWA – Area</td>
<td>0.19</td>
<td>0.15</td>
<td>0.42</td>
</tr>
<tr>
<td>Personal Aldehyde Monitor</td>
<td>1.6</td>
<td>1.3</td>
<td>0.74</td>
</tr>
</tbody>
</table>

In order to make the formaldehyde concentrations sampled from all air sampling studies comparable to the OSHA exposure criteria (Title 29 Code of Federal Regulation subpart 1910.1048), all concentrations were converted to 8-hour TWAs. Table 4-3 displays all formaldehyde concentrations sampled from all three air sampling studies in the anatomical laboratory as 8-hour time-weighted means versus the measured TWAs.
Table 4-3: Eight-hour TWA formaldehyde concentrations from all air sampling studies.

<table>
<thead>
<tr>
<th>Sampling Type</th>
<th>Total Run Time (min.)</th>
<th>Measured TWA Concentration (ppm)</th>
<th>8-Hour TWA Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>June 15, 2010</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWA-Breathing Zone</td>
<td>102</td>
<td>0.25</td>
<td>0.05</td>
</tr>
<tr>
<td>TWA – Area</td>
<td>102</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>Personal Aldehyde Monitor</td>
<td>102</td>
<td>1.3</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>June 24, 2010</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWA-Breathing Zone</td>
<td>250</td>
<td>0.48</td>
<td>0.25</td>
</tr>
<tr>
<td>TWA – Area</td>
<td>250</td>
<td>0.34</td>
<td>0.18</td>
</tr>
<tr>
<td>Personal Aldehyde Monitor</td>
<td>250</td>
<td>0.6</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>June 30, 2010</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWA-Breathing Zone</td>
<td>280</td>
<td>0.62</td>
<td>0.36</td>
</tr>
<tr>
<td>TWA – Area</td>
<td>280</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>Personal Aldehyde Monitor</td>
<td>280</td>
<td>0.29</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Chapter 5

Discussion

Determining the formaldehyde concentrations in the university anatomical laboratory is important in order to know if members of the university who work in the laboratory are being placed into a safe working environment, as stated by OSHA’s General Duty Clause. Certain staff members of the university are required to work in the anatomical laboratory year-round. OSHA regulates occupational exposures to formaldehyde by setting a permissible exposure limit, a short term exposure limit, and an action level at which concentrations of airborne formaldehyde may not exceed. By following OSHA Analytical Method 52 guidelines, concentrations of airborne formaldehyde can be determined.

The anatomy laboratory’s ventilation system was adequate according to the guidelines in the OSHA Laboratory Standard 1910. The laboratory’s ventilation system produced 12.9 air changes per hour on the day of the ventilation study. The OSHA Laboratory Standard 1910 recommends that a laboratory should produce 4-12 air changes per hour.
5.1 Formaldehyde Exposure

This study showed that all 8-hour TWA breathing zone formaldehyde concentrations sampled within the anatomical laboratory during the embalming of a cadaver were under the current OSHA PEL of 0.75 ppm [OSHA, 1992]. The results in this study also demonstrated that all STEL concentrations were under the 2.0 ppm OSHA STEL regulation for formaldehyde.

The mean 8-hour TWA of formaldehyde concentration in this study conducted was 0.19 ppm. The mean TWA formaldehyde concentration was 0.25 ppm for area samples and ranged from 0.15 – 0.34 ppm. The mean formaldehyde concentration was 0.59 ppm for breathing zone TWA samples and ranged from 0.29 – 1.3 ppm. The mean formaldehyde concentration for STEL breathing zone samples in this study was 0.37 ppm and ranged from 0.019 – 0.64 ppm.

After reviewing all data from all of the air sampling studies, the results indicated that university staff and students who occupied the anatomical laboratory during the embalming of a cadaver were not exposed to formaldehyde levels greater than the OSHA PEL of 0.75 ppm, the OSHA STEL ceiling of 2 ppm, nor the OSHA “action level” of 0.5 ppm for an 8-hour time-weighted shift. Therefore the engineering controls, administrative controls, and personal protective equipment utilized for this university anatomical laboratory are preventing formaldehyde overexposures from occurring to individuals in the laboratory.

A number of research studies have shown that the mean formaldehyde concentrations for both breathing zone and area samples in university anatomical
laboratories were below the current OSHA PEL of 0.75 ppm. One study that has shown that formaldehyde concentrations in a university anatomical laboratory were under the OSHA PEL of 0.75 ppm was conducted by Suruda et al. (1993). The mean 8-hour TWA formaldehyde concentration for breathing zone samples was 0.33 ppm. The 8-hour TWA mean concentration for the Suruda et al. study was higher than the results shown for the 8-hour TWA mean in this study.

A research study completed by Chia et al. (1992) focused on formaldehyde exposures to medical students in a university anatomical laboratory. The mean formaldehyde concentration for breathing zone samples was 0.74 ppm and the mean concentration for area samples was 0.50 ppm. The concentrations from Chia et al. were higher than the concentrations from this study.

The 8-hour TWA formaldehyde concentration in this study were lower than the 8-hour TWA concentrations demonstrated in the Suruda et al. (1993), Chia et al. (1992), and Akbar-Khandzadh et. al (1994) studies. Some reasons that may account for the differences of formaldehyde concentrations could include work practices, different embalming tables, different ventilations rates, number of embalming tables, or different embalming fluids used.
Chapter 6

Conclusions

It is concluded that:

1. The 8-hour time-weighted averages collected from this study ranged from 0.03 – 0.36 ppm and was less than 0.75 ppm PEL recommended by OSHA. The STEL samples collected ranged from 0.019 – 0.64 ppm and was less than the 2 ppm STEL recommended by OSHA. Therefore, the hypothesis “The 8-hour time-weighted average formaldehyde concentrations will not exceed the current permissible exposure limit or short term exposure limit recommendations put in place by the Occupational Safety and Health Administration” is not rejected.

2. The highest mean of formaldehyde concentrations was 0.73 ppm, which was derived from the personal aldehyde monitor samples. Therefore the hypothesis “The highest mean of formaldehyde concentrations will come from the personal aldehyde monitors” is not rejected.

3. The lowest mean of formaldehyde concentrations was 0.25 ppm, which was derived from the area time-weighted average samples. Therefore the hypothesis “The lowest mean of formaldehyde concentrations will come from the area time-weighted samples” is not rejected.
References


Appendix A

Basement Floor Plan Depicting Anatomical Laboratory
Appendix B

Formaldehyde Material Safety Data Sheet

FORMALDEHYDE

1. Product Identification

Synonyms: Formaldehyde 37%; Formalin; Morbicid Acid; Methylene Oxide; Methyl aldehyde

CAS No.: 50-00-0
Molecular Weight: 30.03
Chemical Formula: HCHO and CH3OH in water

Product Codes:
J.T. Baker: 2105, 2106, 2108, 2109
Mallinckrodt: 5014, 5016

2. Composition/Information on Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>50-00-0</td>
<td>37%</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methyl Alcohol</td>
<td>67-56-1</td>
<td>10 - 15%</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>7732-18-5</td>
<td>48 - 53%</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Hazards Identification

Emergency Overview

POISON! DANGER! SUSPECT CANCER HAZARD. MAY CAUSE CANCER.
Risk of cancer depends on level and duration of exposure. VAPOR HARMFUL. HARMFUL IF INHALED OR ABSORBED THROUGH SKIN. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. STRONG SENSITIZER. MAY BE FATAL OR CAUSE BLINDNESS IF SWALLOWED. CANNOT BE MADE NONPOISONOUS. FLAMMABLE LIQUID AND VAPOR.

SAF-T-DATA\textsuperscript{(tm)} Ratings (Provided here for your convenience)

<table>
<thead>
<tr>
<th>Health Rating</th>
<th>Severe (Poison)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flammability Rating</td>
<td>Moderate</td>
</tr>
<tr>
<td>Reactivity Rating</td>
<td>Moderate</td>
</tr>
<tr>
<td>Contact Rating</td>
<td>Severe (Corrosive)</td>
</tr>
</tbody>
</table>

Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER

Storage Color Code: Red (Flammable)

Potential Health Effects

The perception of formaldehyde by odor and eye irritation becomes less sensitive with time as one adapts to formaldehyde. This can lead to overexposure if a worker is relying on formaldehyde's warning properties to alert him or her to the potential for exposure.

**Inhalation:**
May cause sore throat, coughing, and shortness of breath. Causes irritation and sensitization of the respiratory tract. Concentrations of 25 to 30 ppm cause severe respiratory tract injury leading to pulmonary edema and pneumonitis. May be fatal in high concentrations.

**Ingestion:**
Can cause severe abdominal pain, violent vomiting, headache, and diarrhea. Larger doses may produce decreased body temperature, pain in the digestive tract, shallow respiration, weak irregular pulse, unconsciousness and death. Methanol component affects the optic nerve and may cause blindness.

**Skin Contact:**
Toxic. May cause irritation to skin with redness, pain, and possibly burns. Skin absorption may occur with symptoms paralleling those from ingestion. Formaldehyde is a severe skin irritant and sensitizer. Contact causes white discoloration, smarting, cracking and scaling.

**Eye Contact:**
Vapors cause irritation to the eyes with redness, pain, and blurred vision. Higher concentrations or splashes may cause irreversible eye damage.

**Chronic Exposure:**
Frequent or prolonged exposure to formaldehyde may cause hypersensitivity leading to contact dermatitis. Repeated or prolonged skin contact with formaldehyde may cause an allergic reaction in some people. Vision impairment and enlargement of liver may occur.
from methanol component. Formaldehyde is a suspected carcinogen (positive animal inhalation studies).

**Aggravation of Pre-existing Conditions:**
Persons with pre-existing skin disorders or eye problems, or impaired liver, kidney or respiratory function may be more susceptible to the effects of the substance. Previously exposed persons may have an allergic reaction to future exposures.

### 4. First Aid Measures

**Inhalation:**
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

**Ingestion:**
If swallowed and the victim is conscious, dilute, inactivate, or absorb the ingested formaldehyde by giving milk, activated charcoal, or water. Any organic material will inactivate formaldehyde. Keep affected person warm and at rest. Get medical attention immediately. If vomiting occurs, keep head lower than hips.

**Skin Contact:**
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

**Eye Contact:**
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

**Note to Physician:**
Monitor arterial blood gases and methanol levels after significant ingestion. Hemodyalysis may be effective in formaldehyde removal. Use formic acid in urine and formaldehyde in blood or expired air as diagnostic tests.

### 5. Fire Fighting Measures

**Fire:**
Flash point: 60°C (140°F) CC
Autoignition temperature: 300°C (572°F)
Flammable limits in air % by volume:
leL: 7.0; uel: 73
Flammable liquid and vapor! Gas vaporizes readily from solution and is flammable in air.

** Explosion:**
Above flash point, vapor-air mixtures are explosive within flammable limits noted above. Containers may explode when involved in a fire.

**Fire Extinguishing Media:**
Water spray, dry chemical, alcohol foam, or carbon dioxide.

**Special Information:**
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive
pressure mode. Water may be used to flush spills away from exposures and to dilute spills to non-flammable mixtures.

6. Accidental Release Measures
Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e.g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802. If a leak or spill has not ignited, use water spray to disperse the vapors, to protect personnel attempting to stop leak, and to flush spills away from exposures.

7. Handling and Storage
Store in a tightly closed container. Protect against physical damage. Store in a cool, dry well-ventilated location, away from any area where the fire hazard may be acute. Outside or detached storage is preferred. Separate from incompatibles. Containers should be bonded and grounded for transfers to avoid static sparks. Storage and use areas should be No Smoking areas. Use non-sparking type tools and equipment, including explosion proof ventilation. Wear special protective equipment (Sec. 8) for maintenance break-in or where exposures may exceed established exposure levels. Wash hands, face, forearms and neck when exiting restricted areas. Shower, dispose of outer clothing, change to clean garments at the end of the day. Avoid cross-contamination of street clothes. Wash hands before eating and do not eat, drink, or smoke in workplace. Protect from freezing. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection
Airborne Exposure Limits:
- OSHA Permissible Exposure Limit (PEL):
  0.75 ppm (TWA), 2 ppm (STEL), 0.5 ppm (TWA) action level for formaldehyde
  200 ppm (TWA) for methanol
- ACGIH Threshold Limit Value (TLV):
  0.3 ppm Ceiling formaldehyde, Sensitizer, A2 Suspected Human Carcinogen
  200 ppm (TWA) 250 ppm (STEL) skin for methanol

Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred
because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.

**Personal Respirators (NIOSH Approved):**
If the exposure limit is exceeded and engineering controls are not feasible, a full facepiece respirator with a formaldehyde cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. Irritation also provides warning. For Methanol: If the exposure limit is exceeded and engineering controls are not feasible, wear a supplied air, full-facepiece respirator, airlined hood, or full-facepiece self-contained breathing apparatus. Breathing air quality must meet the requirements of the OSHA respiratory protection standard (29CFR1910.134). Where respirators are required, you must have a written program covering the basic requirements in the OSHA respirator standard. These include training, fit testing, medical approval, cleaning, maintenance, cartridge change schedules, etc. See 29CFR1910.134 for details.

**Skin Protection:**
Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.

**Eye Protection:**
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

**Other Control Measures:**
See OSHA Standard for more information on personal protective equipment, engineering and work practice controls, medical surveillance, record keeping, and reporting requirements. (29 CFR 1910.1048)

---

**9. Physical and Chemical Properties**

**Appearance:**
Clear, colorless liquid.

**Odor:**
Pungent odor.

**Solubility:**
Infinitely soluble.

**Specific Gravity:**
1.08

**pH:**
2.8 (31% solution)

**% Volatiles by volume @ 21C (70F):**
100

**Boiling Point:**
96C (205F)
Melting Point: 
-15°C (5°F)

Vapor Density (Air=1): 
1.04

Vapor Pressure (mm Hg): 
1.3 @ 20°C (68°F)

Evaporation Rate (BuAc=1): 
No information found.

10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage.

Hazardous Decomposition Products:
May form carbon dioxide, carbon monoxide, and formaldehyde when heated to decomposition.

Hazardous Polymerization:
Trioxymethylene precipitate can be formed on long standing at very low temperatures. Nonhazardous polymerization may occur at low temperatures, forming paraformaldehyde, a white solid.

Incompatibilities:
Incompatible with oxidizing agents and alkalis. Reacts explosively with nitrogen dioxide at ca. 180°C (356°F). Reacts violently with perchloric acid, perchloric acid-aniline mixtures, and nitromethane. Reaction with hydrochloric acid may form bis-chloromethyl ether, an OSHA regulated carcinogen.

Conditions to Avoid:
Heat, flames, ignition sources and incompatibles.

11. Toxicological Information

Formaldehyde: Oral rat LD50: 100 mg/kg; skin rabbit LD50: 270 uL/kg, Irritation data: eye, rabbit, 750ug Severe; inhalation rat LC50: 203 mg/m3; investigated as a tumorigen, mutagen, reproductive effector; Cancer Status: an OSHA regulated carcinogen.

Methanol: oral rat LD50: 5628 mg/kg; inhalation rat LC50: 64000 ppm/4H; skin rabbit LD50: 15800 mg/kg; investigated as a tumorigen, mutagen, reproductive effector.

---NTP Carcinogen---

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Known</th>
<th>Anticipated</th>
<th>IARC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde (50-00-0)</td>
<td>No</td>
<td>Yes</td>
<td>2A</td>
</tr>
<tr>
<td>Methyl Alcohol (67-56-1)</td>
<td>No</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
12. Ecological Information

Environmental Fate:
The following statements refer to the environmental fate of formaldehyde. When released into the soil, this material is expected to leach into groundwater. When released into water, this material is expected to readily biodegrade. When released into water, this material is not expected to evaporate significantly. This material is not expected to significantly bioaccumulate. When released into the air, this material is expected to be readily degraded by reaction with photochemically produced hydroxyl radicals. When released into the air, this material is expected to be readily degraded by photolysis. When released into the air, this material is expected to be readily removed from the atmosphere by dry and wet deposition. When released into the air, this material is expected to have a half-life of less than 1 day. The following statements refer to the environmental fate of methanol. When released into the soil, this material is expected to readily biodegrade. When released into the soil, this material is expected to quickly evaporate. When released into water, this material is expected to readily biodegrade. When released into the water, this material is expected to have a half-life between 1 and 10 days. When released into the air, this material is expected to be readily degraded by reaction with photochemically produced hydroxyl radicals. When released into the air, this material is expected to be readily removed from the atmosphere by wet deposition. When released into air, this material is expected to have a half-life between 10 and 30 days.

Environmental Toxicity:
The following toxicity information is for the formaldehyde portion.
96 Hr LC50 fathead minnow: 24.1 mg/L (flow-through);
96 Hr LC50 bluegill: 0.10 mg/L (flow-through);
96 Hr EC50 water flea: 20 mg/L.
The methanol portion is expected to be slightly toxic to aquatic life. The LC50/96-hour values for fish are between 10 and 100 mg/l.

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Domestic (Land, D.O.T.)
-----------------------
Proper Shipping Name: RQ, FORMALDEHYDE, SOLUTION, FLAMMABLE
Hazard Class: 3, 8
UN/NA: UN1198
Packing Group: III
Information reported for product/size: 200L

International (Water, I.M.O.)

Proper Shipping Name: FORMALDEHYDE SOLUTIONS
Hazard Class: 3, 8
UN/NA: UN1198
Packing Group: III
Information reported for product/size: 200L

15. Regulatory Information

--------\Chemical Inventory Status - Part 1\-------------------------

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>TSCA</th>
<th>EC</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>----</td>
<td>---</td>
<td>-----</td>
</tr>
</tbody>
</table>

Formaldehyde (50-00-0) Yes Yes Yes

Methyl Alcohol (67-56-1) Yes Yes Yes

Water (7732-18-5) Yes Yes Yes

--------\Chemical Inventory Status - Part 2\-------------------------

--Canada--

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Korea</th>
<th>DSL</th>
<th>NDSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phil.</td>
<td>----</td>
<td>---</td>
<td>----</td>
</tr>
</tbody>
</table>

Formaldehyde (50-00-0) Yes Yes No

Methyl Alcohol (67-56-1) Yes Yes No

Water (7732-18-5) Yes Yes No

--------\Federal, State & International Regulations - Part 1\-------

-SARA 302- ----SARA

313------

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>RQ</th>
<th>TPQ</th>
<th>List</th>
</tr>
</thead>
</table>

--------
<table>
<thead>
<tr>
<th>Chemical</th>
<th>CERCLA</th>
<th>RCRA 261.33</th>
<th>8(d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde (50-00-0)</td>
<td>100</td>
<td>U122</td>
<td>No</td>
</tr>
<tr>
<td>Methyl Alcohol (67-56-1)</td>
<td>5000</td>
<td>U154</td>
<td>No</td>
</tr>
<tr>
<td>Water (7732-18-5)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Chemical Weapons Convention:** No  
**TSCA 12(b):** No  
**CDTA:** No  
**SARA 311/312:** Acute: Yes  Chronic: Yes  
**Fire:** Yes  **Pressure:** No  
**Reactivity:** No  

**WARNING:**  
THIS PRODUCT CONTAINS A CHEMICAL(S) KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER.  

**Australian Hazchem Code:** 2SE  
**Poison Schedule:** S6  
**WHMIS:**  
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.  

---  

**16. Other Information**  
**NFPA Ratings:** Health: 3  Flammability: 2  Reactivity: 0  
**Label Hazard Warning:**  
POISON! DANGER! SUSPECT CANCER HAZARD. MAY CAUSE CANCER. Risk of cancer depends on level and duration of exposure. VAPOR HARMFUL. HARMFUL IF INHALED OR ABSORBED THROUGH SKIN. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. STRONG SENSITIZER. MAY BE FATAL OR CAUSE BLINDNESS IF SWALLOWED. CANNOT BE MADE NONPOISONOUS. FLAMMABLE LIQUID AND VAPOR.  
**Label Precautions:**  
Keep away from heat, sparks and flame.  
Do not get in eyes, on skin, or on clothing.  
Do not breathe vapor.  
Keep container closed.  
Use only with adequate ventilation.  
Wash thoroughly after handling.  
Physical and health hazard information is available from employer and from material
safety data sheets.

**Label First Aid:**
In all cases get medical attention immediately. If swallowed and the victim is conscious, dilute, inactivate, or absorb the ingested formaldehyde by giving milk, activated charcoal, or water. Any organic material will inactivate formaldehyde. Keep affected person warm and at rest. If vomiting occurs, keep head lower than hips. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse.

**Product Use:**
Laboratory Reagent.

**Revision Information:**
No Changes.

**Disclaimer:**
************************************************************************
************************
Mallinckrodt Baker, Inc. provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. MALLINCKRODT BAKER, INC. MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, MALLINCKRODT BAKER, INC. WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.
************************************************************************
************************
Appendix C

Embalming Fluid Material Safety Data Sheet

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS#</th>
<th>Percent</th>
<th>TLV (OSHA)</th>
<th>Nature of Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde</td>
<td>50-00-0</td>
<td>9.25</td>
<td>.75 ppm; 8 hr TWA STEL 2 ppm</td>
<td>Corrosive, (Inhale use respirator)</td>
</tr>
<tr>
<td>Ethanol</td>
<td>64-17-5</td>
<td>53.91</td>
<td>1000 ppm</td>
<td>Flammable, Nerve Depression</td>
</tr>
<tr>
<td>Polyethylene Glycol</td>
<td>107-21-1</td>
<td>12.50</td>
<td>55 ppm</td>
<td>Irritant, Poison</td>
</tr>
<tr>
<td>Methanol</td>
<td>67-56-1</td>
<td>2.75</td>
<td>200 ppm 2 hr TWA STEL 250 ppm</td>
<td>Flammable, Flammable, Poison</td>
</tr>
<tr>
<td>Non-ionized Sodium</td>
<td>9056-15-9</td>
<td>9.50</td>
<td>None Established</td>
<td>Irritant, Poison</td>
</tr>
<tr>
<td>EDTA</td>
<td>466-45-8</td>
<td>1.80</td>
<td>None Established</td>
<td>Irritant, Poison</td>
</tr>
</tbody>
</table>

IV. Physical Data

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point (°F)</td>
<td>200-210</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>Greater</td>
</tr>
<tr>
<td>Percent Volatile by volume</td>
<td>95%</td>
</tr>
<tr>
<td>Appearance</td>
<td>Clear, Liquid</td>
</tr>
</tbody>
</table>

V. Health Hazard Data

Effects of Overexposure: Exposed: Can cause severe irritation of eyes, nose, and throat. If absorbed through skin, may cause allergic skin reaction. Inhalation: Harmful. Vapors may cause irritation to mucous membranes, and may be fatal or cause blindness.

Emergency and First Aid Procedures: Eye: Immediately flush eyes with plenty of water; remove contact lenses and continue flushing for at least 15 minutes; seek medical help. Call physician. Skin: Remove and wash contaminated clothing before; rinse skin with plenty of water. If irritation or rash develops, get medical attention. Inhalation: Move person to fresh air. If breathing is difficult, administer oxygen. If breathing has stopped, give artificial respiration. If swallowed: Drink large quantities of water and induce vomiting by touching fingers to back of throat. Call a physician. NEVER give anything by mouth to an unconscious person.
VI. Reactivity Data

Safety
Hazardous Polymerization
Conditions to Avoid
Incompatibility (materials to avoid)

Wasteful Decomposition Products

VII. Precautions for Safe Handling and Use

Steps to be taken in case material is released or spilled

Equipment: Treat all formaldehyde spills with caution. Wear protective gloves, splash goggles, apron and breathing apparatus.

Spills: Absorb liquid and transfer to container. Neutralize spilled material with dilute solutions (3%) ammonia, sodium sulfite or sodium bisulfite.

Clean up: with Federal, State and Local regulations for disposal of chemical waste – Informational UN 1170, Formaldehyde UN 2360 and Placed UN 2821.

Store: Do not store cubes below 55 degrees F. Do not stack more than four cubes high.

VIII. Control Measures

Must be adequate to keep formaldehyde vapor below indicated exposure limits.

Wear protective gloves, splash goggles, and apron.
Have available breathing apparatus in case of spill.

IX. Special Precautions

Store above 35 degrees F. Low temperatures can cause a non-hazardous polymerization or precipitation.

In a two year study at the Chemical Industry Institute of Toxicology, nasal tumors were detected in rats exposed (via injection) to formaldehyde at 6 ppm and mice exposed at 15 ppm. The information in this MSDS has been compiled from information provided by supplier data sheets, from other technical sources and from our testing and experience. Users are responsible for determining the suitability of the information to their circumstances.

The above information is believed to be correct. But the information does not purport to be all inclusive and shall be used only as a guide. Wesnet & Associates shall not be held liable for any damage resulting from handling or from contact with the above product.

Revised January 2005
Appendix D

OSHA Analytical Method 52

Acrolein and/or Formaldehyde

Redwood/Informal Chemical Sampling: Acrolein, Formaldehyde

Methods: 52

Matrix: Air

Target concentrations:
Acrolein: 0.1 ppm (0.25 mg/m³)
Formaldehyde: 2 ppm (0.068 mg/m³)

Air samples are collected by drawing known volumes of air through sampling tubes containing XAD-2 adsorbent which has been coated with 2-Ethylhexyl L-α-phosphatidylethanolamine. The samples are desorbed with toluene and then analyzed by gas chromatography using an nitrogen-selective detector.

Recommended air volumes and sampling rates:

Acrolein (TWA): 48 L at 0.1 L/min
Formaldehyde (TWA): 24 L at 0.1 L/min
Formaldehyde (STEL): 3 L at 0.2 L/min

Reliable quantitation limit (for TWA samples):

Acrolein: 2.7 ppb (0.4 µg/m³)
Formaldehyde: 15 ppb (0.4 µg/m³)

Standard error of estimates of the target concentration:

Acrolein: 7.2%
Formaldehyde: 7.2%

Status of Method:
Evaluated method. This method has been subjected to the established evaluation procedures of the Organic Methods Evaluation Branch. Additional evaluation data was collected because of the 1988 reduction in the formaldehyde PEL.

June 1989

Method Development Team
Industrial Hygiene Chemistry Division
OSHA Salt Lake Technical Center
Sandy UT 84070-5446

1. General Discussion
1.1. Background
1.1.1 History

The current OSHA method for collecting acrolein vapor recommends the use of activated 12% molecular sieves. The samples must be stored in an ice bath during and after sampling and they must be analyzed within 48 h of collection. The current OSHA method for collecting formaldehyde vapor recommends the use of bubblers containing 10% methanol in water as the trapping solution (Ref. 5.1).

This work was undertaken to resolve the sample stability problems associated with acrolein and to eliminate the need to use bubblers to sample formaldehyde. A goal of this work was to develop and evaluate a common sampling and analytical procedure for acrolein and formaldehyde. The simultaneous determination of these aldehydes was an appropriate goal because they can be found together in industrial environments. Further, common sampling and analytical procedures can reduce both field and laboratory workloads.

NIOSH has developed independent methodologies for acrolein (Ref. 5.2) and formaldehyde (Ref. 5.3) which recommend the use of reagent-coated adsorbent tubes to collect the aldehydes as stable derivatives. The formaldehyde sampling tubes contain Chromosorb 102 adsorbent coated with N-benzylthiophenolamine (BETPA) which reacts with formaldehyde vapor to form a stable oxazolidine compound. The acrolein sampling tubes contain XAD-2 adsorbent coated with 2-[2-(hydroxymethyl)pyrrolidin-2-yl]methylphenol (2-HMP) which reacts with acrolein vapor to form a different, stable oxazolidine derivative. Acrolein does not appear to react with BETPA to give a suitable reaction product (Ref. 12), therefore, the formaldehyde procedure cannot provide a common method for both aldehydes. However, formaldehyde does react with 2-HMP to form a very suitable reaction product. It is the quantitative reaction of acrolein and formaldehyde with 2-HMP that provides the basis for this evaluation.

This sampling and analytical procedure is very similar to the method recommended by NIOSH for acrolein. Some changes in the NIOSH methodology were necessary to permit the simultaneous determination of both aldehydes and also to accommodate OSHA Laboratory equipment and analytical techniques.

This successfully evaluated method recommends the collection of acrolein and formaldehyde vapors on pretreated XAD-2 adsorbent which has been coated with 2-HMP. The goals of this work were attained in that both aldehydes can be simultaneously determined without the need to use bubblers and there are no sample stability problems.

In June of 1989, this method was updated with additional data which verified it would adequately accommodate the new PELs for formaldehyde which went into effect in 1989. The new PELs for formaldehyde are 1 ppm for the TWA and 2 ppm for the STEL. The acrolein PEL remains a TWA of 0.1 ppm. The report for the update work has been incorporated into the "Backup Data" section of this method as Section 4.1.

1.1.2 Toxic effects (This section is for information only and should not be taken as the basis of OSHA policy.)

Acrolein: Human exposure to acrolein can occur through inhalation of the vapor or percutaneous absorption of the liquid. The results of exposure are intense irritation of the eyes, the respiratory tract, mucous membranes and finally pulmonary edema or bronchitis. Skin and eye burns may result from prolonged and repeated exposure or splashes of acrolein. Sensitization has been reported to occur in some individuals. (Ref. 5.4)

Acrolein has induced mutagenic effects in various test systems. There is no evidence that acrolein has carcinogenic or co-carcinogenic activity. Acrolein has not been shown to have teratogenic or fetotoxic effects. (Refs. 5.4 and 5.5)

The International Agency for Research on Cancer (IARC) did not make an evaluation regarding the mutagenicity of acrolein because of the preliminary and conflicting nature of the available data. Also, the absence of human data precluded an evaluation of the carcinogenicity of acrolein by IARC. (Ref. 5.6)

Formaldehyde: Symptoms of human exposure to formaldehyde include irritation of the eyes, the nose and the throat which lead to lacrimation, sneezing, shortness of breath, sleeplessness, tight chest, nausea and excess phlegm. Formaldehyde has been shown to cause dermatitis. Formaldehyde is an allergen and susceptible persons can become sensitized to the agent. Formaldehyde has been reported to cause menstrual disorders and secondary sterility in women. Formaldehyde is mutagenic in a variety of test systems. IARC reports that there is sufficient evidence that formaldehyde gas is carcinogenic to rats. IARC also reports that epidemiological studies provide inadequate evidence to assess the carcinogenicity of formaldehyde in man. (Ref. 5.7)
NIOSH recommends that formaldehyde be handled in the workplace as a potential occupational carcinogen. The basis of this recommendation are two inhalation studies that resulted in the same rare form of cancer in rats and in mice. Formaldehyde has also demonstrated mutagenic activity in several test systems. (Ref. 5.9)

The Federal Panel on Formaldehyde has concluded that formaldehyde should be presumed to pose a carcinogenic risk to humans. The panel consisted of scientists from within the federal government and was formed under the authority of the National Toxicology Program. (Ref. 5.10)

1.1.3. Potential workplace exposure

Acrolein: Acrolein is produced by the catalytic vapor phase oxidation of propylene with air. Acrolein production in the United States was estimated to be 61 million pounds in 1974. This figure does not include an additional 99 to 156 million pounds used as a captive intermediate in the production of acrylic acid. The main uses for acrolein are fifty percent for the production of glyc erin, 25% for the production of methionine (a poultry feed supplement) and 25% for other applications. Some of these applications are manufacturing of chemicals and chemical products including glutaraldehyde and 1,2-bis-ethanol, modification of food starch and use as an aquatic herbicide, biocide and algaecide. Acrolein has been used as a war gas and as a limicide in the manufacture of paper and paperboard for use to package food products. (Ref. 5.6)

In 1979, acrolein production was estimated to be 85 to 96 million pounds. Approximately 7500 workers are occupationally exposed to acrolein annually. (Ref. 5.4)

Formaldehyde: Formaldehyde is produced by the catalytic vapor phase oxidation of methanol with air. Most formaldehyde is marketed in a aqueous solution, called formalin, which contains 37 to 50% formaldehyde by weight. The United States produced about 6.4 billion pounds of aqueous formaldehyde in 1978 and most of this amount was used domestically. The United States consumption of formaldehyde was estimated to exceed 7.5 billion pounds in 1983. About half of the formaldehyde produced in the U.S. is used to manufacture synthetic resins. These resins are often used to produce particleboard, fiberboard and plywood. Urea-formaldehyde resins are used to coal materials, to produce paper products and to make foams for insulation. Other important uses include textile treating and molding of plastic materials. Formaldehyde is used in some medicines and also in embalming fluids. It is used in fur and leather tanning and also in the photographic industry. (Ref. 5.9)

NIOSH estimated that 1.6 million workers were exposed to formaldehyde in a survey conducted from 1972 to 1974. About one-third of this total was employed in medical and health services occupations. Another one-third of the total was employed in miscellaneous occupations which included chemicals and chemical products, printing and publishing, paper, machinery, retail store, eating and drinking places, automotive dealers and service stations, funeral services and crematories, photographic studios and dry cleaning plants. (Ref. 5.9)

Other jobs and/or occupations in which exposure to formaldehyde may occur include formaldehyde production workers, seamstresses, hairdressers, glue workers, foundry employees, resin manufacturing workers, wood laminating workers and fabric workers. (Ref. 5.2)

1.1.4. Physical properties

**Acrolein** (Ref. 5.6)

- CAS no.: 107-02-0
- molecular weight: 56.1
- appearance: colorless liquid
- boiling point: 52.5 to 53.5°C
- density: 0.641 at 20°C
- vapor pressure: 200 mm Hg at 17.3°C
- flash point: -26.1°C
- molecular formula: CH₂=CHCHO
- synonyms: 2-propanal; acetaldehyde; acrylaldehyde; acrylic aldehyde; allylaldehyde; prop-2-en-1-ol; propen-1-one; Aqualin; NSC 881;
- propanal
Acrolein polymerizes spontaneously, particularly in the presence of light, alkali or strong acid.

**Formaldehyde (Re:5.2)**

- **CAS no:** 50-00-0
- **molecular weight:** 30.0
- **appearance:** colorless gas
- **boiling point:** -19°C
- **density:** 0.8153 at -20°C; 1.067 (air = 1.000)
- **vapor pressure:** 400 mm Hg at 33°C
- **ignition temp:** 430°C
- **molecular formula:** HCHO
- **synonyms:** formaldehyde, formaldehyde gas, formamide (including polymer forms from solution; formalin, 40; formalin 160% formic acid which formaldehyde can be generated)

Formaldehyde polymerizes rapidly, especially under alkaline conditions.

1.2. Limit defining parameters (The analyte air concentrations reported in this method are based on the recommended air volume for each analyte collected separately and a desorption volume of 1 mL. The amounts are presented as acrolein and/or formaldehyde, even though the derivatives are the actual species analyzed.)

1.2.1. Detection limits of the analytical procedure

The detection limit of the analytical procedure was 23 pg per injection for acrolein. This was the amount of acrolein which gave a measurable response relative to the interferences present in a standard. The detection limit of the analytical procedure was 306 pg per injection for formaldehyde. This was the amount of analyte which gave a peak whose height was 5 times the height of the peak given by the residual formaldehyde derivative (Section 4.6) in a typical blank front section of the recommended sampling tube (Section 4.1).

1.2.2. Detection limits of the overall procedure

The detection limits of the overall procedure were 291 ng per sample (2.7 ppb or 6.1 μg/m³) for acrolein and 482 ng per sample (16 ppb or 20 μg/m³) for formaldehyde. These were the amounts of analyte spiked on the sampling device which allowed recoveries approximately equal to the detection limits of the analytical procedure (Section 4.2).

1.2.3. Reliable quantitation limits

The reliable quantitation limits were 291 ng per sample (2.7 ppb or 6.1 μg/m³) for acrolein and 482 ng per sample (16 ppb or 20 μg/m³) for formaldehyde. These were the smallest amounts of analyte which could be quantitated within the limits of a recovery of at least 75% and a precision (±1.96 SD) of ±25% or better (Section 4.2).

The reliable quantitation limits and detection limits reported in the method are based upon optimization of the instrument for the smallest possible amount of analyte. When the target concentration of an analyte is exceptionally higher than these limits, they may not be attainable at the routine operating parameters.

1.2.4. Sensitivity

The sensitivities of the analytical procedure over concentration ranges representing 0.4 to 2 times the target concentration, based on the recommended air volumes, were 94±3 area units per pg/mL for acrolein and 7589 area units per μg/mL for formaldehyde. These values were determined from the slope of the calibration curves (Section 4.3). The sensitivity may vary with the particular instrument used in the
analysis.

1.25. Recovery

The recovery of acrolein from samples used in a 19-day storage test remained above 88% when the samples were stored at ambient temperature. The recovery of formaldehyde from samples used in an 18-day storage test remained above 92% when the samples were stored at ambient temperature. These values were determined from regression lines which were calculated from the storage data (Section 48). The recovery of the analyte from the collection device must be at least 75% following storage.

1.26. Precision (analytical method only)

The pooled coefficients of variation obtained from replicate determinations of analytical standards over the range of 0.4 to 2 times the target concentration were 0.034 for acrolein and 0.0052 for formaldehyde (Section 42).

1.27. Precision (overall procedure)

The precision at the 95% confidence level for the ambient temperature storage tests were ±1.38% for acrolein and ±1.43% for formaldehyde (Section 46). These values each include an additional ±5% for sampling error. The overall procedure must provide results at the target concentrations that are ±25% at the 95% confidence level.

1.28. Reproducibility

Samples collected from controlled test atmospheres and a draft copy of this procedure were given to a chemist unassociated with this evaluation. The acrolein samples were analyzed following 7 days of storage at ambient temperature. The average recovery was 99.0% and the standard deviation was 10.5%. The formaldehyde samples were analyzed following 15 days of storage. The average recovery was 96.3% and the standard deviation was 1.7% (Section 43).

13. Advantages

13.1. The sampling and analytical procedures permit the simultaneous determination of acrolein and formaldehyde.

13.2. Samples are stable following storage at ambient temperature for at least 18 days.

14. Disadvantage

None

2. Sampling Procedure

2.1. Apparatus

2.1.1. Samples are collected by use of a personal sampling pump that can be calibrated to within ±5% of the recommended sampling rate with the sampling tube in line.

2.1.2. Samples are collected with laboratory prepared sampling tubes. The sampling tube is constructed of flame-treated glass and is about 8 cm long. The i.d. is 4 mm and the o.d. is 5 mm. One end of the tube is tapered so that a glass wool plug will hold the contents of the tube in place during sampling. The other end of the sampling tube is open to its full 4-mm i.d. to facilitate packing of the tube. Both ends of the tube are fire-polished for safety. The tube is packed with a 75-mg backup section, located nearest the tapered end and a 151-mg sampling section of pretreated KAD-2 adsorbent which has been coated with 2-HMP. The two sections of coated adsorbent are separated and retained with small plugs of sawdust glass wool. Following packing, the sampling tube is sealed with two 7/32-in. o.d. plastic end caps. Instructions for the pretreatment and the coating of KAD-2 adsorbent are presented in Section 46, of this method.

2.1.3. Sampling tubes, similar to those recommended in this method, are marketed by Supelco, Inc. These tubes were not available when this work was initiated, therefore, they were not evaluated.

2.2. Reagents
None required

2.3. Technique

2.3.1. Properly label the sampling tube before sampling and then remove the plastic end caps.

2.3.2. Attach the sampling tube to the pump using a section of flexible, plastic tubing such that the large, front section of the sampling tube is exposed directly to the atmosphere. Do not place any tubing ahead of the sampling tube. The sampling tube should be attached in the worker’s breathing zone in a vertical manner such that it does not impede work performance.

2.3.3. After sampling for the appropriate time, remove the sampling from the pump and then seal the tube with plastic end caps. Wrap the tube lengthwise with an official OSHA seal (Form 21).

2.3.4. Include at least one blank for each sampling set. The blank should be handled in the same manner as the samples with the exception that air is not drawn through it.

2.3.5. List any potential interferences on the sample data sheet.

2.4. Breakthrough (Breakthrough was defined as the relative amount of analyte found on a backup sample in relation to the total amount of analyte collected on the sampling train.)

2.4.1. Acrolein: When a test atmosphere containing 3 times the PEL was sampled for 2 times the recommended air volume, the breakthrough was 1% (Section 4.4). No breakthrough of acrolein from the 150-mg to the 75-mg adsorbent bed was observed when the recommended sampling method was followed.

2.4.2. Formaldehyde: For formaldehyde collected from test atmospheres containing 2 times the PEL, the average 5% breakthrough air volume was 41 L. The sampling rate was 0.1 L/min and the average mass of formaldehyde collected was 250 μg (Section 4.4).

2.5. Desorption efficiency

No desorption efficiency corrections are necessary to compute air sample results because analytical standards are prepared using coated adsorbent. Desorption efficiencies were determined, however, to investigate the recoveries of the analytes from the sampling device. The average recoveries, over the range of 0.4 to 2 times the target concentration, based on the recommended air volumes, were 102% for acrolein and 98.2% for formaldehyde. The desorption efficiencies were essentially constant over the ranges studied (Section 4.5).

2.6. Recommended air volumes and sampling rate

2.6.1. The recommended air volume for acrolein is 48 L collected at 0.1 L/min.

2.6.2. The recommended air volume for formaldehyde is 24 L collected at 0.1 L/min for the TWA and 3 L collected at 0.2 L/min for the STEL.

2.6.3. The recommended air volume to be used when both aldehydes are sampled together is 24 L collected at 0.1 L/min.

2.7. Interferences (sampling)

2.7.1. Any collected substance that is capable of reacting with, and depleting the derivatizing reagent is a potential interference. Chemicals which contain a carbonyl group, such as acetone, may be capable of reacting with Z-HMP.

2.7.2. There are no other known interferences to the sampling method.

2.8. Safety precautions (sampling)

2.8.1. Attach the sampling equipment to the worker in such a manner that it will not interfere with work performance or safety.

2.8.2. Follow all safety practices that apply to the work area being sampled.
3. Analytical Procedure

3.1. Apparatus

3.1.1. A gas chromatography (GC), equipped with a nitrogen selective detector. A Hewlett-Packard Model 5890A GC fitted with a nitrogen phosphorus flame ionization detector (NPD) was used for this evaluation. Injections were performed using a Hewlett-Packard Model 7671A automatic sampler.

3.1.2. A GC column capable of resolving the analytes from potential interferences. A 6-ft × 1/4-in.o.d. (2-mm.i.d.) glass GC column containing 10%UCON 50-HB-S100 with 29%KOH on 80/100 mesh Chromosorb WAW was used for this evaluation. Injections were performed on-column.

3.1.3. Vials, glass 2-mL with Teflon-lined caps.

3.1.4. Volumetric flasks, pipets and syringes for preparing standards, making dilutions and performing injections.

3.2. Reagents

3.2.1. Toluene and dimethylformamide, Burdick and Jackson solvents were used in this evaluation.

3.2.2. Helium, hydrogen and air, GC grade.

3.2.3. Acrolein, of known high purity. Aldrich Chemical, Gold Label Grade acrolein was used in this study.

3.2.4. Formaldehyde, 37% by weight in water. Aldrich Chemical, A.C.S. Reagent grade formaldehyde was used in this study.

3.2.5. Amberlite XAD-2 adsorbent coated with 10% by weight, 2-(hydroxymethyl)piperidine (2-HMP) (Section 4.5).

3.2.6. Desorbing solution with internal standard. This solution was prepared by adding 20 µL of dimethylformamide to 100 mL of toluene.

3.3. Standard preparation

3.3.1. Acrolein: Prepare stock standards by diluting known amounts of the aldehyde with methanol. A standard containing 1 mg/mL acrolein was prepared by diluting 12 µL of the 99% reagent to 10 mL with methanol.

3.3.2. Formaldehyde: Prepare stock standards by diluting known volumes of 37% formaldehyde solution with methanol. A procedure to determine the formaldehyde content of these standards is presented in Section 4.5. A standard containing 7.5 mg/mL formaldehyde was prepared by diluting 1 mL of the 37% reagent to 50 mL with methanol.

3.3.3. It is recommended that analytical standards be prepared about 16 h before the air samples are to be analyzed in order to ensure the complete reaction of the analytes with 2-HMP. However, rate studies have shown the reaction to be greater than 95% complete after 4 h. Therefore, one or two standards can be analyzed after this reduced time if sample results are outside the concentration range of the prepared standards.

3.3.4. Place 150-ng portions of coated XAD-2 adsorbent from the same lot number as used to collect the air samples, into each of several glass 2-mL vials. Seal each vial with a Teflon-lined cap.

3.3.5. Prepare fresh analytical standards each day by injecting appropriate amounts of the diluted analytes directly onto 150-ng portions of coated adsorbent. It is permissible to inject both acrolein and formaldehyde on the same adsorbent portion. Allow the standards to stand at room temperature. A standard, approximating the target levels, was prepared by injecting 11 µL of the acrolein and 12 µL of the formaldehyde stock standards onto a single coated XAD-2 adsorbent portion.

3.3.6. Prepare a sufficient number of standards to generate the calibration curves. Analytical standard concentrations should bracket sample concentrations. Thus, if samples are not in the concentration range of the prepared standard additional standards must be prepared to determine detector response.
3.3.7. Desorb the standards in the same manner as the samples following the 16-h reaction time.

3.4. Sample preparation

3.4.1. Transfer the 150-mg section of the sampling tube to a 2-mL vial. Place the 75-mg section in a separate vial. If the glass wool plugs contain a significant number of adsorbent beads, place them with the appropriate sampling tube section. Discard the glass wool plugs if they do not contain a significant number of adsorbent beads.

3.4.2. Add 1 mL of desorbing solution to each vial.

3.4.3. Seal the vials with Teflon-lined caps and then allow them to desorb for 1 h. Shake the vials by hand with vigorous force several times during the desorption time.

3.4.4. Save the used sampling tubes to be cleaned and recycled.

3.5. Analysis

3.5.1. GC Conditions

- Column temperature: bi-level temperature program
  - First level: 100 to 140°C at 4°C/min upon injection
  - Second level: 140 to 180°C at 20°C/min following completion of the first level
  - Isothermal period: Hold column at 180°C until the recorder pen returns to baseline (usually about 25 min after injection)

- Injector temperature: 180°C

- Helium flow rate: 20 mL/min (detector response will be reduced if nitrogen is substituted for helium carrier gas)

- Injection volume: 0.8 mL

- GC column: 6-ft x 1/4-in. o.d. (2-mm i.d.) glass GC column containing 10% UCON 50-HB-5100 with 2% KOH on 80/100 Chromosorb W-AW

- NPD conditions
  - Hydrogen flow rate: 3 mL/min
  - Air flow rate: 50 mL/min
  - Detector temperature: 275°C

3.5.2. Chromatogram Figure 4.11.

3.5.3. Use a suitable method, such as electronic integration, to measure detector response.

3.5.4. Use an internal standard method to prepare the calibration curve with several standard solutions of different concentrations. Prepare the calibration curve daily. Program the integrator to report results in µg/mL.

3.5.5. Bracket sample concentrations with standards.

3.6. Interferences (analytical)

3.6.1. Any compound with the same general retention time as the analytes and which also gives a detector response is a potential interference. Possible interferences should be reported to the laboratory with submitted samples by the industrial hygienist.

3.6.2. GC parameters (temperature, column, etc.) may be changed to circumvent interferences.

3.6.3. A useful means of structure designation is GC-MS. It is recommended this procedure be used to confirm samples whenever possible.

3.6.4. The coated adsorbent usually contains a small amount of residual formaldehyde derivative (Section 42).
17. Calculations

37.1. Results are obtained by use of calibration curves. Calibration curves are prepared by plotting detector response against concentration for each standard. The best line through the data points is determined by curve fitting.

37.2. The concentration, in \( \mu g/mL \), for a particular sample is determined by comparing its detector response to the calibration curve. If either of the analytes is found on the backup section, it is added to the amount found on the front section. Blank corrections should be performed before adding the results together. See Section 4.11 for additional information and suggestions on blank determinations and corrections.

37.3. The acrolein and/or formaldehyde air concentration can be expressed using the following equation:

\[
\text{mg/m}^3 = \left( \frac{A}{B} \right) C
\]

where
- \( A = \mu g/mL \) from Section 37.2.
- \( B = \) desorption volume
- \( C = \) liters of air sampled

No desorption efficiency corrections are required.

37.4. The following equation can be used to convert results in mg/m\(^3\) to ppm.

\[
\text{ppm} = \left( \frac{\text{mg/m}^3 \times 24.46}{\text{MW}} \right)
\]

where
- mg/m\(^3\) = result from Section 37.3.
  - 24.46 = molar volume of an ideal gas at 760 mm Hg and 25°C
  - MW = molecular weight (acrolein = 56.1, formaldehyde = 30.0)

18. Safety precautions (analytical)

38.1. Avoid skin contact and inhalation of all chemicals.

38.2. Restrict the use of all chemicals to a fume hood whenever possible.

38.3. Wear safety glasses and a lab coat in all laboratory areas.
Appendix E

Air Sampling Pump Sampling Form

<table>
<thead>
<tr>
<th>I. EMPLOYEE INFORMATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST INITIAL</td>
<td>LAST NAME</td>
</tr>
<tr>
<td>DEPT.</td>
<td>BLDG.</td>
</tr>
<tr>
<td>EXPOSURE DURATION (HRS):</td>
<td>EXPOSURE (TIMES PER DAY):</td>
</tr>
<tr>
<td>JOB PERFORMED:</td>
<td></td>
</tr>
<tr>
<td>PPE Used:</td>
<td>Respirator:</td>
</tr>
<tr>
<td>EXPOSURE REPRESENTS:</td>
<td>BALANCE OF DAY:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. SAMPLING AREA INFORMATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT.</td>
<td>BLDG.</td>
</tr>
<tr>
<td>SOURCE:</td>
<td></td>
</tr>
<tr>
<td>ENGINEERING CONTROLS:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. SAMPLING INFORMATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Time</td>
<td>Temp (°C)</td>
</tr>
<tr>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Start</td>
<td></td>
</tr>
<tr>
<td>End</td>
<td></td>
</tr>
<tr>
<td>OPEN Face</td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. SAMPLING INFORMATION</th>
<th>INDICATION APPROPRIATE SAMPLE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Face</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IV. SURVEY INSTRUMENT INFORMATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>INSTRUMENT (PUMP):</td>
<td>MODEL:</td>
</tr>
<tr>
<td>MEDIA:</td>
<td>MFG/PART #:</td>
</tr>
<tr>
<td>CALIBRATION METHOD:</td>
<td>PRE-CAL Date:</td>
</tr>
<tr>
<td>BIOS CALIBRATOR</td>
<td>BY:</td>
</tr>
<tr>
<td>ROTAMETER</td>
<td>FLOW (L/min):</td>
</tr>
<tr>
<td>FLOW (L/min):</td>
<td>Temp (°C):</td>
</tr>
<tr>
<td>TOTAL TIME (MN.):</td>
<td>AVG. FLOW (L/ Min.):</td>
</tr>
<tr>
<td>AVG. TEMPERATURE DURING SAMPLING:</td>
<td>TEMPERATURE CORRECTION FACTOR:</td>
</tr>
</tbody>
</table>
Appendix F

Duct Traverse

***All measurements are in inches.***

[Diagram of duct traverse with measurements in inches indicated]