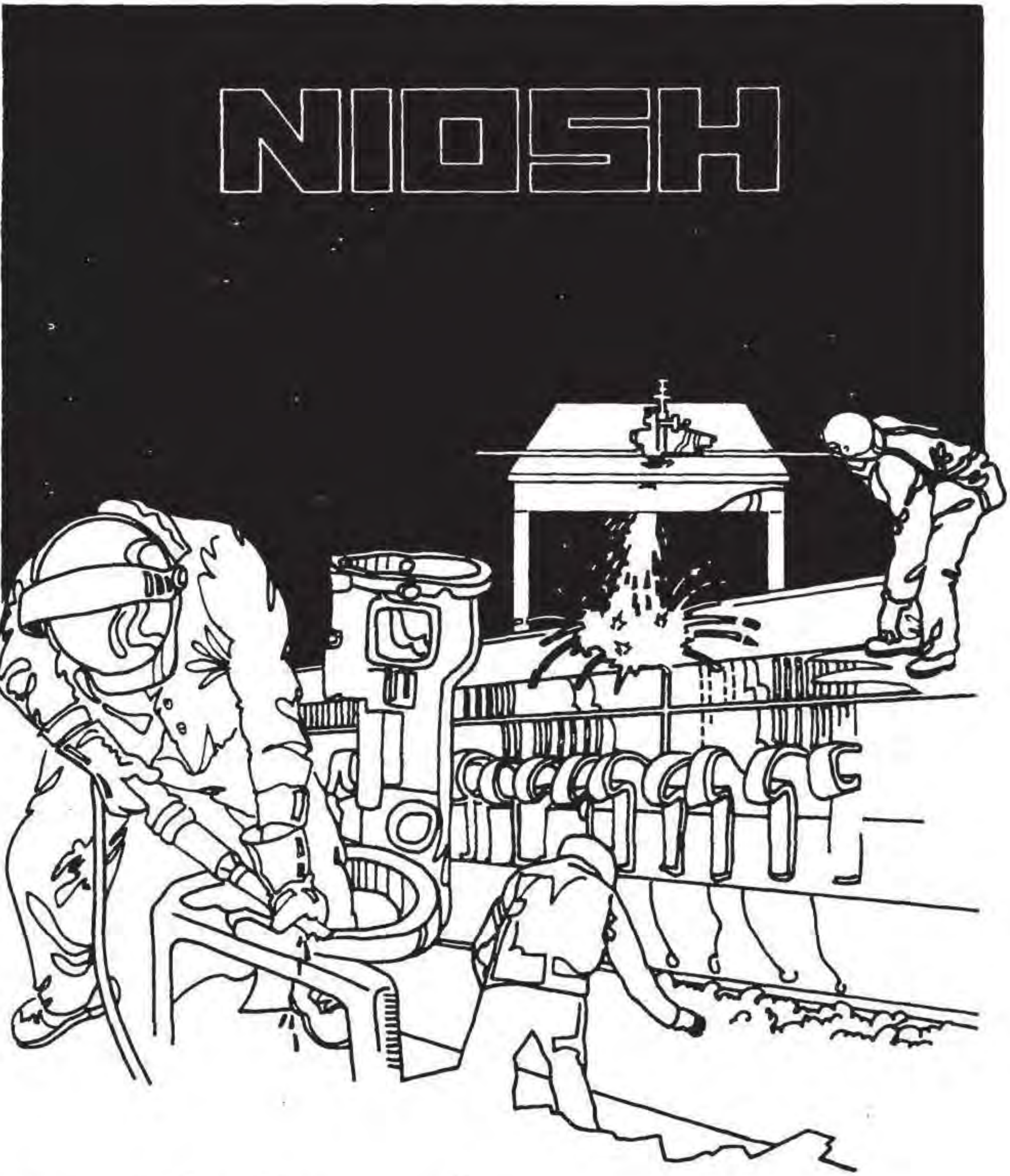
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health




# Health Hazard Evaluation Report

HETA 84-221-1523
PENNSYLVANIA HOSPITAL
PHILADELPHIA, PENNSYLVANIA

# PREFACE

The Hazard Evaluations and Technical Assistance Branch of 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 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 employer 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.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) 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.

HETA 84-221-1523
NOVEMBER 1984
PENNSYLVANIA HOSPITAL
PHILADELPHIA, PENNSYLVANIA

NIOSH INVESTIGATORS:
Richard L. Stephenson, I.H.
Tar-Ching Aw, M.D.

## I. SUMMARY

On March 1, 1984, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate symptoms of headache, breathing difficulty, and chest discomfort associated with occupational exposure to isocyanates during floor waterproofing operations in the Core Building at the Pennsylvania Hospital, Philadelphia, Pennsylvania. A polyurethane floor sealant system was being used there to cover the penthouse section floor.

On March 5-8, 1984, NIOSH investigators conducted an environmental investigation and a medical survey on March 7-8 and 12-13, 1984. Long-term personal and area air sampling was performed during the waterproofing operations to characterize exposures to isocyanates (monomeric MDI, PAPI©, TDI, and total reactive isocyanate groups - TRIG) and to organic solvents (xylene, petroleum distillates, and ethylene glycol).

Results of the personal and area air samples for TRIG revealed 5 of 12 samples had detectable concentrations: two personal samples at 192 ug/m$^3$ and 96.1 ug/m$^3$, and three stationary area air samples at 48.9 ug/m$^3$, 49.9 ug/m$^3$, and 67.5 ug/m$^3$. (There is no standard or NIOSH recommended standard in the United States for TRIG; the British standard is 20 ug/m$^3$.) No detectable concentrations of monomeric MDI, PAPI©, and TDI were found in any of the 5 personal or 7 stationary area samples. Analysis of the four stationary area high volume air samples for organic solvents revealed only trace amounts of xylene and toluene, so the personal air samples for these solvents were not analyzed. No detectable concentrations of ethylene glycol were found in any of the 11 (5 personal and 6 area) samples.

The medical evaluation indicated that two of the eight roofers who returned to work on the penthouse unit roofing operations had respiratory symptoms at and after working with the materials used. One of them had a physiologically significant pre- to post-shift decline in both one-second forced expiratory volume ($FEV_1$) and $FEV_1$/forced vital capacity ratio on the day of exposure to the materials. This worker, who has a previous history of exposure to isocyanates, had very limited exposure to the work processes and waterproofing materials during the NIOSH survey. The symptoms of cough, shortness of breath, and chest tightness, and the pulmonary function test results are consistent with isocyanate hypersensitivity. Systemic absorption of the solvent xylene was documented in one of the eight roofers, as indicated by the presence of a small amount (0.21 g/g creatinine) of the metabolite methyl hippuric acid in the urine.

The results of this investigation indicated that employees were exposed to isocyanates (although not to detectable levels of the monomer for MDI, PAPI©, or TDI) and were experiencing symptoms and pulmonary function changes consistent with this exposure during waterproofing operations at Pennsylvania Hospital. Measures to improve working conditions are recommended in Section VIII of this report.

KEYWORDS: SIC 1542 (General Contractors: Hospital Construction), 1799 Special Trade Contractors (Waterproofing), total isocyanates, organic solvents, polyurethanes, roofers, MDI, PAPI©, TDI

## II. INTRODUCTION

On March 1, 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Roofers, Waterproofers, and Allied Workers Union to evaluate employee exposures during floor waterproofing operations in the Core Building at the Pennsylvania Hospital, Philadelphia, Pennsylvania. A polyurethane floor sealant system was being used to cover the penthouse section floor as part of the finishing stage of construction of the Core Building. The request was prompted by the workers' exposures to isocyanates and their reported symptoms of headache, breathing difficulty, and chest pain.

NIOSH investigators conducted an environmental/medical investigation at the Pennsylvania Hospital on March 5-8, and 12-13, 1984. A response letter summarizing the medical and environmental activities conducted during the survey was distributed in April 1984. Although no air sampling or medical test results were reported at that time, preliminary recommendations concerning work practices, potential exposures to isocyanates, and personal protective equipment were given.

## III. BACKGROUND

Pennsylvania Hospital, the nation's first hospital, was founded in 1751 and has been located at its current site in downtown Philadelphia since 1756. Through the years, the Pennsylvania Hospital complex has gone through several structural changes. Most recently, in 1981, the Elm Building and Outpatient Building were demolished, and construction began on the replacement structures - the Core Building and the Widener Ambulatory Surgery Building.

The Core Building is an eleven-story hospital center with 186 beds on six patient floors. As part of the final stages of construction, a Mameco weatherproofing floor sealant system was installed on the Core Building's penthouse floor by the Waterproofers Union workers. Work in the penthouse section to apply the waterproofing materials began on February 28-29, 1984. Initially, workers had been supplied with half-face particulate respirators, and then later with half-face respirators with (high-efficiency) organic vapor-particulate cartridges. On March 1, 1984, work was temporarily halted when six of the eight roofers experienced health effects after using the materials for the waterproofing processes. The work was delayed until air supplied respiratory equipment could be obtained late on March 3 and early on March 6, 1984.

The floor waterproofing procedures involve the use and application of four different materials in succession. Initially, a one part moisture-cured polyurethane general purpose sealant (Mameco-Vulkem 116) is caulked around risers, baseboards, uprights, floors and walls (near the floor). Very little drying time is needed, and the work proceeds quickly to the second item applied, Vulkem 452. This one-part aliphatic urethane coating material (Vulkem 452) is applied with a trowel to fill in cracks in the flooring. The cure time, or set-up time, for this viscous material is about ten minutes. The third material put down is Vulkem 350, a one-part liquid polyurethene deck waterproofing material which is poured on the floor, squeegeed, and then rolled out with a long-handled paint roller. The 350 component cures from reaction with atmospheric moisture to form a rubber-like membrane surface. Set-up takes about 24 hours, and the cured Vulkem 350 has a tacky surface. Sand is broadcast by hand over the sticky flooring to give it a finished non-skid surface. Larger quantities of Vulkem 350 are used than of any of the other flooring components. The final material applied (Vulkem 351) is a two-part liquid polyurethane deck coating system which is applied to the flooring using a long-handled roller and/or a brush. Prior to application the two components, parts A and B, are mixed for about six minutes with an electric drill equipped with paint mixer blades. All four waterproofing materials contain one or more of the following isocyanates: methylene bisphenyl isocyanate (MDI), polymethylene polyphenylisocyanate (PAPI®), or toluene diisocyanate (TDI).

The quantity of materials used daily varied with the surface area to be covered and the number of workers assigned to the tasks. During the NIOSH environmental survey on March 5-8, 1984, one to two workers applied the floor coating components, while another employee acted as a watchperson to check that no smoking occurred in the penthouse during the floor covering processes.

## IV. EVALUATION DESIGN AND METHODS

### A. Environmental

Long-term personal and area environmental air sampling was performed on March 6-8, 1984 during the penthouse floor waterproofing operations to characterize employee exposure to various isocyanates [monomeric MDI, PAPI®, TDI, and total reactive isocyanate groups (TRIG)] and organic solvents (xylene, petroleum distillates, and ethylene glycol). Bulk samples of the waterproofing compounds were obtained to aid in the analysis of the air samples. The sampling and analytical methods for these substances, including collection device, flow rate, and referenced analytical procedures are presented in Table I.[1]

A synopsis of the newly developed NIOSH air sampling/analytical method for total reactive isocyanate groups is as follows:

> A known volume of air is bubbled through a midget impinger containing a known quantity of a toluene solution of 1-(2-methoxyphenyl)-piperazine. An aliquot of the toluene solution is acetylated and then evaporated to dryness. The residue is dissolved in methanol and an aliquot is injected into a high-performance liquid chromatograph equipped with a UV detector capable of detection at 254 nm. The change in concentration of 1-(2-methoxyphenyl)-piperazine is quantitated and the number of moles of reactive isocyanate groups present determined. The isocyanate groups are quantitated regardless of the size of the molecule to which they are attached.

Four high-volume charcoal-tube area air samples for organics (media-charcoal tube) were collected during the survey to aid in the laboratory analyses of the personal air samples. These four screening air samples were analyzed by a gas chromatograph equipped with a flame ionization detector.

B. Medical

A standardized occupational exposures and symptom questionnaire was administered to all eight roofers who were involved in the waterproofing operations. Baseline pulmonary function tests (PFTs) were done by NIOSH personnel on all eight roofers on a non-working day after the weekend (Monday, March 13, 1984). Serial PFTs were done on five of these eight roofers who returned to work on the same process the following day. The PFTs included determination of one-second forced expiratory volume ($FEV_1$), and forced vital capacity (FVC), and calculation of the $FEV_1$/FVC ratio. PFTs were performed before shift, at the end of shift, and four to six hours after the end of shift. An inquiry about respiratory symptoms experienced at the time of each PFT was made. Ohio Medical Products Model 822 dry rolling seal spirometer, connected to a Spirotech dedicated computer, was used for the PFTs. This computer component records the flow-volume curves, analyzes them, and calculates predicted values based on age, height, sex, and race. A test reading was considered adequate for interpretation and use in the study only if there were three acceptable trials and the two best curves differed by no more than 5% with respect to both $FEV_1$ and FVC. $FEV_1$/FVC ratio was calculated using the best readings available for $FEV_1$ and FVC, regardless of whether they occurred on the same tracing. Predicted normal values were based on data from Knudson et al, 1976.[2]

Exposure to xylene was assessed by determination of the amount of its specific metabolite, methylhippuric acid, in the urine. End-of-shift urine samples were collected from the five roofers who returned to work in the penthouse unit. These samples were preserved with thymol and maintained at reduced temperatures while in transit. Upon receipt by the laboratory, the urine samples were stored at 4° C until analysis. They were analyzed by NIOSH Method 8301[3].

## V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for 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 if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual suseptibility, 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 evaluation criterion. These combined effects are not usually considered in 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 Recommendations, 2) The American Conference of Governmental Industrial Hygienits (ACGIH) Threshold Limit Values (TLV's)®, and 3) The U. S. Department of Labor, Occupational Safety and Health Administration (OSHA) Occupational Health Standards. Often, the NIOSH recommendations and ACGIH TLV's® are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's® usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the

NIOSH-recommended standards, 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 industry is legally required to meet only those levels specified by an OSHA standard.

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 short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Isocyanates

All isocyanates contain the -N=C=O group,[4] which reacts readily with compounds containing reactive hydrogen atoms to form urethanes. The di- and poly-isocyanates contain, respectively, two and three or more of these groups.[5] The chemical reactivity of the isocyanates makes them ideal for polymer formation. Hence, they are widely used in the manufacture of polyurethane foams, paints, adhesives, fibers, resins, and sealants.[6]

The processes and operations in which diisocyanates are used will determine the severity of the hazard. Industrial processes involving evaporation from large surface areas may result in a greater potential vapor hazard than operations involving pouring-in-place or frothing techniques.[7]

In general, the potential respiratory hazards encountered during the use of diisocyanates in the workplace are related to their vapor pressures. The lower-molecular-weight diisocyanates tend to be more readily volatilized into the work place atmosphere than the higher-molecular-weight diisocyanates. Although the vapor pressures of the higher-molecular-weight diisocyanates are relatively low, they may generate vapor concentrations sufficient to cause respiratory and mucous membrane irritation if they are handled in poorly ventilated areas. Also, the potential for skin irritation is generally higher for the lower-molecular-weight diisocyanates, and the severity of these irritant responses is reduced with increasing molecular weight.[7]

Exposure to isocyanates can cause skin and mucous membrane irritation, nausea, vomiting and abdominal pain.[8,9] In high concentrations, isocyanates have a primary irritant effect on the respiratory tract. They can also act as respiratory sensitizers, producing asthma-like symptoms in sensitized individuals, even at very low concentrations.

Asthmatic attacks may occur immediately after exposure or at an interval of hours after cessation of exposure, presenting as nocturnal cough and breathlessness. Exposure to isocyanates may also result in chronic impairment of pulmonary function.[7] Isocyanate exposure during accidental spills is a major cause of sensitization, and there is evidence that massive exposures may produce effects on the central nervous system.[7] One recently completed animal study found dose-related statistically significant cancer excesses in mice and rats administered TDI by gavage (not the usual route of human exposure) in very high concentrations. The tumors were distant from the site of administration.[10]

In the United States, federal Occupational Safety and Health Administration (OSHA) exposure standards for diisocyanates have been established only for toluene diisocyanate and methylene bisphenyl isocyanate. The current federal OSHA standard[11] and American Conference of Governmental Industrial Hygienists (ACGIH)[12] Threshold Limit Value (TLV)® for MDI is a ceiling limit of 0.02 parts of MDI per million parts of air (ppm), (0.2 milligrams per cubic meter of air, $mg/m^3$). The federal OSHA standard[11] and ACGIH[12] TLV® for TDI is a ceiling limit of 0.02 ppm (0.14 $mg/m^3$) and an 8-hour TLV® of 0.005 ppm (0.04 $mg/m^3$), respectively.

The current NIOSH recommended standard for occupational exposure to MDI and TDI is 0.05 $mg/m^3$ and 0.035 $mg/m^3$, respectively, for up to a 10-hour workshift 40-hour workweek. The NIOSH recommended standard was based on three types of effects of exposure to MDI: direct irritation, sensitization, and chronic decrease in pulmonary function. This standard applies to diisocyanate monomers only, and not to higher polymers of these compounds.[7] Little is known about the toxicological effects of polymeric isocyanates. No long-term studies have been conducted on polymeric isocyanates, and furthermore, their potential for inducing pulmonary hypersensitivity, as shown for monomeric isocyanates, has not been investigated.[13] However, results of a recent NIOSH study revealed that work in an industrial setting where polymeric isocyanate exposures were documented was associated with small mean decreases in $FEV_1$ and FVC which were not observed in an unexposed group. Also, the change in $FEV_1$ over the shift correlated with personal airborne exposure to polymeric but not monomeric MDI.[14]

On February 2, 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. This new control limit is an 8-hour TWA of 20 ug of isocyanate group per cubic meter of air, and a 10-minute TWA of 70 ug of isocyanate group per cubic meter of air. This new control limit, in units of ug (NCO)/$m^3$, requires that the analytical methods be applicable to "total isocyanate", i.e., the sum of all isocyanate species, including monomers and prepolymers.[15]

## VI. RESULTS

### A. Environmental

It should be noted that the roofers involved in applying the polyurethane-based waterproofing compounds to the penthouse floor wore either half-facepiece or full-face supplied-air respirators from March 5, 1984, to the completion of the job; this included the time period during which NIOSH conducted the on-site environmental evaluation.

Results of the personal and area air samples obtained during the penthouse floor waterproofing operations to determine employee exposure to total reactive isocyanate groups (TRIG) are presented in Table II. Five of the 12 samples had detectable TRIG: two personal (worker) samples at 192 ug/$m^3$ and 96.1 ug/$m^3$; and three stationary area air samples at 48.9 ug/$m^3$, 49.9 ug/$m^3$, and 67.5 ug/$m^3$. No detectable isocyanates were found on any of the five personal and 7 area samples collected for monomeric MDI, PAPI®, and TDI.

The analytical results for the total reactive isocyanate groups were originally reported in micromoles of NCO per sample. These values were converted to micrograms per cubic meter (as shown in Table II) using the molecular weight of 42 (N+C+O) for the NCO radical. These calculations were performed so that the resulting values could be compared with the United Kingdom's new standard for total isocyanate groups 20 ug/$m^3$ for an 8-hour TWA.[15] The range of total reactive isocyanate groups found amongst the five (of 12) measureable values was 48.9-192 ug/$m^3$, TWA, all exceeding the United Kingdom's standard.

The four high volume area air samples revealed only trace amounts of xylene and toluene. The airborne toluene was most likely due to its use as the sampling reagent. Since only trace quantities of organic solvents were found on the high-volume air samples the personal air samples for organic solvents (petroleum distillates, xylene, and toluene) were assumed to be too low to warrant analysis.

No detectable ethylene glycol was found on any of the eleven air (five personal and six area) samples collected during the waterproofing operations on March 6-8, 1984 (analytical limit of detection: 0.01 mg/sample).

B. Medical

The eight roofers were all white males 26 to 57 years old (median = 37.5 years). They had worked on roofing operations for 3 to 35 years (median = 13.5 years). The group included six cigarette smokers, one cigar smoker, and one non-smoker. Four of the eight (50%) reported a personal and/or family history of asthma, hay-fever, eczema, or other allergies. None of them had previous lung disease or chest injury. None had any training in respiratory protection, nor had any of them been fit tested previously for respirators.

Two of the eight roofers had previously been exposed, on separate occasions, to the same materials as the ones which were being used in the waterproofing process at Pennsylvania Hospital. One of the occasions was five years ago, and the other a year ago. Both these individuals developed symptoms of chest tightness and cough after working with these materials in the penthouse unit at Pennsylvania Hospital. One experienced cough after one hour, shortness of breath after two hours, and chest tightness after four hours of exposure to the materials. This persisted episodically for two days. Other symptoms include nausea, lightheadedness, dizziness, blurring of vision, vomiting, and irritation of the nose and throat, all of which improved soon after the worker left the worksite. The other roofer experienced a "bad cough" for about half an hour on the same night. He also could taste and smell the odor of the sealant used, even after leaving work. The other six roofers were apparently using these specific materials for the first time. Two were symptom-free. Four had a variety of symptoms during and shortly after work, including headache (3 roofers), lethargy (2), nausea (1), dizziness (1), and abdominal discomfort (1).

The baseline pulmonary function tests for all eight roofers were within normal limits ($FEV_1$ and FVC more than 80% of predicted, $FEV_1$/FVC ratio more than 70%), except for one worker with a slightly reduced $FEV_1$ (77% of predicted). He was symptomatic and had previously handled the same materials on one previous occasion five years ago. The serial pulmonary function tests for the five roofers who returned to work showed one worker with a drop in $FEV_1$ of 12% over the shift and a 16% drop (compared to pre-shift) five hours after the end of shift. The corresponding drop in $FEV_1$/FVC was 8% at the end of shift and 9% five hours after the end of shift. There were accompanying symptoms of cough, chest tightness, and shortness of breath. One asymptomatic worker had a decline in $FEV_1$ of 9% over the shift, and a 15% decline five hours after the end of shift, with no fall in $FEV_1/FVC$. The other three roofers had no significant serial changes in $FEV_1/FVC$ ratio.

The urine anaylses for methylhippuric acid showed a small amount in one of the five roofers. The amount detected was 0.1 mg/ml (0.21 g/g creatinine). The ACGIH[12] has proposed an end-of-shift level of 2.5 g/g creatinine of hippuric acid in the urine as a biological exposure index (BEI) for toluene. Workers are not expected to suffer any ill-effects if the BEI is not exceeded. The ACGIH has stressed that measurements above BEIs are not necessarily indicators of a disease process, but if high levels persist, medical examination by a physician and investigation of the work place and work practices are suggested.

## VII. DISCUSSIONS AND CONCLUSIONS

Two of the eight roofers did not experience any health effects after working with the materials used in the waterproofing process. The symptoms described by the other six roofers included respiratory symptoms and symptoms consistent with organic solvent exposure. The respiratory symptoms occurred in the two individuals with a previous history of exposure to the same materials. One of the two had serial pulmonary function tests which showed a physiologically significant decline in $FEV_1$ and $FEV_1/FVC$ at the end of shift and five hours after the end of shift (the other worker did not return to work on the penthouse unit). Significant decline has been defined as a decrease in $FEV_1$ greater than 8%, and a decrease in $FEV_1/FVC$ of more than 6%.[16] Declines of this magnitude are considered abnormal if not clearly attributable to non-disease related variables[16] (such as cigarette smoking before the PFTs or a recent heavy meal, both of which would have invalidated the PFTs). Such declines in PFT parameters, occurring together with symptoms of cough, chest tightness, and shortness of breath, indicate airways obstruction. This effect may be related to exposure to isocyanates, which are a known cause of both reversible and irreversible airways obstruction.[17] The air sampling data indicated employee exposure to isocyanates, all of which are thought to be other than monomeric. Also, isocyanates are present as an ingredient in the materials used for waterproofing operations. A history of previous exposure to the same materials in these two roofers is supportive of a possible isocyanate sensitization. Further detailed medical evaluation of these roofers is needed to confirm isocyanate sensitization.

Although NIOSH's air sampling data for organic solvents revealed only trace levels which would not be expected to cause symptoms, the symptom inquiries in four roofers suggested work-related nausea, headache, lethargy, and dizziness. This may be due to fluctuating solvent exposures in the enclosed area of the penthouse unit at the hospital or differences in susceptibility to the organic solvents such that some individuals develop symptoms from low-level exposures. Biological monitoring documented xylene absorption by only one roofer. He had 0.21 g/g creatinine of the specific xylene metabolite methylhippuric acid in the urine. Engstrom[18] suggests 0.665 and 1.28 g/g creatinine of urinary methylhippuric acid at the end of the workday as indicative of exposures to xylene of 50 and 100 ppm respectively. The current ACGIH threshold limit value for xylene in air is 100 ppm. Lauwerys[19] indicates that an exposure at this level will result in a urinary methylhippuric acid of 1 to 3 g/g creatinine.

## VIII. RECOMMENDATIONS

In view of the findings of the environmental and medical investigations, the following recommendations are made to ameliorate existing or potential hazards and to provide a better work environment for the employees. (A number of the recommendations were also made in a letter sent to management and union representatives in April, 1984.)

1. Supervisors and their employees should familiarize themselves with product manufacturers' recommendations regarding precautionary measures and specific directions before attempting to use any materials in the conduct of their work. Current Material Safety Data Sheets and all available information concerning products used, including health effects, should be obtained and made available to all potentially exposed personnel. Furthermore, a continuing education program, conducted by a person or persons qualified by experience or special training, should be instituted to ensure that all employees have current knowledge and understanding of the job safety and health hazards, proper work practices, and maintenance procedures. Materials should be labeled with information on proper use, personal protective devices needed, and descriptions of adverse health effects.

2. There should be a respirator program consistent with the guidelines found in DHEW (NIOSH) Publication No. 76-189, "A Guide to Industrial Respiratory Protection," and the requirements of the General Industry Occupational Safety and Health Standards (29CFR 1910.134). (Copies have been provided to both management and union representatives.) Any respirators used, including the approved components and replacement parts should have NIOSH/MSHA approval.

If non-certified or substituted respirator components are used, the NIOSH/MSHA approval of the entire respirator assembly is voided, and the protection offered by the respirator may be compromised.

The NIOSH criteria document for occupational exposure to diisocyanates (DHEW, NIOSH, Publication No. 78-215) recommends that a worker exposed to diisocyanates should be provided with, as a minimum, a type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure mode, or with full facepiece, helmet, or hood operated in continuous-flow mode. However, it must be realized that providing respiratory protection for individuals wearing corrective glasses is a problem. A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece. Systems have been developed for mounting corrective lenses inside full facepieces. When a worker must wear corrective lenses as part of the facepiece, the facepiece and lenses should be fitted by qualified individuals to provide good vision, comfort, and a good tight seal.

3. The medical recommendations for current and future waterproofing employees exposed to isocyanates, as outlined in the NIOSH diisocyanate criteria document,[7] should be followed. These recommendations include the need for pre-placement examinations and periodic medical surveillance:

   a. Preplacement examinations should include at least comprehensive medical and work histories, with special emphasis on pre-existing respiratory conditions such as asthma. A smoking history should also be compiled.

      Physical examination giving particular attention to the respiratory tract and baseline measurements of forced vital capacity (FVC) and forced expiratory volume at 1 second ($FEV_1$) should be done. The worker's ability to use negative and positive pressure respirators should be assessed.

   b. Periodic examinations should be made available at least annually, or as determined by the responsible physician. This should include, interim medical and work histories, and clinical examination giving particular attention to the respiratory tract and measurements of $FEV_1$ and FVC.

   c. During examinations, applicants or employees found to have medical conditions that could be directly or indirectly aggravated by exposure to diisocyanates, e.g.; respiratory allergy, chronic upper or lower respiratory irritation, chronic obstructive pulmonary disease, or evidence of sensitization to diisocyanates, should be counseled on their increased risk from working with these substances. Chronic bronchitis, emphysema, disabling pneumoconiosis, or cardiopulmonary disease with significantly impaired ventilatory capacity similarly suggest an increased risk from exposure to diisocyanates. If a history of allergy is elicited, applicants should be counseled that they may be at increased risk of adverse health effects from exposure to diisocyanates. Employees should also be advised that exposure to diisocyanates may result in delayed effects, such as coughing or difficulty in breathing during the night.

## IX. REFERENCES

1. National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods; Analytical Method, 5505 Total Isocyanates; Third Edition, Publication No. 84-100, 1984; Vol. 3, Publication No. 77-157-C, 1977.

2. Knudson, R et al. The maximal expiratory flow-volume curve. Amer. Rev. Resp. Disease. 113:587-600, 1976.

3. National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods; Analytical Method 8301, Biological Samples, Hippuric and Methyl, Hippuric Acids in Urine; Third Edition, Publication No. 84-100, 1984; Vol. 1.

4. EMAS. Chief employment medical adviser's notes of guidance. Tunbridge Wells: Courier Printing Company, Ltd. 1973.

5. Woolrich, Paul F. Toxicology, Industrial Hygiene and Medical Control of TDI, MDI, and PMPPI. AIHA Journal, Vol. 43, February, 1982.

6. Geraci, C. L., Seymour, M. J., Pryor, P. D. Chemical Characterization of TDI and TDI Product Exposures During Urethane Foam Fabrication. Presentation at American Industrial Hygiene Conference, May 22-27, 1983, Philadelphia, Pennslyvania.

7. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to diisocyanates. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1978. (DHEW publication no. (NIOSH) 78-215).

8. National Institute for Occupational Safety and Health. Occupational diseases: a guide to their recognition. Revised ed. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW (NIOSH) publication no. 77-181).

9. International Labour Office. Encyclopaedia of occupational health and safety. Vol I/a-k. Geneva: International Labour Office, 1971. Third (Revised) Edition, 1983.

10. Dieter, M. P., NTP, Technical Report on the Carcinogenesis Bioassay of Toluene Diisocyanate. NIH Publication No. 82-2507, National Toxicology Program, Research Triangle Park, North Carolina, August, 1982.

11. Occupational Safety and Health Administration. OSHA Safety and Health Standards. 29CFR 1910.1000. Occupational Safety and Health Administration, Revised Marhc 11, 1983.

12. American Conference of Governmental Industrial Hygienists. Threshhold Limit Values for Chemical Substances and Physical Agents in the Work Environment and Biological Exposure Indices with Intended Changes for 1984-85. Cincinnati, Ohio: ACGIH, 1983.

13. Weyel, D. A., Rodney, B. S., and Alaire Y. Sensory Irritation, Pulmonary Irritation, and Acute Lethality of a Polymeric Isocyanate and Acute Lethality of 2, 6 - Toluene Diisocyanate. Toxicology Appl. Pharmacol, 1982; 64: 423-430.

14. National Institute for Occupational Safety and Health. Health Hazard Evaluation Report No. HETA 80-073. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1984.

15. Silk, S. J., Hardy, H. L. Control Limits for Isocyanates. Ann. Occupational Hygiene. Vol. 27, No. 4, pp. 333-339, 1983.

16. Horvath Jr. EP. Pulmonary Function Testing in Occupational Medicine. Technical Manual #71-1, Navy Environmental Health Center, Naval Station, Norfolk, Virginia 23511, 1971 (Rev. 2/79).

17. Parkes WR. Occupational Lung Disorders, 1974. Butterworth and Co. (Publishers) Ltd. London.

18. Engstrom, K., Husman, K., Pfaffli, P., Riihimaki, V. Evaluation of Occupational Exposure to Xylene by Blood, Exhaled Air, and Urine Analysis. Scand. J., Work Env., Health 4: 114, 1978.

19. Lauwerys RR. Industrial Chemical Exposure: Guidelines for Biological Monitoring. Biomedical Publications. Davis, California, 1983.

## IX. AUTHORSHIP AND ACKNOWLEDGEMENTS


| | |
|---|---|
| Report Prepared by: | Richard L. Stephenson<br>Industrial Hygienist<br>Industrial Hygiene Section |
| | Tar-Ching Aw, M.D.<br>Occupational Physician<br>Medical Section |
| Field Assistance:<br>Environmental | John N. Zey<br>Industrial Hygienist<br>Industrial Hygiene Section |
| Field Assistance:<br>Medical | Susan Owen, R.N.<br>University of Alabama<br>at Birmingham |
| | Dorriss Q. Hale<br>Health Technician<br>Medical Support Section |
| | Larry Catlett<br>Chief<br>Support Services Branch |
| Laboratory Assistance:<br>Medical | Frederick Phipps<br>Chemist<br>Clinical and Biochemical<br>Support Division |
| Laboratory Assistance:<br>Environmental | Edward J. Slick<br>Chemist<br>Measurements Support Section |
| Originating Office: | Hazard Evaluations and Technical<br>Assistance Branch<br>Division of Surveillance, Hazard<br>Evaluations, and Field Studies |
| Report Typed By: | Lynette K. Jolliffe<br>Clerk/Typist<br>Industrial Hygiene Section |

## X. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Keystone Roofing Company, Inc.
2. United Union of Roofers, Waterproofers, and Allied Workers, Locals 30 & 30B, AFL-CIO
3. NIOSH, Region III
4. OSHA, Region III

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.

Table I

Air Sampling and Analysis Methodology
Pennsylvania Hospital
Philadelphia, Pennsylvania
HETA 84-221

| Substance | Collection Device | Flow Rate (liters per minute) | Analysis | References[1] |
|---|---|---|---|---|
| Methylene Bisphenyl Isocyanate (MDI) | Midget Impinger with 15 ml of 1 - (2-methoxyphenyl) - piperazine in toluene | 1.0 | High Performance Liquid Chromotography | NIOSH Method 5505 Total Isocyanates |
| Toluene Diisocyanate (TDI) | " | " | " | " |
| Polymethylene Polyphenyl Isocyanate (PAPI®) | " | " | " | " |
| Total Reactive Isocyanate Groups (TRIG) (monomer & polymer) | " | " | " | " |
| Ethylene Glycol | Silica Gel Tube | 0.05 & 0.2 | Gas Chromatography | NIOSH Method S338 with modifications* |
| Organic Solvents: | | | | |
| Xylene | Charcoal Tube | 0.05 & 0.2 | Gas Chromatography Equipped with a Flame Ionization Detector | - |
| Toluene | " | " | " | - |
| Petroleum Distillates | " | " | " | - |

*The modifications included sample preparation, instrument condition settings, and/or column selection.

Table II

Results of Environmental Air Samples
For
Total Reactive Isocyanate Groups[1]

Pennsylvania Hospital
Penthouse Waterproofing Operations
Philadelphia, Pennsylvania
HETA 84-221

| Sample Location | Date/Time | Sample Volume (liters) | uMoles/Sample[2] | Total Reactive[3] Isocyanate Groups (ug/m3)[4] |
|---|---|---|---|---|
| Personal | 3/06/84 0930-1142 1240-1522 | 294 | ND | ND[5] |
| Area Sample: About 12' from south end of west chiller | 3/06/84 1019-1525 | 306 | ND | ND |
| Area Sample: About 13' from south end of east chiller | 3/06/84 1020-1525 | 305 | 0.49 | 67.5 |
| Personal | 3/07/84 0848-1147 1235-1330 1340-1417 | 271 | 0.62 | 96.1 |
| Personal | 3/07/84 0851-1146 1332-1532 | 295 | 1.35 | 192 |
| Area Sample: On south end of east chiller | 3/07/84 0920-1539 | 379 | 0.45 | 49.9 |
| Area Sample: Southwest area of penthouse | 3/07/84 0937-1549 | 367 | ND | ND |

(Continued)

Table II

(Continued)

| Sample Location | Date/Time | Sample Volume (liters) | uMoles/Sample[2] | Total Reactive[3] Isocyanate Groups (ug/m3)[4] |
|---|---|---|---|---|
| Personal | 3/08/84<br>0906-1128<br>1257-1535 | 300 | ND | ND |
| Personal | 3/08/84<br>0905-1035<br>1054-1128<br>1254-1530 | 280 | ND | ND |
| Area Sample:<br>Southwest area<br>of penthouse | 3/08/84<br>1106-1532 | 266 | ND | ND |
| Area Sample:<br>On south end of<br>east chiller | 3/08/84<br>0936-1545 | 369 | 0.43 | 48.9 |
| Area Sample:<br>Adjacent to #1 EHR<br>Glycol By-Pass Feeder | 3/08/84<br>0932-1552 | 380 | ND | ND |
| Evaluation Criteria:<br>Normal workday, 40 hour/week, time-weighted average: | | | * | * |

*There is no available evaluation criteria in the United States for total reactive isocyanate groups.

Laboratory analytical limit of detection is 0.4 uMoles/sample.

1. All concentrations are time-weighted averages for the period sampled.

2. & 3. The conversion from micromoles of NCO per sample to micrograms per cubic meter of air is made using the NCO radical and the molecular weight of 42 (N+C+O) and dividing by the air volume.

4. $ug/m^3$ = micrograms per cubic meter of air.

5. ND = nondetectable concentration.