

# EXPOSURE OF MUSEUM STAFF TO FORMALDEHYDE DURING SOME WET SPECIMEN ACTIVITIES

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*Abstract.*—Biological specimens are frequently preserved for study and display by initial treatment with formaldehyde. Significant quantities of this chemical are retained in these specimens throughout the transfer to less toxic storage solvents such as alcohol, when these specimens are used for necropsy, and in some specimens which are permanently stored in formalin. Anyone working with these objects, including their transfer to other containers, is potentially exposed to both the formaldehyde as well as the current storage solvent. Exposure assessments during several operations with these materials measured the levels of exposure and found these exposures were generally below maximum recommended levels in those situations where local exhaust ventilation was used, but levels did exceed some recommended criteria where only general room ventilation was available. It is recommended that some type of local ventilation system be made available in facilities which work with wet specimens on a routine basis and that personal protective equipment such as gloves, eye protection and aprons or lab coats also be utilized to reduce exposures.

## INTRODUCTION

The use of formaldehyde in the preservation of animal specimens has been a common practice for many years. This material is obtained commercially as formalin, a solution of 33% to 50% gaseous formaldehyde in water with a small amount of methanol as a stabilizer. Standard practice calls for the immersion of a specimen in a formalin solution in the field with subsequent transfer to an ethanol solution for long term storage. Such stored objects can then be used for study, display or other purposes.

The potential for exposure to formaldehyde occurs at any step in these procedures where the objects are handled, including initial immersion, transfer to another solvent, and handling during dissection or other study. While formaldehyde is ubiquitous in the environment at levels up to one part per billion by volume (ppb), maximum occupational exposure limits are established by several organizations in the U. S. to minimize irritation of the eyes and upper respiratory tract and to protect against other effects. These organizations and their respective limits are given in Table 1. The ACGIH (2002a) reports an odor threshold for formaldehyde to be as low as 50 ppb; levels from 500 to 3,000 ppb can produce lower airway and chronic pulmonary obstruction; higher concentrations can cause pulmonary edema, inflammation, pneumonia and death. Formaldehyde is connected with cancer in some animal species and is categorized as a suspected human carcinogen. For these reasons, it is recommended that the more stringent NIOSH limits be followed.

Table 1. Maximum occupational exposure limits for formaldehyde. (ACGIH 2002b, NIOSH 2003b, OSHA 2005).

Organization	Occupational exposure limit
NIOSH (National Institute for Occupational Safety and Health)	16 ppb eight-hour time weighted average 100 ppb 15 minute exposure limit
OSHA (Occupational Safety and Health Administration)	750 ppb eight hour time weighted average exposure 100 ppb 15 minute exposure limit
ACGIH (American Conference of Governmental Industrial Hygienists)	300 ppb ceiling, not to be exceeded at any time

### METHODS

The nature of work in most museums and conservation facilities is quite diverse, and tasks which would potentially expose workers to formaldehyde are not performed daily as might be the case in many occupations nor do these tasks necessarily require 8 hours when they are performed. While this intermittent exposure tends to lessen any toxic effects of formaldehyde, it made the evaluation of exposures more difficult since some advance notice was required for travel to the testing site and several hours of sampling during formaldehyde use were required to obtain accurate measurements. For these reasons, arrangements were made to evaluate facilities which were able to stockpile a sufficient amount of formaldehyde-associated work to occupy employees for several hours and were willing to coordinate that work with an on-site exposure assessment visit.

Three facilities participated in this study. The first was a National Park Service collections management center which was planning a large project requiring up to five employees for two or more days in the transfer, evaluation, and cataloging of several hundred specimens stored in liquid known to contain some formaldehyde. The second facility was an osteology preparation lab that had several dozen five gallon containers with whale ovaries stored in liquid also containing formaldehyde. This facility required three employees working for two days to remove, clean, inspect, tag and re-package these specimens. The third location was a college laboratory teaching comparative anatomy with sharks and cats preserved in formaldehyde. Here sample durations ranged from two to four hours rather than full shift, but preliminary testing indicated this would produce sufficient analyte for quantification. While obviously not a museum or conservation facility, the type of work done during testing here is considered similar enough for comparison of exposures.

The specimens in the college laboratory were obtained commercially from a scientific supply house that had embalmed them with a formalin solution, subsequently rinsed that solution and shipped the specimens preserved in Ward-Safe holding solution (2.76% methanol, 1.44% 1,2-propanediol, 0.68% proprietary material, and 95.01% water) (Ward's 1998). Specimens from the other two facilities had been treated with formaldehyde and subsequently rinsed and stored in ethanol. In some cases, however, collection records were incomplete and this treatment was not verifiable. Variable levels of the original formaldehyde fixative are as-

sumed to have been transferred to the final storage solution and also to have been retained in the tissue of all specimens.

Time weighted average measurements of airborne formaldehyde were collected at all three facilities from the breathing zones of workers and in selected locations in the work areas. Using NIOSH method 3500 for airborne formaldehyde, air was pulled through a treated silica gel cartridge at 1.5 liters per minute (lpm) with a battery powered sampling pump clipped to the belt of the employee (NIOSH 2003a). Samples were refrigerated until analysis by high performance liquid chromatography (HPLC) with an ultraviolet detector. Because ethanol was known to also be present in these work environments, personal exposure was evaluated by collecting ethanol samples according to NIOSH method 1400 using charcoal sorbent at 0.2 lpm with analysis by gas chromatography with flame ionization detection (NIOSH 1994).

At the college anatomy laboratory breathing zone and area samples were collected for formaldehyde as above and also by using passive monitoring devices (cat. # 526-200/201, SKC Inc., Eighty Four, PA). Passive sampling of the environment differs from the previously described “active” sampling in that no pump or mechanical device is used to move the air through the sampling device. Instead, collection of the sample is accomplished by diffusion of analyte onto sorbent material, with analysis of contaminant by the same procedure once the sample is obtained.

Another more sophisticated technique titled “video exposure monitoring” was also employed in this facility. Video exposure monitoring uses a conventional video camera to record the actions of the individuals potentially exposed to contaminant while they are being simultaneously monitored for the concentration of that contaminant in their breathing zone. A fluctuating bar can subsequently be superimposed on the video, representing the level of exposure, with periodic (e.g., one per second) updates to indicate the change in exposure resulting from various tasks. Video exposure monitoring was utilized in this anatomy lab to assist in the identification of specific actions related to high transient exposures, and that data has been presented elsewhere (Ryan et al. 2003).

Environmental measurements of formaldehyde were made during normal work operations at the facilities and using the techniques described above. The only task parameter that the workers considered unusual in some cases was the duration of the work with wet specimens since some stockpiling had occurred to have sufficient work to facilitate the testing.

During August 2003 and April 2004, 11 personal and 19 area samples were collected at the collections management center with durations ranging from 0.4 to 8.8 hours. This sampling was conducted during work with wet specimens in containers ranging in size from approximately 20 ml (0.7 fl oz) to 200 L (55 gal). These containers held a variety of animal species which were removed, inspected, treated or relabeled when necessary, and re-packaged in alcohol. Much of this work was conducted in either an exhausted or a re-circulating laboratory hood.

In April and September 2004, 14 personal samples (no area samples) were collected in the osteology preparation laboratory with durations ranging from 1.1 to 4.0 hours. During this sampling three workers were involved in opening 20 L (5 gal) containers holding specimen in liquid solution, rinsing each specimen with water, inspecting, bagging, tagging and re-packaging each in new solution not

Table 2. Summary of personal and area formaldehyde measurements, calculated over sample duration and as eight hour time weighted average. (NIOSH eight hour TWA limit is 16 ppb).

	N	Duration TWA (ppb)			8 hour TWA (ppb)		
		Mean	Median	Range	Mean	Median	Range
Collection management center, personal samples	11	20	16	5.5-44	9	9	2.0-27
Collection management center, area samples	19	19	13	0.6-140	4	2	0.1-16
Osteology Preparation Laboratory, personal samples	14	47	34	1-358	12	12	0.2-64
Comparative Anatomy Laboratory, personal samples	13	210	176	70-430	80	86	28-116
Comparative Anatomy Laboratory, area samples*	12	160	140	60-380	90	91	45-135

\* Values should be considered as minimums due to overloading on some sorbent tubes.

containing formaldehyde. After initially opening the containers, most work was done in an exhausted lab hood.

In February 2001, 13 personal and 12 area samples were collected at the comparative anatomy laboratory with durations from 2.0 to 3.5 hours during the dissection and study of preserved cats and sharks by undergraduate students in a college comparative anatomy lab. Specimens were removed from a large metal storage container where they had been immersed in the solution described above, and taken to tables where the work was done. There was no local exhaust ventilation in this facility but it was observed that doors were generally opened in the afternoon lab sessions when accumulated formaldehyde levels were at their daily maxima. The amount of general exhaust ventilation and air introduced from open doors was not quantified. There were no windows in this facility.

## RESULTS

A summary of all personal and area monitoring for formaldehyde at these facilities is presented in Table 2. The mean, median and range of exposures are presented for the duration of time during which the samples were collected, and also as an 8 hour time weighted average exposure (TWA) with the assumption that un-sampled time was zero exposure.

The highest personal exposure at the collections management center was 27 ppb averaged over an eight hour work day and three of the 11 samples were above the most stringent recommended maximum of 16 ppb. None of the personal breathing zone samples was above any of the recommended 15 minute maximum exposure levels, although one area measurement of 140 ppb exceeded the 100 ppb NIOSH limit.

Three of the 14 measurements at the osteology preparation laboratory were above the NIOSH 16 ppb recommended 8 hour exposure maximum. Those measurements were 17, 20 and 64 ppb and did not exceed any of the other eight hour criteria.

All personal environmental measurements at the comparative anatomy laboratory exceeded the recommended eight hour maximum, although even here none of these measurements exceeded the legal exposure standard established by OSHA of 750 ppb.

Three ethanol samples were collected at the osteology facility with durations from 1.5 to 2.0 hours. These samples ranged from three to six ppb which corresponds to an eight hour time weighted average exposure range from 0.3 to 1.5 ppb. Monitors for volatile organic compounds including alcohols in the comparative anatomy lab showed only very low (i.e., ppb) exposures at or below the lower limit of detection for the chemicals screened. All of these samples indicate levels of exposure at least three orders of magnitude below the recommended maximum level of 1,000 ppm (1,000,000 ppb).

#### CONCLUSIONS AND RECOMMENDATIONS

It must be stressed that this is a preliminary study and that additional data is required under more controlled conditions; however, the results of this preliminary work indicate:

- a high degree of variability in the duration of exposures, ranging from a few minutes to several hours per day,
- a high degree of variability in the tasks being conducted,
- a high degree of variability in the exposure measurements, both personal and area,
- a generally low level of exposure to formaldehyde, in many instances <10% of the recommended exposure maximums, and
- occasional short term exposures exceeding the recommended exposure maximums, particularly in the comparative anatomy laboratory.

Although no measures of local exhaust ventilation were made, it is noted that the formaldehyde concentrations were greater in the comparative anatomy lab where only general room ventilation was available. Good work practice dictates that local exhaust ventilation be used whenever toxic chemicals are used.

While it seems that the most consistent theme with the data is its variability, most measurements were within the levels of exposure considered acceptable based on comparison with the exposure limits presented above. These limits were developed based on available information to reflect the levels of exposure to which most workers may be exposed daily during a working lifetime without adverse health effects.

Results from the limited measurements of ethanol lead to the conclusion that this and other compounds of similar toxicity are not likely to be present in this work environment at significant concentrations.

It would be expected that during normal operations where work had not been stockpiled to allow for testing (as was done here), the duration of exposures and consequently the exposure average over time would be lower than that measured during this work. This should not, however, be considered as justification for exposures above recommended levels since, as mentioned above, formaldehyde is both a suspected human carcinogen and a sensitizing agent, capable of producing allergic reactions and sensitization following occupational and non-occupational exposures. It is recommended that some type of local ventilation system be made available in facilities which work with wet specimens on a routine basis to reduce inhalation exposure. Additionally, personal protective equipment such as safety glasses or face shields, gloves, and lab coats or aprons should be used to prevent direct skin and eye contact.

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