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Case Studies

Exposure to Formaldehyde During Garment Manufacturing

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Reported by Alan Echt and Gregory A. Burr

Background

The National Institute for Occupational Safety and Health (NIOSH) received a request from employees at a garment manufacturing plant in Arkansas concerning health effects, including cancer and lung disease, which the workers attributed to workplace formaldehyde exposure. In the 4 months prior to the request, formaldehyde exposures at this plant had been evaluated by the Arkansas Department of Labor (DOL), the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA), the International Ladies' Garment Workers' Union, and the company's insurance carrier.

A state industrial hygienist reported in July that employees were wearing unapproved respirators, that there was no written respiratory protection program, and that the company had not developed a written hazard communication program. Results of air sampling performed for formaldehyde ranged from <0.04 parts per million (ppm) of formaldehyde in air to 0.10 ppm (one sample), time weighted over the period sampled. The results of sampling, conducted in August by the union, indicated that employees were exposed to formaldehyde below the limit of detection of the passive sampler (<0.04 ppm). An OSHA compliance inspection, conducted in October, resulted in citations for an unmarked exit and for not developing or implementing a hazard communication program. In addition, representatives of the garment manufacturer's loss control insurance carrier visited the plant in October. Their evaluation focused on work practices, control measures, and the results of previous sampling. These representatives concluded that formaldehyde exposures at concentrations measured by the union and the Arkansas DOL would not pose a hazard to the majority of workers, and advised the company to implement the recommendations from the Arkansas DOL report.

Process Description

Precured permanent-press fabrics were received from various suppliers, spread on large tables, and cut according to the garment pattern. Cut pieces were fused (bonding the lining to the garment) and then sewn to assemble the garment (ladies sportswear). Finally, the assembled garment was pressed, inspected, bagged, and shipped. Some spot cleaning was performed with 1,1,1-trichloroethane during final inspection. Approximately 1000 finished garments were produced each day. (Clothing made of rayon blends was being manufactured on the day of the NIOSH evaluation.) The entire facility was air conditioned and the pressing department was equipped with roof-top ventilators. However, the air conditioning system did not provide any outdoor air to the plant. Smoking was permitted in the front office and in the cafeteria.

Evaluation Methods

During the NIOSH field survey, eight full-shift personal breathing zone (PBZ) samples for formaldehyde were collected and analyzed in accordance with NIOSH Method 2541 with modifications.[1] Samples were collected on solid sorbent tubes (10% 2-[hydroxymethyl] piperidine on XAD-2 resin) in plastic holders connected via a length of Tygon® tubing to battery-powered personal sampling pumps operating at a flow rate of 100 ml/min. To collect PBZ samples representative of potential formaldehyde exposures for cutters and bundlers, the pumps were attached to a belt at the employee's waist, while the sorbent tube holder was attached to the employee's lapel. Since employees in the liner department were seated while sewing garments, the sampling pumps were attached to the back of the employee's chair while the sorbent tube holder was attached to the employee's lapel. Pumps used to collect PBZ samples were turned off during the lunch break. The analytical limit of detection (LOD) was 0.4 μg/sample, which equates to a minimum detectable concentration (MDC) of 0.008 ppm, based on the maximum air sampling volume for this set of samples, 38.3 L. The limit of quantitation (LOQ) for this sample set was 1.3 μg/sample, which equates to a minimum quantifiable concentration (MQC) of 0.028 ppm.

Twelve general area (GA) samples for formaldehyde were collected and analyzed in accordance with NIOSH Method 3500.[1] Samples were collected with midget impingers containing approximately 15 ml of 1 percent sodium bisulfite solution. Each impinger was preceded by a tared, 37-mm diameter, 5-μm pore size polyvinylchloride (PVC) filter in order to exclude formaldehyde-containing particulate from the impinger and thus prevent a positive bias. Tygon tubing was used to connect the filter cassette to the impinger and to connect the impinger to a battery-powered sampling pump calibrated at a flow rate of 1 L/min. The analytical LOD for this set of samples was 2 μg/sample, which equates to an MDC of 0.004 ppm, based on the maximum sample volume for this set of samples, 439 L. The MQC for this sample set was 0.007 ppm, based on an analytical LOQ of 3.9 μg/sample.

To assess the degree of total particulate (e.g., dust, lint) exposure, the PVC filters were analyzed according to NIOSH Method 0500 with modifications.[1] These modifications included the following: (1) the back-up pads were not desiccated and (2) the filters were stored in an environmentally controlled room (21 ± 3°C and 50 ± 5% relative humidity) and subjected to the room conditions for several days for stabilization. The LOD of this method, 0.02 mg, was determined by the precision of the balance used to weigh the filters.

Eight PBZ samples for formaldehyde on dust were also collected. As with the PBZ samples for formaldehyde, employees in the cutting and bundling areas wore sampling pumps on belts at their waists, with the sampling device attached

to their lapels. Employees sewing garments wore the sampling device with the sampling pumps attached to the backs of their chairs. Samples were collected on tared, 25-mm diameter, 5-μm pore size PVC filters placed in personal samplers for inhalable dust. These samplers collect inhalable (inspirable) particles in the size range which represents the dust the worker takes in through the nose and mouth during the act of breathing (i.e., particles with an aerodynamic diameter up to 100 μm).[2,3] Inhalable particles have been described as those that can be deposited anywhere in the respiratory tract.[3] The samplers were connected via Tygon tubing to battery-powered sampling pumps operating at a flow rate of 2 L/min. Samples collected in this manner were analyzed using both NIOSH Method 5700[1] and the analysis procedure from the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI) method, *Formaldehyde in Water Leachates of Paper and Wood Dust Particles*.[4] Two bulk samples of settled dust (lint) were analyzed according to these methods as well. The LOD for the NIOSH method for this sample set was 0.5 μg/sample, or an MDC of 0.6 $\mu g/m^3$ for a sample volume of 815 L, the maximum sample volume for this set of samples. The MQC for the NIOSH method for this sample set was 1.8 $\mu g/m^3$, based on an LOQ of 1.5 μg/sample and a sample volume of 815 L. For the NCASI analysis, the LOD was 0.4 μg/sample and the LOQ was 1.4 μg/sample. Based on the maximum sample volume of 815 L, the MDC was 0.5 $\mu g/m^3$ and the MQC was 1.7 $\mu g/m^3$.

Evaluation Criteria

Formaldehyde

Formaldehyde is a colorless gas with a pungent and irritating odor at ambient temperatures,[5] its odor threshold is approximately 0.8 ppm.[5,6] Formaldehyde may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.[5] Mild eye irritation with tearing and other transient symptoms of mucous membrane irritation have been observed in some persons at concentrations of 0.1 to 0.3 ppm.[7] For most people, however, a tingling sensation in the eyes, nose, and the back of the throat is not experienced until concentrations reach 2 to 3 ppm.[7] Mild to unpleasant eye irritation occurs in acclimated workers at 2 to 10 ppm, and intolerable irritation (tissue damage possible) occurs at levels above 25 ppm.[5] A number of studies suggest that formaldehyde causes asthma and/or exacerbates preexisting respiratory conditions.[7]

Formaldehyde is one of the most common causes of skin disease in the workplace.[7] The major effects of formaldehyde on the skin are irritant dermatitis and allergic contact dermatitis.[7] Irritant dermatitis is the result of direct injury to the skin and is characterized by redness and thickening of the affected areas. Skin sensitization to formaldehyde is well known.[7] For sensitized individuals, repeated contact tends to cause more severe reactions, and sensitization usually persists for life.[7]

Based on the results of laboratory tests which have demonstrated the carcinogenic and mutagenic activity of formaldehyde in animals, NIOSH and OSHA recommend that formaldehyde be handled in the workplace as a potential occupational carcinogen.[8,9] NIOSH recommends that occupational exposures to formaldehyde be controlled to the lowest feasible limit.[10] On December 4, 1987, OSHA issued a comprehensive regulation covering occupational exposure to formaldehyde (29 CFR 1910.1048). This rule reduced the 8-hour time-weighted average (TWA) permissible exposure limit (PEL) to 1 ppm and established a 2 ppm 15-minute short-term exposure limit (STEL). The comprehensive standard also included an action level of 0.5 ppm, measured as an 8-hour TWA, and provisions for employee exposure monitoring, medical surveillance, recordkeeping, regulated areas, emergency procedures, preferred methods of exposure control, maintenance and selection of personal protective equipment, and hazard communication.[8]

On May 27, 1992, OSHA amended its existing regulation for occupational exposure to formaldehyde to take effect on June 26, 1992. The final amendments lowered the 8-hour PEL for formaldehyde from 1 ppm to an 8-hour TWA of 0.75 ppm. The amendments also added medical removal protection provisions to supplement the existing medical surveillance requirements for those employees suffering significant eye, nose, or throat irritation, and for those suffering from dermal irritation or sensitization from occupational exposure to formaldehyde. Additional hazard labeling, including a warning that formaldehyde presents a potential cancer hazard, was required where formaldehyde levels, under reasonably foreseeable conditions of use, may potentially exceed 0.5 ppm. The final amendments provided for annual training of all employees exposed to formaldehyde at levels of 0.1 ppm or higher.[8]

The American Conference of Governmental Industrial Hygienists (ACGIH) classifies formaldehyde as a suspected human carcinogen (i.e., a chemical substance associated with industrial processes which are suspect of inducing cancer, based on either limited epidemiological evidence or demonstration of carcinogenesis in one or more animal species by appropriate methods).[3] The recommendation of ACGIH concerning a suspected human carcinogen is that worker exposures by all routes be carefully controlled to levels as low as reasonably achievable below its threshold limit value (TLV).[3] On June 2, 1992, ACGIH adopted a ceiling limit TLV of 0.3 ppm. A ceiling limit is a concentration that should not be exceeded during any part of the working exposure. ACGIH formerly recommended an 8-hour TLV–TWA of 1 ppm and a 15-minute STEL of 2 ppm for formaldehyde. The revised TLV was adopted to further reduce sensory irritation for workers handling formaldehyde or formaldehyde-containing products. Moreover, ACGIH stated that due to the reported dose-dependent carcinogenic effect in the rat and mouse and the inadequate epidemiologic data on the cancer risk in humans, it was advisable to reduce formaldehyde workplace exposure to the lowest possible level.[11]

Total Particulates

Total particulates (nuisance dusts) have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The lung tissue reaction caused by inhalation of nuisance dusts has the following characteristics: (1) the architecture of the air spaces remains intact; (2) scar tissue is not formed to a significant extent; and (3) the tissue reaction is potentially reversible.[3]

The current OSHA PEL for particulates not otherwise regulated is 15 mg/m^3 for total dust.[12] The ACGIH TLV for

particulates not otherwise classified is 10 mg/m^3 for total dust.[3] These criteria were established to minimize mechanical irritation of the eyes and nasal passages, and to prevent visual interference. NIOSH has not developed specific criteria for total particulates.

Formaldehyde on Dust[13]

In two mortality studies dealing with occupational exposure to formaldehyde, a difference in results has brought into question the source of formaldehyde exposure in each study. In a study by Stayner *et al.*,[14] in which statistically significant elevations in proportionate mortality were observed for cancers of the parotid gland, gallbladder, and multiple myeloma, formaldehyde measurements revealed low levels, assumed to be in a vapor phase due to off-gassing of formaldehyde from cloth used in garment manufacture. In a reanalysis of data from an earlier study, Blair *et al.*[15] stated that the pattern for nasopharyngeal cancer suggested that simultaneous exposure to formaldehyde and particles may be a risk factor for this tumor." The factories in the Stayner study and the Blair study where excess nasopharyngeal cancers were found were noted to be dusty. Therefore, the particulate matter to which employees were exposed may have contained either adsorbed or chemically bound formaldehyde, the latter of which could be released in the warm, moist environment of the upper respiratory tract. Much work remains to be done in this area to better assess the effect of formaldehyde-containing dust on the incidence of cancers of the upper respiratory tract. There are currently no workplace evaluation criteria for formaldehyde-containing dust.

Results and Discussion

The results of PBZ and GA samples for formaldehyde are presented in Tables 1 and 2, respectively. The PBZ sample results ranged from 0.14 to 0.17 ppm, 8-hour TWA. These results were less than the OSHA PEL and OSHA action level, as well as the ACGIH TLV. However, these results exceeded the NIOSH recommended exposure limit (REL) of lowest feasible concentration, and exceeded the 0.1 ppm level for OSHA-required annual employee training. The GA sample results ranged from 0.16 to 0.25 ppm, 8-hour TWA. For both sampling methods, concentrations inside the plant exceeded outdoor concentrations, indicating that reducing concentrations inside the plant was possible by increasing the amount of outdoor air entering the facility.

TABLE 1. Results of Personal Breathing Zone Air Samples for Formaldehyde

Job	Sample Duration (Minutes)	Formaldehyde (ppm)	8-Hour TWA (ppm)
Sewer	358	0.22	0.16
Sewer	350	0.22	0.16
Sewer	354	0.23	0.17
Sewer	341	0.23	0.16
Cutter	383	0.18	0.14
Cutter	368	0.20	0.15
Bundler	363	0.20	0.15
Bundler	360	0.21	0.16

The results of samples collected for total particulate, presented in Table 3, indicated that exposures did not approach the applicable evaluation criteria. The highest 8-hour TWA concentration measured, 0.15 mg/m^3, was 100 times less than the applicable OSHA PEL, and more than 60 times less than the ACGIH TLV. NIOSH has not developed specific criteria for total particulates.

Due to analytical problems with the analysis of formaldehyde on dust by NIOSH Method 5700, only the results of the analysis by the NCASI method were obtained. The results of sampling for formaldehyde on inhalable dust (Table 4) should be interpreted cautiously, as there are no occupational exposure criteria for this material. The results indicated, however, that dust from clothing manufacturing processes in this facility did contain formaldehyde. The formaldehyde on dust measurements may not have the same biological significance as the formaldehyde vapor measurements, as the particulate formaldehyde data may be representative of formaldehyde exposure at a point of retention in the respiratory tract, while the vapor phase measurements represent exposure to the entire respiratory tract. Furthermore, the point of retention depends on the particle size distribution of the aerosol, which was not determined in this evaluation. Two bulk samples of settled dust contained 0.70 and 0.80 μg of formaldehyde per milligram of the sampled material.

Conclusions

- Formaldehyde concentrations measured in this facility on the day of the survey exceeded the NIOSH recommendation that formaldehyde exposures be maintained at the lowest feasible concentration and, in some cases,

TABLE 2. Results of General Area Air Samples for Formaldehyde

Activity	Sample Duration (Minutes)	Formaldehyde (ppm)	8-Hour TWA (ppm)
Cutting pockets, sewing center backs	429	0.27	0.24
Sewing pockets	414	0.26	0.22
Liners	412	0.29	0.25
Sleeves	411	0.29	0.25
Final press (bench pressers)	412	0.23	0.20
Sewing liners	398	0.30	0.25
Spreading and cutting area	389	0.25	0.20
Outside	380	0.01	0.01
Receiving, bulk fabric storage	439	0.17	0.16
Fuser, exit side	436	0.24	0.21
Shelf near spreading table	424	0.29	0.25
Collar sewing (small parts)	431	0.28	0.25

TABLE 3. Results of General Area Samples for Total Particulate

Activity/Location	Sample Duration (Minutes)	Total Particulate (mg/m³)	8-Hour TWA (mg/m³)
Cutting pockets and sewing center backs	429	0.05	0.05
Sewing pockets	414	0.02	0.02
Liners	412	0.10	0.09
Sleeves	411	0.13	0.11
Final press	412	0.05	0.04
Sewing liners	398	0.05	0.04
Spreading and cutting area	389	0.10	0.08
Outside	380	0.05	0.04
Receiving, bulk fabric storage	439	0.16	0.15
Fuser, exit side	436	0.17	0.15
Shelf near spreading table	424	0.12	0.11
Collar sewing (small parts)	431	0.14	0.13

approached the ACGIH TLV of 0.3 ppm as a ceiling limit. While measured exposures were less than the OSHA PEL and action level, they exceeded the level where OSHA mandates annual training of all exposed employees.

- The fact that these results differ from the results of sampling conducted by representatives of two other government agencies and the labor union cannot be explained by faulting their evaluation techniques. One possible explanation for the differences in measured exposures is that the amount of formaldehyde released from fabrics is highly variable, depending on the treatment used, the length of time the fabric was stored, and other factors.
- Total particulate concentrations measured in the plant were less than the nuisance dust evaluation criteria; however, because the dust was found to contain formaldehyde, these criteria may not be sufficiently protective. The health effects of measurable concentrations of formaldehyde on inhalable dust are not clear. However, these results may explain employee complaints of irritating dust in a facility where total particulate exposures were low.

Recommendations

- Because the levels of formaldehyde were similar on samples collected throughout the plant, the use of general dilution ventilation might be effective in reducing these exposures. Other options to consider include working with the fabric suppliers to minimize the amount of free formaldehyde released from a given fabric type, or refusing delivery of particularly problematic fabric lots.
- Provide personal protective equipment, such as gloves or long sleeves, to prevent skin contact with formaldehyde-treated cloth. Dermatitis in the textile and apparel industries is well documented and formaldehyde is a well-known sensitizer.[7] The OSHA formaldehyde standard states that contact with irritating or sensitizing materials shall be prevented to the extent necessary to eliminate the hazard.[8] OSHA has interpreted this to require a two-tiered approach to prevent employee contact with these materials.[16]

1. When dermatitis is the result of skin sensitization from previous exposure to formaldehyde, only those employees with the skin problems need to be protected.
2. When the skin problems are the result of irritant dermatitis, as a minimum, all employees who do the same job as the workers with skin problems must be protected.

- Provide OSHA-mandated training for employees exposed to formaldehyde in concentrations in excess of 0.1 ppm, and implement the elements of the hazard communication portion of the formaldehyde standard. Make medical surveillance available for employees who develop signs and symptoms of overexposure to formaldehyde. The OSHA formaldehyde standard contains the provision that employers, when determining whether an employee may be experiencing signs and symptoms of possible overexposure to formaldehyde, may rely on the evidence that signs and symptoms will occur only in exceptional circumstances when airborne exposure is less then 0.1 ppm.[8] However, the concentrations of formaldehyde measured by the NIOSH investigators exceeded 0.1 ppm, and OSHA has determined that this section of the standard is a guideline and not an exemption.[17]
- NIOSH recommends that workers should not be involuntarily exposed to tobacco smoke.[18] Exposure to environmental tobacco smoke (ETS) may be responsible for irritant symptoms and can exacerbate allergic symptoms. Further, NIOSH has determined that

TABLE 4. Results of Personal Breathing Zone Samples for Formaldehyde on Inhalable Dust

Job	Sample Duration (Minutes)	Formaldehyde (μg/sample)	Sample Weight (mg)	Formaldehyde (μg/mg)	Inhalable Particulate (mg/m³)
Sewer	375	2.4	0.11	29	0.14
Sewer	354	2.3	0.22	11	0.31
Sewer	354	(0.5)	0.27	(1.9)	0.38
Sewer	350	(1.3)	0.16	(8.1)	0.23
Cutter	368	ND	0.85	—	1.2
Cutter	381	3.4	0.90	3.8	1.2
Bundler	363	(1.1)	0.72	(1.5)	0.99
Bundler	360	2.3	0.66	3.5	0.92

ETS poses an increased risk of lung cancer and possibly heart disease to occupationally exposed workers.[18] The best method for controlling worker exposure to ETS is to eliminate tobacco use from the workplace and to implement a smoking cessation program.

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Editorial Note: Alan Echt and Gregory A. Burr are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation is contained in Health Hazard Evaluation Report No. 93-0028-2366, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800)35-NIOSH.