NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2004-0038-2966
US Roofing Contractors
Philadelphia, PA

May 2005

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

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

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Chandran Achutan and Rick Driscoll of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Dino Mattorano and Lynda Ewers of HETAB. Analytical support was provided by DataChem, and Ardith Grote, Robert Streicher and Kathleen Ernst of the Division of Applied Research and Technology. Desktop publishing was performed by Shawna Watts. Editorial review was performed by Ellen Galloway.

Copies of this report have been sent to International and Local United Union of Roofers, Waterproofers and Allied Workers, and management representatives at US Roofing Contractors, and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of MDI and Volatile Organic Compound Exposures to Roof Installers

NIOSH conducted an evaluation at US Roofing Contractors, at the request of the United Union of Roofers, Waterpoofers and Allied Workers. The request asked NIOSH to evaluate exposures to 4,4'-Methylene-bisphenyl isocyanate (MDI) and volatile organic compounds (VOCs) during a roof installation process.

What NIOSH Did

- We took personal breathing zone (PBZ) and area air samples for MDI during polyurethane foam spraying.
- We took PBZ and area air samples for VOCs during the spray gun cleaning process.
- We took PBZ air samples for VOCs during the roof installation process.
- We conducted confidential medical interviews with seven employees.

What NIOSH Found

- Personal exposure to MDI exceeded exposure criteria for full-shift and short-term samples.
- Personal exposure to VOCs did not exceed exposure criteria.
- Employees reported symptoms that were consistent with overexposure to MDI.
- We observed poor hygiene practices such as eating at the workplace before washing hands.
- We observed poor work practices such as improper use of respirators.

What US Roofers Managers Can Do

- Improve their respiratory protection program.
- Install portable hand washing stations.
- Train employees on hazards associated with MDI and organic solvents.
- Prohibit smoking in the work area.

What the US Roofers Employees Can Do

- Be aware of the chemical contamination all around them.
- Shave before donning a respirator.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2004-0038-2966

Health Hazard Evaluation Report 2004-0038-2966
US Roofing Contractors
Philadelphia, PA
May 2005

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SUMMARY

On November 4, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Union of Roofers, Waterproofers and Allied Workers to conduct a health hazard evaluation (HHE) at US Roofing Contractors in Philadelphia, Pennsylvania. The request asked NIOSH to evaluate employee exposures to 4,4'-Methylene-bisphenyl isocyanate (MDI) during the spray application of FastTrack 100® polyurethane foam, and exposures to volatile organic compounds (VOCs) during the rubber roofing membrane installation and spray gun cleaning. The request stated that employees had reported respiratory symptoms such as difficulty breathing, coughing, chest tightness, and skin irritation, which they believe may be work related.

A total of 26 full-shift, task-based, and short-term personal breathing zone (PBZ) samples for MDI and VOCs were collected on October 13, 2004 and on October 25-28, 2004. Confidential medical interviews with seven employees were completed on October 14, 2004.

More than 50% of the PBZ samples for MDI exceeded the NIOSH Recommended Exposure Limit of 50 micrograms per cubic meter (µg/m^3), and the NIOSH and OSHA ceiling limit of 200 µg/m^3. The VOC PBZ results were all below exposure criteria. Of the seven respondents interviewed using a standard questionnaire, four reported symptoms that they attribute to FastTrack 100 exposure. These symptoms ranged in severity from stuffy nose, itchy/watery eyes, to shortness of breath and wheezing. Of the four workers reporting symptoms, three reported chest tightness, cough, sinus congestion, and shortness of breath and two workers reported headaches. One worker with no previous history of asthma reported a combination of wheezing, shortness of breath, and cough that met our case definition for presumptive work-related asthma; this worker was strongly advised to have his respiratory symptoms evaluated by his personal physician for possible occupational asthma. In the event that any worker is determined to have an MDI-associated occupational asthma, he or she must be reassigned to a job that does not involve exposure to MDI-containing materials.

NIOSH investigators conclude that a health hazard exists from exposure to MDI during the polyurethane foam application. Recommendations are provided to reduce exposures to roofers during the spraying of MDI-containing foam, including respiratory protection.

Keywords: 1761 (Roofing, Siding and Sheet Metal work), 4,4'-Methylene-bisphenyl isocyanate, MDI, roofers, volatile organic compounds, respiratory effects

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INTRODUCTION

On November 4, 2003, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Union of Roofers, Waterproofers and Allied Workers to conduct a health hazard evaluation (HHE) at US Roofing Contractors in Philadelphia, Pennsylvania. The request asked NIOSH to evaluate employee exposures to 4,4'-Methylene-bisphenyl isocyanate (MDI) during the spray application of FastTrack 100® polyurethane foam, and to volatile organic compounds (VOCs) during the installation of the rubber roofing membrane and solvent cleaning of the spray gun. The request also stated that employees had reported respiratory symptoms such as difficulty breathing, coughing, chest tightness, and skin irritation, which they believed may be work related.

An opening conference was held on October 12, 2004, between NIOSH representatives, management officials, the Local 30 union representative, and staff members from the Center to Protect Workers' Rights (CPWR). The CPWR was involved at the invitation of union officials. US Roofing Contractors identified a hospital roof in Paoli, Pennsylvania, as a potential work site. NIOSH investigators had planned to conduct air sampling and medical evaluations from October 13-15, 2004. However, due to inclement weather, air sampling for MDI and VOCs was only conducted on one day (October 13, 2004). Medical interviews were conducted on October 14, 2004 to ascertain health issues related to the work environment. Between October 25-28, 2004, NIOSH investigators returned to this job site to further assess employee exposures to MDI and VOCs.

BACKGROUND

The first step in the roof installation process is to remove the old insulation and clear the area of all debris. Patch areas where old insulation has been removed are first sprayed with adhesive foam and new board insulation is pressed into the space and cut to fit. The roofers typically kneel on the board insulation while fitting it into place. After repairs are completed, the roof is ready for the rubber membrane to be applied to the roof with a foam containing MDI.

As a section of the roof is sprayed with foam, the roofers wait for a few minutes for the foam to react with the floor before rolling the membrane into the foam. Using weighted rollers, brooms, and hand rollers, the roofers then push down the membrane covering the expanding foam.

A "hose-helper" stands behind the foam sprayer to keep the hose centered on the sprayer's back, and to take up the slack. Once the spraying is completed, the spray gun is detached for cleaning by the equipment operator. The spray gun parts are cleaned by heating them in a crock pot containing a cleaning solvent. The main constituents of this cleaning solvent are N- methyl-2-pyrrolidinone and 2(2 butoxyethoxy) ethanol. The equipment operator cleans the spray gun parts. This employee also maintains the respirators for the crew, and on occasion, assists the crew in the roof application.

The areas sprayed during the NIOSH visits ranged from approximately 25 to 900 square feet, with a median of 200 square feet. Five to eight roofers were present at any one time during the spraying and roof installation.

METHODS

Industrial Hygiene Evaluation

Area air samples (samples collected in fixed locations) and personal breathing zone samples (PBZ) were collected for MDI and VOCs. The PBZ samples included full-shift (samples collected over the entire workday), task-based (samples collected during MDI foam spraying), and short-term (samples collected for approximately 15 minutes during MDI foam spraying) samples. MDI was sampled and analyzed according to the NIOSH Manual of Analytical Methods (NMAM) 5525[1]. MDI was collected using spill-resistant impingers containing 15 milliliters (mL) of 3% 1 (9 anthracenylmethyl) piperazine in butyl benzoate. The impingers were placed in leather holders and pinned on the workers' lapels, to approximate their breathing zone. The impingers were connected to a battery-operated personal sampling pump placed on the workers' belts. The pumps were set to a flow rate of 1 liter per minute. During the October 13, 2004 survey, this connection was made via Tygon® tubing. During the subsequent survey, an additional impinger was connected between the spill-resistant impinger on the worker and the pump, to trap any excess solution overflowing from the spill-resistant impinger. In addition, the Tygon tubing was replaced with chemical-resistant Fluran® tubing, so that the pooled solution was not contaminated with the chemical residues in Tygon tubing.

Full-shift, short-term, and task-based PBZ samples for MDI were collected from seven roofers during the October 13, 2004 survey, and from eight roofers during the October 25-28, 2004 survey for a total of 26 samples. Twenty area samples were collected over both survey dates.

Air samples for VOCs were collected during the roof installation, and during the cleaning of the spray guns used to apply the polyurethane foam. Air samples were collected using thermal desorption tubes for qualitative analysis and charcoal tubes for quantitative analysis. Thermal desorption tubes were sampled at a flow rate of 50 milliliters per minute (mL/min) and analyzed per NMAM 2549.[2] The charcoal tubes were run at a flow rate of 200 mL/min, and analyzed by a combination of NMAM 1302 and NMAM 2501. Based on the thermal desorption sample results, xylene, toluene, ethylbenzene and aliphatic hydrocarbons were identified for quantification by the charcoal tube samples.

Epidemiologic Evaluation

Confidential interviews were conducted with each of the seven workers on duty October 14, 2004. In addition, each participant completed a respiratory symptom questionnaire. The questionnaire, based upon both the American Thoracic Society's Standardized Adult Questionnaire and the NIOSH Asthma Questionnaire, asked workers whether they had ever been diagnosed with asthma, whether they wheeze when breathing, have a persistent cough, or experience difficulty breathing. In addition to the respiratory questionnaire, pulmonary function records were reviewed. Two workers had 3 years of records, two had 2 years and one worker had only 1 year for review.

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 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases 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 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, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[5] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Isocyanates

The feature common to all diisocyanates (monomers) is the presence of two -N=C=O (isocyanate) functional groups attached to an aromatic or aliphatic parent compound. These compounds are widely used in surface coatings, polyurethane foams, adhesives, resins, elastomers, binders, and sealants.

Exposure to isocyanates is irritating to the skin, mucous membranes, eyes, and respiratory tract.[6,7] The most common adverse health outcome associated with isocyanate exposure is asthma due to sensitization; less prevalent are contact dermatitis (both irritant and allergic forms) and hypersensitivity pneumonitis (HP).[7,8,9] Contact dermatitis can result in symptoms such as rash, itching, hives, and swelling of the extremities.[6,9] A worker suspected of having isocyanate-induced asthma/sensitization exhibits the traditional symptoms of acute airway obstruction, e.g., coughing, wheezing, shortness of breath, tightness in the chest, and nocturnal awakening.[6,8] An isocyanate-exposed worker may first develop an asthmatic condition (i.e., become sensitized) after a single (acute) exposure, but sensitization usually takes a few months to several years of exposure.[6,8,10,11,12] The asthmatic reaction may occur minutes after exposure (immediate), several hours after exposure, or a combination of both immediate and late components after exposure (dual).[8,11] The late asthmatic reaction is the most common, occurring in approximately 40% of isocyanate-sensitized workers.[13] After sensitization, any exposure, even to levels below an occupational exposure limit or standard, can produce an asthmatic response that may be life threatening. Diagnosis of isocyanate induced asthma requires a thorough occupational history. As with other asthmatic conditions, pulmonary function tests may be within normal limits between episodes. In controlled laboratory environments, provocation testing may be used in diagnosis.

Experience with isocyanates has shown that monomeric, prepolymeric and polyisocyanate species are capable of producing respiratory sensitization in exposed workers.[14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30] Since the intermediates may be chemically similar to these compounds, it is reasonable to assume that they may also produce this condition. Prevalence estimates for isocyanate-induced asthma in exposed worker populations vary considerably: from 5% to 10% in diisocyanate production facilities[10,31] to 25% in polyurethane production plants[31,32] and 30% in polyurethane seatcover operations.[33] The scientific literature contains a limited amount of animal data suggesting that dermal exposure to diisocyanates may also produce respiratory sensitization.[34,35,36,37] This finding has not been tested in dermally exposed workers.

Hypersensitivity pneumonitis (HP) also has been described in workers exposed to isocyanates.[38,39,40,41] Currently, the prevalence of isocyanate-induced HP in the worker population is unknown, and is considered rare compared to the prevalence rates for isocyanate-induced asthma.[9] Whereas asthma is an obstructive respiratory disease usually affecting the bronchi, HP is a restrictive respiratory disease affecting the lung parenchyma (bronchioles and alveoli). The initial symptoms associated with isocyanate-induced HP are flu-like, including shortness of breath, non-productive cough, fever, chills, sweats, malaise, and nausea.[8,9] After the onset of HP, prolonged and/or repeated exposures may lead to an irreversible decline in pulmonary function and lung compliance, and to the development of diffuse interstitial fibrosis.[8,9] Early diagnosis is difficult since many aspects of HP, i.e., the flu-like symptoms and the changes in pulmonary function, are common to many other respiratory diseases and conditions.

The only effective intervention for workers with isocyanate-induced sensitization (asthma) or HP is cessation of all isocyanate exposure. This can be accomplished by removing the worker from the work environment where isocyanate exposure occurs, or by providing the worker with supplied-air respiratory protection and preventing dermal exposures.

NIOSH and OSHA have established a ceiling concentration of 200 micrograms per cubic meter of air (µg/m^3) as a ceiling (10-minutes) concentration not to be exceeded. NIOSH has also established a REL of 50 µg/m^3 as a time-weighted exposure not to be exceeded as an average during any work period of up to 10 hours. The ACGIH has established a TLV of 51 µg/m^3 as a time-weighted average not to exceed 8 hours.

The United Kingdom Health and Safety Executive (UK-HSE) has developed a standard based on the concentration of total reactive isocyanate groups (TRIG) in a volume of air.[42] Airborne TRIG concentrations can be determined using data from NMAM 5525. First, the monomer and oligomer concentrations are summed to obtain the total weight of isocyanate-containing compounds in a given air sample. Next, the molecular weight of the isocyanate functional groups in the parent compound is divided by the molecular weight of the parent compound. This yields a constant that reflects the percentage of a compound's molecular weight contributed by the TRIGs. For MDI and MDI-based oligomers, the TRIG constant is 0.34. Finally, the total weight of isocyanate containing compounds in a given air sample is multiplied by the TRIG constant. The product is the concentration of TRIGs in air. The UK-HSE ceiling limit for TRIGs is 70 µg/m^3 and the full-shift TWA is 20 µg/m^3.

Xylenes

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group (CH_3) substitutions. Xylene is used in paints and other coatings, and as a raw material in the synthesis of organic chemicals, dyes, and pharmaceuticals.

The vapor of xylene has irritant effects on the skin and mucous membranes, including the eyes and respiratory tract. This irritation may cause itching, redness, inflammation, and discomfort. Repeated or prolonged skin contact may cause erythema, drying, and defatting which may lead to the formation of vesicles (liquid-filled sacs). At high concentrations, repeated exposure to xylene may cause reversible damage to the eyes.[43]

Acute xylene inhalation exposure may cause headache, dizziness, incoordination, drowsiness, and unconsciousness.[44] Previous studies have shown that concentrations from 60 to 350 ppm may cause giddiness, anorexia, and vomiting.[43] At high concentrations, exposure to xylene has a narcotic effect on the central nervous system

(CNS), and minor reversible effects on the liver and kidneys.[43,44,45]

Historical accounts of hematopoietic (formation of blood cells) toxicity as a result of xylene exposure are likely due to the high concentration of benzene contamination in xylene prior to 1940. These effects are not associated with contemporary xylene exposure.[44,46,47]

The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are 100 ppm as an 8-hour TWA. In addition, OSHA and NIOSH have published STELs for xylene of 150 ppm averaged over 15 minutes.

Toluene

Toluene is a colorless, aromatic organic liquid containing a six carbon ring (a benzene ring) with a methyl group (CH_3) substitution. It is a typical solvent found in paints and other coatings, and used as a raw material in the synthesis of organic chemicals, dyes, detergents, and pharmaceuticals.

Inhalation and skin absorption are the major occupational routes of entry. Toluene can cause acute irritation of the eyes, respiratory tract, and skin. Since it is a defatting solvent, repeated or prolonged skin contact will remove the natural lipids from the skin which can cause drying, fissuring, and dermatitis.[43,48]

The main effects reported with excessive (inhalation) exposure to toluene are CNS depression and neurotoxicity.[43] Studies have shown that subjects exposed to 100 ppm of toluene for six hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).[49,50,51] No symptoms were noted below 100 ppm in these studies. There are a number of reports of neurological damage due to deliberate sniffing of toluene-based glues resulting in motor weakness, intention tremor, ataxia, as well as cerebellar and cerebral atrophy.[52] Recovery is complete following infrequent episodes; however, permanent impairment may occur after repeated and prolonged glue-sniffing abuse. Exposure to extremely high concentrations of toluene may cause mental confusion, loss of coordination, and unconsciousness.[10,531154]

Originally, there was a concern that toluene exposures produced hematopoietic toxicity because of the benzene ring present in the molecular structure of toluene. However, toluene does not produce the severe injury to bone marrow characteristic of benzene exposure as early reports suggested. It is now believed that simultaneous exposure to benzene (present as a contaminant in the toluene) was responsible for the observed toxicity.[12,48,55]

The NIOSH REL for toluene is 100 ppm as an 8-hour TWA. NIOSH has also set a recommended STEL of 150 ppm for a 15-minute sampling period. The OSHA PEL for toluene is 200 ppm as an 8-hour TWA. The recently adopted ACGIH TLV® is 50 ppm for an 8-hour exposure level. This ACGIH TLV® carries a skin notation, indicating that cutaneous exposure contributes to the overall absorbed inhalation dose and potential systemic effects.

2(2-butoxyethoxy) ethanol

2(2-butoxyethoxy) ethanol is a colorless liquid with a mild odor. It may cause irritation to the respiratory tract. Symptoms may include coughing, sore throat, labored breathing, and chest pain. Prolonged skin contact causes mild to moderate local redness and swelling. The chemical can be absorbed through the skin with prolonged and widespread contact. It can also cause eye irritation, redness, and pain. Small, repeated exposures of this material are generally more toxic than single, large exposures. Chronic exposures may produce central nervous system and kidney effects.

N-methyl-2-pyrrolidinone

N-methyl-2-pyrrolidinone is a colorless liquid with a mild odor. The acute effects of the chemical include irritation to the eyes, skin, and respiratory tract. Prolonged or repeated skin contact with the liquid may lead to drying or cracking skin, and possible dermatitis. Overexposure may cause nausea, headache, dizziness, vomiting and weakness.

RESULTS

Industrial Hygiene Results

The PBZ results are provided in Table 1. Task-based results for MDI monomer were compared to the TWA by extrapolating the results to reflect an 8-hour workday. Sample IMP 37 was compared to a 300-minute workday to reflect actual length of time worked. When MDI containing polyurethane foam was not being sprayed, the worker's exposure was assumed to be zero. The extrapolated results are listed under the column "MDI Time-Weighted Average" in Table 1.

Of the 26 personal samples, 8 exceeded the NIOSH REL of 50 µg/m^3 and 6 exceeded the NIOSH ceiling limit of 200 µg/m^3 for MDI monomer. The sprayer had the highest exposure (76.5-178 µg/m^3 for the NIOSH REL; 78.2 328 µg/m^3 for the NIOSH Ceiling limit), while the operator had the lowest (exposures ranged from non-detected to 0.29 µg/m^3). MDI oligomers were detected in 24 of 26 samples, including two samples in which MDI monomer was not detected.

For the full-shift (TWA) samples and short-term samples, the TRIG was calculated by adding the "MDI monomer as NCO" and "MDI oligomer as NCO" columns, and multiplying it by 0.34. NCO refers to the nitrogen-carbon-oxygen functional group for isocyanates. For the task-based results, the sum of the "MDI monomer as NCO" and "MDI oligomer as NCO" columns is first extrapolated to reflect the TWA, and then multiplied by 0.34. The results are displayed in the "TRIG" column of Table 1. The UK-HSE criteria for TWA of 20 µg/m^3 was exceeded once, and the UK-HSE short-term limit of 70 µg/m^3 was exceeded twice.

Area sample results (Table 2) indicate that MDI monomer is not present in the environment up to 2 hours after the spraying has ceased. However, MDI-oligomers are present in the environment up to 2 hours after spraying has ceased. An area sample collected during employee lunch break showed detectable levels of MDI oligomers, but not the monomer.

The VOC PBZ results, presented in Table 3, were below all applicable criteria for toluene, xylene, and ethylbenzene. There are no exposure criteria for N-methyl-2-pyrrolidinone and 2(2 butoxyethoxy) ethanol.

Epidemiologic Evaluation Results

All seven employees completed the respiratory questionnaire at the worksite. Participants had worked with FastTrack 100 from 2 weeks to 5 years. Three workers reported no health problems or symptoms. Four of the seven respondents reported symptoms they attribute to the FastTrack 100 exposure. These symptoms ranged in severity from stuffy nose, itchy/watery eyes to shortness of breath and wheezing. Of the four workers reporting symptoms, three reported chest tightness, cough, sinus congestion, and shortness of breath and two workers reported headaches. One worker, with no previous history of asthma, reported a combination of wheezing, shortness of breath, and cough that met our case definition for presumptive asthma. This worker was referred to his personal physician to be evaluated for possible occupationally-induced asthma.

All records, with one exception, showed normal spirometry results. The one abnormal result showed borderline obstruction. Overall, the spirometry results showed excessive variability (greater than 5% variability) between spirometry trials, making it difficult to validly interpret the test results. In one case, pulmonary function parameters improved rather than declined (as would be expected with age).

DISCUSSION

The results from all of the October 2004 surveys show high exposures to MDI. The October 13, 2004 survey may have underestimated the MDI levels because of sample loss from the impingers. In these samples some fluid was lost when the impingers were tilted during increased worker activity. To minimize sample loss during the subsequent survey, personal sampling was limited to the time period when polyurethane foam was sprayed (task-based sampling). The TWA was determined by extrapolating the results to the actual number of hours worked. In addition, a back-up impinger was used during the second survey to collect overflow. Chemically inert tubing connected the impingers and, in the event of an overflow, the liquids from both the impingers would be pooled. However, sample loss during the second survey was minimal, and in most cases did not require solutions to be pooled.

The impinger method used in this survey (NMAM 5525) is suitable for collecting the fast-curing MDI monomer and the slower-reacting MDI oligomer. This method is more versatile than methods that employ filters as the collection medium, because the latter does not effectively capture the MDI monomer, potentially underestimating total MDI levels in the environment. The disadvantages of NMAM 5525 as a personal sampling method are that the impingers are bulkier to wear than the filters, and they are prone to spill or overflow if the employees are twisting, turning, and lying on their backs.

The results from the area samples show that no MDI monomer was present in the environment immediately after spraying. This is because MDI monomer is a fast-curing compound. However, the slower reacting MDI oligomer was present in the environment 2 hours after spraying was completed.

Roofers were potentially exposed to MDI via the inhalation, dermal, and ingestion routes. Roofers were observed wearing Protech® full face air purifying respirators with combination cartridges (chlorine, organic vapors, acids, and particulates), which if worn properly, can reduce MDI exposure through inhalation. However, for respirators to be effective and protect workers from harmful exposures they must be selected, inspected, and maintained properly. Respiratory protective devices should never be worn when a satisfactory face seal cannot be obtained. There are many conditions that may prevent a good seal between the worker's face and the respirator. Some of these conditions include facial hair, glasses, or an unusually structured face. We noticed many employees with facial hair donning respirators. In addition, employees were also observed partially removing the respirator to communicate with their coworkers. These actions may expose workers to potentially hazardous levels of MDI. US Roofing subcontracts the qualitative fit testing of respirators. Employees noted that when an employee with facial hair is fit tested, he might hold his breath to pass the fit-test. A computer-based quantitative test is more desirable because it is objective and more accurate. US Roofing Contractors has designated one employee to be responsible for cleaning and maintaining the respirators each day. Respirator cartridges are changed every other day on the respirator worn by the sprayer, and once a week on the respirators worn by the other roofers.

Most employees were wearing long-sleeved shirts while spraying foam. In the warmer months, we were told that employees either wear a short-sleeved shirt or are shirtless, all of which can increase the potential for dermal exposure. In addition, employees were observed wearing cotton gloves while spraying polyurethane foam during the rubber membrane installation. While cotton gloves provide dexterity, they may not adequately protect workers' hands from MDI exposure. Neoprene, nitrile, or butyl rubber gloves provide better protection against MDI than cotton gloves.

NIOSH investigators observed employees transferring chemicals from their original containers to smaller, improperly labeled soda containers. This practice creates the potential for someone to accidentally drink from the wrong container. This practice also violates the OSHA Hazard Communications Standard (CFR 1910.1200).[56]

Employees were observed eating, drinking, and smoking in the workplace without first washing their hands. They were also observed spreading chemicals with their bare hands. These practices can increase MDI exposure through ingestion of chemicals from hand to mouth. In addition, smoking in the presence of flammable liquids presents a safety hazard.

The insulation process employed by US Roofing Contractors involves spraying a layer of isocyanate-containing polyurethane foam, then installing insulation material. NIOSH staff was told that in some processes, multiple layers of polyurethane foam are sprayed in lieu of the insulation material. Isocyanate exposure to employees utilizing this latter process is expected to be higher than what was observed during this survey.

Sensitization to workplace materials can lead to occupational asthma in susceptible individuals. At least one of the seven workers interviewed was found to have symptoms consistent with MDI-associated occupational asthma; he was referred to his personal physician for evaluation.

CONCLUSIONS

MDI levels exceeded the NIOSH and OSHA full-shift and short-term standards. Employees wore their respirators improperly and had poor work practices and personal hygiene, which increased their exposure to MDI. If any worker is diagnosed with occupational asthma caused by exposure to MDI-containing roofing compounds, that worker should be immediately accommodated in a job that does not involve MDI exposure. Occupational asthma can be a life threatening condition, and workers who report wheezing or shortness of breath following exposure to MDI-containing materials should be referred for medical follow-up.

RECOMMENDATIONS

Based on the observations and the results of this survey, the following recommendations are made to improve employee health and safety.

1. Refer employees who wheeze or become short of breath following exposure to MDI roofing compounds to their personal physicians immediately to be evaluated for occupational asthma.
2. Assign employees diagnosed with MDI-associated occupational asthma to jobs that do not expose them to MDI-containing compounds.
3. Train employees on proper respirator use. Respirators should not be removed until spraying is complete. Employees who use respirators must be clean-shaven.
4. Perform quantitative fit testing of respirators. Quantitative fit testing is more objective than qualitative fit testing.
5. Install portable hand washing units in workplaces without easy access to restrooms.
6. Train employees on the hazards associated with chemicals in the work environment consistent with paragraph (h) of OSHA's Hazard Communication Standard [Code of Federal Regulations 1910.1200].[56]
7. Encourage employees to stop smoking. Offer smoking cessation classes and literature on harmful effects of cigarette smoke.
8. Work with the manufacturers of the polyurethane foam to substitute MDI with a less toxic compound.
9. Prohibit eating, smoking, and drinking in the work area.
10. Use proper personal protective clothing, including butyl rubber gloves, neoprene, nitrile, and protective suits to decrease dermal exposures.

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Table 1
Personal sampling results (µg/m^3) for MDI from October 13, 2004 and 26-28, 2004
US Roofing Contractors, Philadelphia, PA

Date	Sample ID	Job Description	Sample Type	Duration (min)	MDI monomer	MDI monomer as NCO	MDI oligomer as NCO	TRIG	MDI Time Weighted Average
10/13/04	IMP 1	Sprayer/Installer	Time-Weighted Average	451	89.1	31.1	14.7	15.6	89.1
10/13/04	IMP 7	Sprayer/Installer	Task-Based Sample	234	343	114	65.4	29.8	167
10/13/04	IMP-10	Sprayer/Installer	Short-Term Sample	10	298	101	44.0	49.2	NA
10/13/04	IMP-11	Sprayer/Installer	Short-Term Sample	3	78.2	26.2	ND	8.90	NA
10/13/04	IMP 2	Hose-helper/Installer	Time-Weighted Average	398	62.5	7.27	5.06	4.19	62.5
10/13/04	IMP 3,9	Installer	Time-Weighted Average	579	68.1	23.1	20.5	14.8	68.1
10/13/04	IMP 4	Installer	Time-Weighted Average	426	101	34.4	21.3	19.0	101
10/13/04	IMP 5	Installer	Time-Weighted Average	431	66.4	22.8	16.1	13.2	66.4
10/13/04	IMP 6	Installer	Time-Weighted Average	435	26.1	8.91	4.80	4.66	26.1
10/13/04	IMP 8	Operator	Time-Weighted Average	374	0.29	0.10	ND	0.03	0.29
10/26/04	IMP 15	Sprayer/Installer	Task-Based Sample	122	282	99.5	71.3	14.8	71.7
10/26/04	IMP 16	Hose-helper/Installer	Task-Based Sample	107	152	49.5	52.0	7.69	33.9
10/27/04	IMP 28	Sprayer/Installer	Short-Term Sample	16	328	115	88.8	69.4	NA
10/27/04	IMP 29	Sprayer/Installer	Short-Term Sample	18	260	86.8	48.9	46.1	NA
10/27/04	IMP 30	Hose-helper/Installer	Short-Term Sample	25	ND	ND	8.87	3.02	NA
10/27/04	IMP 31	Hose-helper/Installer	Short-Term Sample	20	299	102	64.9	56.8	NA
10/27/04	IMP 26	Installer	Short-Term Sample	16	503	170	108	94.6	NA
10/27/04	IMP 27	Installer	Short-Term Sample	18	407	133	111	83.0	NA
10/27/04	IMP 24	Installer	Short-Term Sample	16	35.7	12.2	54.0	22.5	NA
10/27/04	IMP 25	Installer	Short-Term Sample	18	27.9	9.29	11.6	7.11	NA
10/28/04	IMP 37	Sprayer	Task-Based Sample	219	109	37.6	27.9	16.2	79.6
10/28/04	IMP 38	Installer	Task-Based Sample	220	50.5	16.8	10.5	4.25	23.2
10/28/04	IMP 39	Installer	Task-Based Sample	219	43.2	14.4	10.2	3.82	19.7
10/28/04	IMP 35	Installer	Task-Based Sample	219	62.5	21.0	12.1	5.14	28.5
10/28/04	IMP 36	Operator	Task-Based Sample	155	ND	ND	0.54	0.06	NA
10/28/04	IMP 34	Installer	Task-Based Sample	218	29.3	9.98	5.93	2.46	13.3

ND: Not Detected; NA: Not Applicable
MDI: 4,4'-Methylene-bisphenyl isocyanate
NCO: Nitrogen-Carbon-Oxygen
TRIG: Total Reactive Isocyanate Group

Table 2
Area sampling results (µg/m^3) for MDI from October 13,2004 and October 26-28, 2004
US Roofing Contractors, Philadelphia, PA

Date	Sample ID	Sample Location	Duration (min)	MDI monomer	MDI monomer as NCO	MDI oligomer as NCO
10/13/04	IMP 12	About 5 feet from ground	10	107	36.0	ND
10/25/04	IMP 13	Sample collected 2 hours after spraying	59	ND	ND	3.24
10/25/04	IMP 14	Sample collected 2 hours after spraying	60	ND	ND	1.24
10/26/04	IMP 17	Sample collected 2'from ground-employee BZ	114	146	48.7	45.0
10/26/04	IMP 18	Sample collected immediately after spraying	232	ND	ND	ND
10/26/04	IMP 19	Sample collected 2'from ground	357	27.6	9.47	7.50
10/26/04	IMP 20	Sample collected 2'from ground	349	86.4	29.2	21.8
10/26/04	IMP 21	Sample collected 2'from ground	353	33.4	11.1	9.00
10/26/04	IMP 22	Sample collected 2'from ground	226	ND	ND	0.18
10/26/04	IMP 23	Sample collected 2'from ground	354	22.1	7.62	4.81
10/27/04	IMP 32	Sample collected 2'from ground	144	78.7	26.8	27.7
10/27/04	IMP 33	Sample collected 2'from ground	144	351	117	82.9
10/28/04	IMP 40	Sample collected 2'from ground	231	25.8	9.01	6.61
10/28/04	IMP 41	Sample collected 2'from ground	222	4.59	1.53	0.71
10/28/04	IMP 42	Sample collected immediately after spraying	23	ND	ND	2.24
10/28/04	IMP 43	Sample collected 2'from ground	221	16.2	5.44	3.13
10/28/04	IMP 44	Sample collected 2'from ground	227	10.5	3.59	0.88
10/28/04	IMP 45	Sample collected 2'from ground	233	14.1	4.76	2.23
10/28/04	IMP 46	Collected when employees were having lunch	30	ND	ND	4.57
10/28/04	IMP 47	Sample collected 2'from ground	214	9.69	3.27	2.00

ND: Not Detected

Table 3
Area and personal sampling results for Volatile Organic Compounds from October 13, 2004 and October 26-28, 2004
US Roofing Contractors, Philadelphia, PA

Date	Sample ID	Sample location	Sample duration (min)	N-methyl-2-Pyrrolidinone (ppm)	2(2-butoxyethoxy)ethanol (ppm)	C7 as Heptane (ppm)	Ethylbenzene (ppm)	Xylenes (ppm)	Toluene (ppm)
10/13/04	Roofer 7	Personal	330	NR	NR	NA	NA	NA	NA
10/13/04	Area	Trailer	420	0.06	ND	NA	NA	NA	NA
10/13/04	Roofer 4	Personal	105	NA	NA	12.8	0.12	0.47	20.3
10/26/04	Roofer 4	Personal	170	NA	NA	5.01	ND	0.14	6.79
10/26/04	Roofer 5	Personal	184	NA	NA	5.07	ND	0.14	7.03
10/27/04	Roofer 7	Personal	36	0.17	ND	NA	NA	NA	NA
10/27/04	Roofer 7	Personal	267	0.03	ND	NA	NA	NA	NA

NR: Not Reported (Sample destroyed during shipping)
ppm: parts per million
ND: Not Detected
NA: Not Applicable

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