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SUMMARY

Investigators from the National Institute for Occupational Safety and Health (NIOSH) performed a health hazard evaluation (HHE) at Ohio University in response to a request from the University's Health and Safety Department. The request was to evaluate construction workers' exposures to organic solvent vapors during the removal of asbestos-containing tile mastic. On August 3-4, 1992, NIOSH investigators visited the University. During this visit, investigators spoke with representatives of the University's Health and Safety Department, the environmental firm supervising the abatement, and the contractor performing the abatement, and performed air monitoring to determine the workers' exposures to solvent vapors.

Seven personal breathing zone air samples (PBZ) and one area air sample were collected over a portion of one shift (3.5 to 5 hours). The area sample and a bulk sample of the solvent were analyzed qualitatively by gas chromatography with mass spectroscopy (GC-MS). Based on the results from qualitative analysis, the PBZ samples were analyzed quantitatively by GC for ethylene glycol monobutyl ether (EGBE), and total refined petroleum solvent (RPS).

Exposures ranged from 8 to 107 milligrams per cubic meter (mg/m^3) for EGBE, and from 42 to 410 mg/m^3 for RPS. During the partial shifts that were monitored, six of the workers were exposed to EGBE at levels above the NIOSH Recommended Exposure Limit (REL) of 24 mg/m^3. Three workers were exposed to RPS at levels that were above the REL of 350 mg/m^3. Exposures to EGBE were below the OSHA Permissible Exposure Limit (PEL) of 240 mg/m^3 for the construction industry.

The results indicate that workers were potentially overexposed to ethylene glycol monobutyl ether and refined petroleum solvent. This indicates a need for routine exposure monitoring for organic vapors during the use of solvents to remove tile mastic. Recommendations provided include changes in work practices, and improved use of personal protective equipment.

KEYWORDS: SIC 1799 (Special Trade Contractors. Not Elsewhere Classified); tile mastic; asbestos abatement; solvents; ethylene glycol monobutyl ether; 2-butoxyethanol; butyl cellosolve.®

INTRODUCTION

Investigators from the National Institute for Occupational Safety and Health (NIOSH) performed a health hazard evaluation (HHE) at Ohio University, Athens, Ohio, in response to a request from the University's Health and Safety Department. The request was to evaluate construction workers' exposures to organic solvents during the removal of asbestos-containing tile mastic. On August 3, 1992, NIOSH investigators visited the University and spoke with representatives of the University's Health and Safety Department, the environmental firm hired by the university to manage the abatement, and the abatement contractor. On August 4, air monitoring was performed to measure workers' exposures to solvent vapors.

BACKGROUND

A contractor was employed by Ohio University to remove asbestos-containing materials (ACM) from Porter Hall, a five-story structure built in 1959. The ACM primarily consisted of floor tile (52,000 square feet), ceiling tile (274 square feet), and thermal system insulation (14,000 linear feet). The abatement project began in July 1992, with completion predicted to be in September 1992. Removal began on the fifth floor, with the intent of finishing one floor at a time until removal on all five floors was completed.

The removal of floor tile often includes the removal of the tile mastic, the adhesive which bonds the tile to the floor. Organic solvents are commonly used to remove the mastic. The organic solvent used to remove mastic from the fourth floor of Porter Hall on the morning of August 4, was Sentinel 747™, a mixture of refined petroleum solvents including ethylene glycol butyl ether (EGBE).

The solvent was applied by spraying it onto the floor with a hand-held chemical sprayer, spreading the solvent across the mastic-containing surface using a push broom, waiting approximately 15 minutes while the solvent dissolves the mastic, then collecting the mixture of solvent and dissolved mastic using a squeegee and a wet vacuum. (For floor surfaces near walls and door jams, cloth rags and putty knives were used to remove the solvent-mastic mixture.)

The removal of the tile mastic was performed under containment (outside walls and doorways had been sealed off with polyethylene plastic) with air filtration devices (AFDs) used to provide negative pressure in the containment area. (The representative of the environmental firm reported that the contract specified a pressure differential of -0.02" water gauge inside the containment which is consistent with the requirements of the Occupational Safety and Health Administration's [OSHA] asbestos-in-construction standard [29 CFR* 1926.58].)[1]

The abatement crew consisted of 20 workers, 19 of whom were male. They typically work four 10-hour shifts per week. Hours generally spent in containment were

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* *Code of Federal Regulations*. See References

reportedly from 7:00 to 11:45 in the morning, and from 1:00 to 5:45 in the afternoon. The number of workers assigned to containment at a given time is based on the type and status of the project. On August 4, there were seven workers inside containment in the morning and three in the afternoon. (The remaining workers were preparing other floors for ACM removal.) On August 4, mastic removal was only performed in the morning shift because Sentinel 747™ was ineffective at removing the mastic that remained on the fourth floor.

During the removal of mastic, workers wore protective suits and half-face respirators which were provided by the employer. The suits were made of 100% spunbonded polypropylene. The respirators were equipped with high-efficiency particulate air (HEPA) filters and organic vapor cartridges. One worker wore leather gloves which he reported had been supplied by the employer. Eye protection was not worn by any of the workers.

METHODS

Seven personal breathing zone (PBZ) air samples, and one area air sample were collected from approximately 7:30 to 11:30 on the morning of August 4, 1992. Sample collection and analysis was performed using a modification of NIOSH Method 1500.[2] Sample air was drawn through a 150 milligram (mg) charcoal tube at a flow rate of either 50 or 200 cubic centimeters per minute (cc/min). The sampling times are provided in Table 1 in the Results and Discussion Section of this report. The area sample and a bulk sample of the solvent were analyzed qualitatively by gas chromatography combined with mass spectroscopy (GC-MS). Based on the results from the qualitative analysis, the PBZ samples were analyzed quantitatively by GC for EGBE and RPS. The solvent used for desorption of the charcoal was 5% isopropanol in carbon disulfide. The limits of detection (LOD) provided by the laboratory were 0.005 and 0.03 milligrams per sample for EGBE and RPS respectively. The limits of quantitation (LOQ) provided by the laboratory were 0.02 and 0.1 milligrams per sample for EGBE and RPS respectively.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to ten hours per day, 40 hours per week, for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled to the level set by the evaluation criterion. These combined effects are often not considered by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[3] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[4] and 3) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs) for general industry.[5] For the construction industry, OSHA adopted the 1970 ACGIH TLVs[6] as exposure limits.[7**] The OSHA exposure limits may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that employers are legally required to comply with OSHA standards and meet those levels specified by OSHA PELs.

An 8-hour time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values (C) which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures. STELs are defined as 15 minute TWA exposures which should not be exceeded at any time during the workshift. Ceiling values are limits for instantaneous exposures which should not be exceeded at any time during the work shift.

Ethylene Glycol Monobutyl Ether

Ethylene glycol monobutyl ether (EGBE), also known as 2-butoxyethanol and Butyl Cellosolve,® is a colorless liquid with a mild ether odor. Inhalation of EGBE has been

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** OSHA is currently in the process of updating the PELs for the construction industry.

reported to cause eye and mucous membrane irritation in humans at air concentrations of approximately 500 mg/m^3, and to be hematoxic*** in animals (rodents).[8] The NIOSH REL is 24 mg/m^3 as an 8-hour TWA. The REL was extrapolated from animal toxicity data (rats). It is intended to prevent hematoxicity, but should also prevent eye and mucous membrane irritation. The OSHA PEL is 240 mg/m^3 as an 8-hour TWA for the construction industry. This level was intended to prevent irritation.[9] In addition to uptake from inhalation exposures, EGBE is absorbed through the skin.[10] For this reason, both skin and respiratory uptake should be considered when evaluating workers exposures to EGBE.

Refined Petroleum Solvents

Refined petroleum solvents (RPS) refer to organic solvents derived from the refining of crude oil, usually through fractional distillation. NIOSH recommends an exposure limit of 350 mg/m^3 as an 8-hour TWA for RPS that contain less than 20% aromatic hydrocarbons.[11] This recommendation was based on toxicity data that related animal and human exposures to eight mixtures of organic solvents with resulting health effects. Of these mixtures, the one closest in composition to Sentinel 747™ is "140 flash aliphatic solvent," a class of stoddard solvent comprised of approximately 96% aliphatic hydrocarbons with five to twelve carbon atoms, and the remaining 4% comprised of aromatic hydrocarbons. The REL of 350 mg/m^3 for stoddard solvent is intended to prevent sensory irritation and long-term health effects that include renal and nervous system toxicity. The OSHA PEL for stoddard solvent is 1150 mg/m^3 for the construction industry. This level was intended primarily to prevent irritation.[9]

Dermal exposure to stoddard solvents, and organic solvents in general, are capable of causing irritant contact dermatitis (swelling of the skin). The clinical signs associated with solvent exposures may include reddening, scaling, and fissuring of the skin.[12] In addition, dermatitis can reduce the effectiveness of the skin as a protective barrier to the absorption of chemicals, thereby increasing the individuals potential for exposure.[13]

RESULTS AND DISCUSSION

Air Monitoring

PBZ exposures to EGBE ranged from 8 to 107 mg/m^3 and from 42 to 410 mg/m^3 to RPS; these results are tabulated in Table 1. Six workers were exposed to EGBE at levels above the NIOSH REL of 24 mg/m^3, and three workers were exposed to RPS at levels above the REL of 350 mg/m^3. Exposures of all workers were below the OSHA

Table 1
Air Monitoring Results

Worker #	Sample Period	mg/m^3 EGBE	mg/m^3 RPS
1	0702-1145	73	270
2	0727-1149	8	42
3	0804-1146	84	400
4	0709-1148	37	170
5	0707-1148	30	130
6	0725-1147	107	410

*** Toxic damage of the blood forming system.

construction industry PELs of 240 mg/m^3 for EGBE and 1150 mg/m^3 for stoddard solvent.

The results indicate that several workers were potentially overexposed to EGBE and RPS. This conclusion is based on the monitoring of a portion of one shift (3.5 to 5 hours), and comparing these exposures to the 8-hour TWA exposure limits. Based on reports of typical work operations, this comparison is appropriate because workers generally perform similar work between the afternoon and morning shifts. The reason that the work differed in the afternoon of August 4 was that the Sentinel 747™ was ineffective at removing the mastic that remained on the fourth floor.

If properly fitted and maintained, the half-face respirators used are approved by NIOSH for environments with air concentrations of up to ten times that of the exposure limit. However, maintenance and fit problems were identified that may have resulted in an actual protection level of less than ten for some of the respirators used.

The use of respirators to prevent overexposures to workers requires the implementation of a complete respirator program that is consistent with 29 CFR 1910.134.[14] (A list of some of the requirements for such a program are presented in Appendix I of this report.) One of the requirements of this standard is that workers' exposures be evaluated. Representatives of the abatement contractor and the environmental consulting firm reportedly had not performed monitoring to evaluate workers' exposure to solvents during the removal of tile mastic.

An additional requirement of the respiratory standard is to provide a respirator maintenance program. The program should include: routine inspection (before and after each use), cleaning and disinfecting, repair, and proper storage. NIOSH investigators noted that exhalation valve covers were missing from two of the workers' respirators which indicates that there is a need for improvements in the maintenance program. The valve cover protects the exhalation valve from being damaged. A damaged valve could allow contaminated air to enter the respirator through the exhalation port. Respirators with a missing cover are not considered to be approved, therefore, their use is a violation of the OSHA respiratory standard. (In general, a respirator that is structurally different from the complete unit which was tested and certified by NIOSH, is not considered an approved respirator.)[15]

Several workers reported that the respirators worn were uncomfortable near the bridge of the nose. In addition to causing discomfort, this may cause workers to frequently shift their respirators, potentially leading to a reduction in the level of protection provided by the respirator. This may be alleviated by providing respirators of various sizes and from at least two manufacturers, which are requirements listed in Appendix C of the Asbestos Construction Standard (29 CFR 1926.58).[1]

In attempting to control workers' exposures to chemicals, substitution with a less harmful material, or the implementation of engineering controls are preferred over the use of respirators because the effectiveness of substitution and engineering controls does not depend on the worker to properly use and care for a respirator.

During the afternoon of August 4, workers tested several products in an attempt to remove a mastic which Sentinel 747™ was ineffective in removing. In addition to the product's effectiveness, the relative hazard presented by the use of various chemical products should be considered when choosing the product(s). Unfortunately, this information may not be available to the contractor in any form other than the MSDS which often does not contain adequate toxicity data. In this situation, an industrial hygienist or other occupational health professional should be able to provide information on the relative toxicity of the products being considered for use.

Engineering controls can include changes in the process which are designed to reduce exposures, or providing ventilation in order to contain and remove contaminants.

Other methods of removing tile mastic include mechanically scraping the mastic from the floor using hand-held tools or beadblasting with hardened steel shot. Scraping by hand is not considered to be economically feasible for large projects such as Porter Hall. Beadblasting is reported to be effective, but requires expensive equipment. In addition, both of these methods may increase workers' exposures to asbestos fibers because they: 1) break up the mastic, increasing the potential of it becoming friable, and 2) are dry methods, whereas the solvent method keeps the mastic material wet, thus reducing the chance of fibers becoming airborne. For these reasons, many contractors prefer the solvent method.

There are two general categories of ventilation for reducing chemical exposures: local exhaust ventilation (LEV) and general ventilation. If feasible, LEV is the preferred method of control because it is designed to capture emissions at the source. However, because the source of emissions during the removal of mastic are large floor surfaces, LEV is not likely to be feasible.

In contrast to LEV, general ventilation attempts to lower the concentration of contaminants by exchanging contaminated air with "clean air." The AFDs, which are used to prevent the escape of asbestos fibers from the containment area, also provide general exhaust ventilation by providing "clean air" from outside the containment area and exhausting room air directly to the outside. An increase in the number of AFDs would reduce solvent exposures, however, the amount of ventilation necessary to reduce all exposures to below the occupational limits may be impractical. For example, to reduce the highest personal EGBE exposure of 107 mg/m^3 to below the REL of 24 mg/m^3 would require an increase in ventilation of approximately 500% (assuming similar mixing of EGBE in the room air) or a 5-fold increase in the number of AFDs. It may be more appropriate to limit removal to smaller areas and concentrate the available AFD in that area. However, in order to determine the level of exposure reduction necessary, and the effectiveness of control methods, it is necessary that exposures be evaluated by the employer.

Work Practices

An additional route of exposure that was not measured during this investigation was absorption of EGBE through the skin. Gloves appropriate to control dermal exposures were not worn by workers. One worker did wear leather gloves which became soaked with the solvent-mastic mixture. The use of leather gloves may have actually increased his exposure relative to other workers because of the prolonged contact between the skin surface and the solvent-soaked leather.

In addition to dermal absorption through the skin of the hand, workers were observed wiping their hands and tools on the suit material covering their arms and legs. This practice presents another source of dermal exposure.

There was also a potential for dermal exposure if the footwear worn by workers, which varied from tennis shoes to knee-high rubber boots, allowed the solvent to come in contact with the skin. Footwear made of a material that offers good resistance to penetration by the solvent would reduce the potential for dermal exposure. In addition, several workers were observed to slip on floor surfaces that were wet from the solvent. The use of footwear with non-skid soles would reduce the potential for accidental falls and strains.

Workers did not wear eye protection on the day of the investigation. Wearing eye protection during the use of organic solvents is warranted in order to reduce the hazard of a splash into the eyes, and also to reduce eye irritation which may be experienced as a result of exposures to solvent vapors. Options for adequate eye protection from splash include chemical goggles, a face shield, or a full-face respirator. Only unvented chemical goggles or full-face respirators can protect the eyes from irritating vapors. It is important that the use of eye protection not interfere with the face seal of the respirator, a requirement that restricts the use of chemical goggles to those models which have been designed to be worn with a half-face respirator. (These goggles are shaped differently in order that they not interfere with the respirator seal at the nose bridge.) Also, employees may find it cumbersome or uncomfortable to wear the half-face respirator and goggles. The use of a full-face respirator may provide a solution to both of these potential problems.

It is likely that the use of a vacuum cleaner to collect the solvent-mastic mixture increased exposures by aerosolizing the mixture. The manufacturer of Sentinel 747,™ recommends the use of clay-based or litter-box absorbents to facilitate disposal and reduce aerosolization.[16]

RECOMMENDATIONS

1. The use of Sentinel 747™, and other organic solvents to remove tile mastic, represents a potential health hazard that should be evaluated by the abatement contractor. If they do not possess the expertise or resources to evaluate exposures, an industrial hygienist should be consulted.

2. The employer should develop a written respiratory program for his employees that is consistent with the occupational respiratory protection standard, 29 CFR 1910.134. This program should include provisions for routine inspection and maintenance of respirators. The two respirators that were missing exhalation valve covers should have covers installed which were specifically manufactured for those respirators.

3. The employer should provide a variety of respirator sizes and/or models which every worker required to wear a respirator can choose from in order to achieve an effective and comfortable fit.

4. To reduce the potential for dermal exposure to EGBE, the employer should provide, and require the use of gloves made of butyl rubber, Saranax®, or a material with comparable resistance to penetration by EGBE.

5. The employer should provide boots designed to be chemical resistant, made of rubber, neoprene, or a material of comparable resistance to organic solvents. The boots should also have a non-skid sole to reduce the potential for accidental falls and strains.

6. The employer should provide employees with adequate eye protection to reduce the potential for solvent to splash into the eye, and to reduce the potential for eye irritation from exposures to solvent vapors.

7. The employer should discourage the practice of employees wiping their hands and tools (putty knives) onto the suit material.

8. An alternative to using a vacuum cleaner to collect the solvent-mastic mixture, such as the use of a solid absorbent, should be investigated by the employer.

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APPENDIX I

Introduction

The Occupational Safety and Health Administration's General Industrial Standard on respiratory protection, 29 CFR 1910.134, which also applies to construction industry, requires that a respiratory protection program be established by the employer and that appropriate respirators be provided and be effective when such equipment is necessary to protect the health of the employee. They should be used as a primary control for employee protection only where engineering controls are not feasible or are currently being installed. The standard requires the employer to address ten basic requirements which would provide for an acceptable respiratory protection program. These requirements are summarized below for easy reference:

I. Provide Written Operating Procedures

The employer must prepare written standard operating procedures governing the selection and use of respirators. The procedures must include a discussion or explanation of all items specified in 29 CFR 1910.134(b).

II. Proper Selection of Respirator

The proper selection of a suitable respirator is dependant upon a number of parameters including: physical nature of the contaminant, concentration of contaminant in the air, toxicity of contaminant and warning properties of the substance (e.g., odor or irritation, which can indicate the end of the service life of the respirator).

III. Training and Fitting for the Employee

Requires that the user be instructed and trained in the proper use of respirators and their limitations, as well as with their maintenance. Qualitative fit testing of respirators fit in a test atmosphere is required. Some OSHA standards now require quantitative fit testing before assignment of a respirator to any employee. In addition, the employee shall be familiar with personal face fit testing techniques and perform this practice of fitting each time the respirator is worn.

IV. Cleaning and Disinfecting

Respirators should be cleaned and disinfected on a daily basis if used routinely throughout the day or less frequently if used less often. Respirator cleanliness is particularly important in dusty environments or where respirators are shared by several individuals.

V. Storage

Respirators should be stored in a dry, clean storage area which is protected from extremes in temperature, sunlight or physical damage.

VI. Inspection and Maintenance

Inspection schedules vary in frequency for specific types of respiratory protection equipment but should at least be inspected for damage or malfunctions both before and after each daily use. Records must be kept for emergency use respirators of at least monthly inspection dates and the inspectors findings. Developing a check list of items to look for is a good idea when inspecting any reusable respirator.

VII. Work Area Surveillance

Surveillance by the employer of the work area is required and includes identification of the contaminant, nature of the hazard, concentration at the breathing zone, and if appropriate, biological monitoring.

VIII. Inspection and Evaluation of Program

The effectiveness of the instituted program measures should be periodically evaluated. It is the employer's responsibility to administer the respiratory protection program so that it is effective. This includes mandatory employee participation where appropriate and provision of all other items cited herein.

IX. Medical Examination

It is required that a medical assessment of the employees ability to wear a respirator be performed prior to providing him with a respirator.

X. Approved Respirators

Only respiratory protection devices approved by NIOSH or MSHA, or both, can be used. Interchanging parts of different respirators nullifies approval.

Further information on respirators and instructions for establishing an appropriate respiratory protection program can be found in the NIOSH guide to Industrial Respiratory Protection, DHHS (NIOSH) Publication No. 87-116. Single copies are available free and can be obtained from:

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