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J.L. Long Middle School
Dallas, Texas

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PREFACE

The Respiratory disease Hazard Evaluations and Technical Assistance Program (RDHETAP) 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 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 and 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.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Greg Kullman, Gina Buono, Beth Knutti and Emily Allen, of the Respiratory Disease Health Hazard Evaluations and Technical Assistance Program, Division of Respiratory Disease Studies (DRDS). Medical field assistance was provided by Beth Knutti, Pam Hixon and Joe Viola. Field assistance was provided by Greg Kullman, Dan Hewett and Steve Berardinelli. Desktop publishing was performed by Terry Stewart. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 94-0265-2703
J.L. Long Middle School
Dallas, Texas
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SUMMARY

In May of 1994, the National Institute for Occupational Safety and Health (NIOSH) received a formal request for a health hazard evaluation (HHE) at the J.L. Long Middle School in Dallas, Texas. The request was from the director of health services for the Dallas Independent School District. Employees of the school reported a variety of building-related health complaints, including an elevated prevalence of physician-diagnosed asthma. On May 15, 1994, NIOSH investigators completed a site walk-through evaluation. Medical and environmental investigations were done in August of 1994. An interim NIOSH industrial hygiene report was issued on November 9, 1994.

An indoor air contaminant was suspected of causing the elevated prevalence of asthma at the school. Environmental investigations completed prior to the NIOSH HETA uncovered indoor air quality (IAQ) problems and provided recommendations for improvements in the maintenance of ventilation systems and the control of potential bioaerosols. During the NIOSH walk-through evaluation, isocyanates from the roofing materials were identified as a potential exposure source; subsequent air sampling during test applications of foam roofing and sealing compounds, at a site remote from the school, revealed that the roofing/repair processes used at the school could have released isocyanates. Ventilation practices used at the school during roofing activities could have entrained isocyanates into the school. Isocyanate exposures could have occurred through ventilation system outside air intakes, and possibly through open or unsealed windows adjacent to roofing operations.

A medical survey was conducted on August 3-15, 1994. From a list supplied by the school administration of those individuals diagnosed with asthma, all asthmatics still employed by the school were invited to have pulmonary function testing. This included having a baseline spirometry performed off-site 5 days before returning to the school building and then being outfitted with a belt spirometer on which to perform self-administered spirometry (using a belt spirometer) through August 15. When individuals reported for the baseline test, they were also asked to complete a questionnaire determining work histories, exposure history, respiratory symptoms. The remainder of the staff were also asked to complete the questionnaire. Thirty-seven percent (37%) complained of chest wheezing or whistling. Twenty-five respondents (29%) said that they had asthma. Twenty of these 25 said that their asthma was worse since being at J.L. Long Middle School. Fourteen of 15 employees from the list supplied by the school administration participated in baseline pulmonary function testing. Twenty-one percent (3/14) of the participants had abnormal pulmonary function. Two exhibited mild obstructive lung patterns, and one had a moderate obstructive lung pattern. These three also reported that they had physician-diagnosed asthma and were symptomatic.

An occupational health evaluation by a local asthma clinic, as well as medical questionnaire and pulmonary function tests administered by NIOSH, demonstrated an elevated prevalence of asthma, relative to the U.S. population, at the J.L. Long Middle School in Dallas, Texas. Based on sampling results from a test application of roofing materials, NIOSH investigators concluded that the potential for isocyanate exposures existed through entrainment into the school during roofing or following periodic roof repair. This exposure is suspect in the increased prevalence of asthma among school employees. Recommendations for preventing isocyanate exposures during school roofing activities are provided in Section VIII. Medical recommendations for asthmatic workers are also provided.

Keywords: SIC 8211 (Educational Facilities, Elementary and Secondary), isocyanates, MDI, indoor air quality, indoor environmental quality, IAQ, IEQ, roofing.

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INTRODUCTION

n May of 1994, the National Institute for Occupational Safety and Health (NIOSH) received a formal request for a health hazard evaluation (HHE) at J.L. Long Middle School in Dallas, Texas, from the director of health services for the Dallas Independent School District. Employees of the school had reported a variety of building-related health complaints, including an elevated incidence of physician-diagnosed asthma.

An initial site walk-through survey was conducted May 16-17, 1994. NIOSH industrial hygienists met with representatives from the Dallas Independent School District's maintenance and medical services, as well as the principal and two teachers from the J.L. Long Middle School. Reports from previous medical and environmental studies were reviewed. A combined medical and environmental survey was conducted during August 3-15, 1994, just prior to the start of the school session. The investigation included environmental sampling at the school and during a test application of the roofing materials suspected of causing the high incidence of asthma among school employees. The medical survey included a questionnaire and pulmonary function testing of school workers. The employees participating in the pulmonary function testing received individual test results in October of 1994. An interim industrial hygiene report was issued on November 9, 1994. This final report serves to summarize the various activities, observations, and findings and closes this evaluation.

BACKGROUND

J.L. Long Middle School, part of the Dallas Independent School District, is a three level brick building located at 6116 Reiger Ave. in Dallas, Texas. The building has two stories above ground and one below ground joined to an open, center courtyard. In addition to classrooms and offices, the J.L. Long Middle School building houses science labs, a gymnasium and locker room, a library, an auditorium, an art room, vocational shops, home economics rooms, a music room, a cafeteria, and two courtyards. The school's heating, ventilation, and air conditioning (HVAC) are provided by a series of independent systems located throughout building. The systems have the capacity for outside air intake with some of the intakes located on the roof and others located above ground level in one of the courtyard areas. Occupancy of the building during the time of this evaluation included 102 staff and 1033 pupils.

Among the staff, a high percentage of the teachers were diagnosed with asthma. This diagnosis was made by a Baylor Asthma and Pulmonary Rehabilitation Center Study and presented in a May 1994 report by Mark W. Millard, MD. This report described 34 (40%) asthma cases among approximately 85 staff members.[1]

Several indoor environmental air quality investigations were completed at the school; these include investigations by the Texas Department of Health (July, 1992), Garrett and Associates (December 1992 and October 1993), Dr. Thomas L. Kurt (October 1993), and the Dallas County Health Department (January 1994).

The 1992 Texas Department of Health Report, based on an industrial hygienist's visit, investigated temperature, relative humidity (RH), carbon dioxide (CO_2), and volatile organic compounds (VOCs). Slightly elevated CO_2 was found, indicating a slight under supply of fresh air. Allergic and asthmatic reactions could not be explained by these data.

Environmental investigations by Garrett and Associates (1992 and 1993) involved site visits and industrial hygiene sampling for CO_2, RH, temperature, and bioaerosols. Garrett and Associates cited potential exposure to dust mite allergens and bacteria from bird droppings as potential exposure problems. The reports provided HVAC preventive maintenance recommendations and recommendations for the relocation of outside air intakes on HVAC systems in one section of the courtyard.

An October 28, 1993, report based on a walk-through inspection by an environmental consultant (Dr. Thomas Kurt) also provided HVAC recommendations including better cleaning and preventive maintenance to address microbiological contamination in HVAC condensate pans. Recommendations to relocate the courtyard air handlers outside air intakes 10 feet above ground were provided. This consultant stressed the need for periodic cleaning of pigeon droppings and feathers from the courtyard area. Recommended for further study were also included in the report.

The Dallas County Health Department's report (January 1994) concluded that legionellosis was not a likely explanation for the respiratory health symptoms reported at J.L. Long Middle School. A recommendation for further examination of those staff members with health complaints, by a pulmonary physician, was provided to evaluate the possibility of building-related asthma.

A May 1994 report of a clinical investigation done on the employees of the JL Long Middle School was completed by the Baylor Asthma and Pulmonary Rehabilitation Center in Dallas, Texas.[(1)] Data for that study was derived from pulmonary function testing, methacholine challenge testing, skin tests, peak flow diaries, and a questionnaire. The conclusion reached in that study suggested that there was an increased prevalence of asthma in the staff and that there was some relation to the building based on declines in lung function and the development of positive methacholine tests related to return to work. Further environmental evaluation was recommended concentrating on fumes and chemical sensitizers.

METHODS

Environmental Evaluation

Two NIOSH industrial hygienists made an initial site visit May 16-17, 1994. On the initial walk-through evaluation, NIOSH investigators discovered that the white roof of the building was formed using compounds that contained isocyanates. Isocyanate-containing compounds were also used for periodic roof repair. The HVAC outside air intakes located on the roof would allow the vapors from roof repair and recoating processes to become entrained in the ventilation system by existing HVAC operation and roofing practices. Maintenance services staff members for the school district reported that urethane foam roofing was installed during the period of June 6, 1987, through July 1, 1988; and that repairs were conducted in November and December 1992; April and June 1993; and during the period of November 1993 through January 1994.

Subsequent NIOSH environmental evaluations were conducted August 2-15, 1994. Environmental evaluation of temperature, RH, and carbon monoxide (CO) was conducted using direct reading instruments, and 4,4'-diphenylmethane-diisocyanate (MDI) was measured using a direct reading instrument that uses colorimetric tape. Locations that were evaluated for temperature, RH, and CO_2 level on the initial survey in May 1994, included the area outside the entrance, the art room, the library, an office, the gym office, and rooms 3, 4, 14, 15, 110, 111, 131, 206, 207. In August, 1994, rooms 4, 7, 8, 11, 15, 17, 106, 110, 111, 131, 206 or 207, the area outside the entrance, the office, the auditorium, the hall outside the auditorium, the gym office, and the rooftop were evaluated for isocyanates. The gym office was reported by several people to have excess moisture that supported mold growth. Other areas were selected to provide a representative sample of the building as a whole.

Isocyanates

Maintenance services staff from the Dallas Independent School District arranged the opportunity for observation and sampling of an application of roofing materials at a site away from the school; this test application of roofing materials was done in a remote section of parking lot at the School district physical plant. The application involved the pouring of polyurethane foam and painting the foam with two different urethane coatings to simulate roofing operations. The Material Safety Data Sheets (MSDs) for the foam and coating materials indicated that both contain isocyanates (MDI or toluene diisocyanate - TDI). Isocyanate samples were taken using a direct reading air monitor and colorimetric sampling and analytical methods for both MDI and TDI. Samples were also taken on all floors throughout the school and on the school's roof. During the test application, the investigators and individual doing the application of the foam and coatings used respiratory protection, eye protection, and chemical protective clothing including a body suit, gloves, and boots.

For the isocyanate monitoring at the school and during the test application of roofing materials, an MDA TLD-1 toxic gas detector was used. This monitor uses a colorimetric tape and a color sensor with an electronic output to indicate isocyanate concentration. This instrument was set up to monitor either MDI or TDI, since these isocyanate compounds were believed to be present in the roofing and sealant materials. This instrument has cross-sensitivities to other isocyanates.[2]

Indoor Environmental Quality (IEQ) Parameters

Inspections of the evaluated area and HVAC systems were conducted to determine current conditions. In addition to collecting this information, indicators of occupant comfort were measured. These indicators were temperature, RH, and CO_2 concentration. Colormetric indicator tubes were used to assess CO_2.[2]

Temperature and humidity measurements were made using an electronic, battery-operated meter. This meter is capable of providing direct readings for dry-bulb temperature and RH, ranging from -4 to 140°F and 0 to 100% respectively. Instrument calibration is performed monthly using primary standards.[2]

CO_2 concentrations were measured using a portable CO_2 meter. This portable, battery-operated instrument uses a non-dispersive infrared absorption detector to measure CO_2 in the range of 0-4975 parts per million (ppm), with a sensitivity of ±25 ppm. Instrument zeroing and calibration were performed prior to use with zero air and a known concentration of CO_2 span gas.[2]

Medical Evaluation

All current employees (teachers, administrators, counselors, clerks, aides, and interpreters, N=102) were invited to complete a questionnaire designed to assess health, symptoms, and past work experiences. A list of 15 individuals previously diagnosed with asthma by the Baylor Asthma Clinic were asked to report for a baseline spirometry test approximately one week before they were to report to the building for work. After completion of the baseline spirometry and the questionnaire, they were asked to use a belt spirometer for the next 13 days to perform spirometry at certain intervals during all waking hours. The plan was to have this group use the belt spirometer the 5 days prior to entering the school building, the first week on entering the building after being out for the summer, the weekend following the first week back in the building and the following Monday.

Questionnaire

The presence of respiratory symptoms and nasal and eye irritation were assessed by questionnaire. Chronic phlegm was defined similarly. Questions were asked about chest wheezing or whistling, chest tightness, and symptoms of asthma. Questions were also asked about prior work exposures. Individuals who currently smoked were defined as current smokers, and those who had smoked, but do not currently smoke cigarettes, were classified as former smokers.

Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five expiratory maneuvers were recorded for each participant. All values were corrected to body temperature, ambient pressure, saturated with water vapor (BTPS). The largest forced vital capacity (FVC), and forced expiratory volume in one second (FEV_1) were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American Thoracic Society's (ATS) recommendations for spirometry.[3] Predicted values were calculated using the Knudson reference equations.[4] Predicted values for blacks were determined by multiplying the value predicted by the Knudson equation by 0.85.[5] Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction.[4] By definition five percent of a normal, non-smoking population would be expected to have predicted values that fall below the LLN, while 95% will have predicted values above this value.

Using this comparison, obstructive and restrictive patterns are defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN.

Restriction: Observed FVC below the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the NIOSH classification scheme. For those persons with values below the LLN, the criteria are:

	OBSTRUCTION (FEV_1/FVCx100)	RESTRICTION (% Predicted FVC)
Mild	>60	>65
Moderate	≥45 to ≤60	≥51 to ≤65
Severe	<45	<51

Belt Spirometer Measurements

The NIOSH belt spirometer was developed for use in occupational asthma investigations. This device is composed of two units - a modified flow sensor (Tamarac, Inc), and a small micrprocessor for data collection and storage. Both software and data can be transferred from the microprocessor to a standard IBM compatible personal computer. In a typical application, the unit is carried by the worker and an alarm sounds every 2 hours to prompt the worker to perform an FVC maneuver during waking hours. The device stores the raw flow-time curve at a rate of 100 samples per second for up to 9 seconds of forced exhalation. In addition, the sensor temperature and the date and time of the maneuver are automatically stored. The device is capable of storing up to 256 curves before data must be downloaded. BTPS correction of the unheated ceramic sensor is based on the instantaneous temperature of the air leaving the sensor. The device has been tested using a mechanical pump simulator with the 24 ATS waveforms and found to meet the ATS recommended accuracy limits.[5]

There are several advantages of this device over the method which used the miniWright peak flow meter to assess variable airflow obstruction.

Since the belt spirometer saves the entire flow-time curve, it is possible to review the flow-volume curve of each individual FVC maneuver to assess the adequacy of the subject's effort. This allows the separation of lower pulmonary function values due to poor test performance from those due to an acute response. In addition to peak expiratory flow (PkF), temporal values of FVC, FEV_1, and FEV_1/FVC% values are also available for detecting changes which may be related to workplace exposures. These spirometry results are enhanced when combined with a log of symptoms and exposures.

There are two sources of information used in the interpretation of the belt spirometry data. One is a set of flow-volume curves and the other is a plot of the various parameters as a function of time, grouped by day. The purpose of the flow-volume curves is to assess the quality of the FVC maneuvers. In addition, the curves can be used to determine if there is a change in the flow rates at any particular lung volume.

For each subject, a separate page is printed for each day of data. The flow-volume curves are placed on the page in chronological order, left to right and top to bottom. Above each set of flow-volume curves is the military time the maneuvers were started, the curve number, FEV_6, FEV_1, and PkF. Although only the values from the three best curves (those with the largest sum of FVC and FEV_1) are printed, all of the flow-volume curves are plotted.

For the trend analysis, four parameters are reported (FVC, FEV_1, PkF, and FEV_1/FVC). In order to detect daily and weekly changes in these parameters, the FVC, FEV_1, and PkF are expressed as a percentage of their respective weekly mean. The upper limit of normal for FVC and FEV_1 is 15 percent (daily and weekly changes) and for PkF is 20 percent.

The recommended procedure for interpreting these results is to first review the trend analysis. If a particular trend is observed or the upper limits of normal are exceeded, then the flow-volume curves for the relevant testing sessions should be reviewed to insure that the test performance was adequate. In addition, any interpretation should be consistent with the observed changes in all of the parameters.

EVALUATION CRITERIA

Isocyanates

Isocyanates are potent irritants of the mucous membranes of the eyes, gastrointestinal, and respiratory tracts. Direct skin contact can also cause a marked inflammatory reaction. The irritant effects on the respiratory tract may progress to a chemical bronchitis or asthma, characterized by severe bronchospasm. Isocyanates can also sensitize workers so that they are subject to severe asthma attacks, even when they are re-exposed at concentrations below exposure criteria. Sudden death due to acute severe asthma in sensitized subjects may occur.[11-18]

Sporadic cases of hypersensitivity pneumonitis (HP) have also been reported in workers exposed to isocyanates. Individuals with acute HP typically develop symptoms 4 to 6 hours after respiratory exposure; symptoms are often "flu-like" with fever, muscle aches, and sometimes headaches. They may also have a dry cough, chest tightness, and difficulty breathing. Individuals with chronic HP will often experience progressive difficulty in breathing, fatigue, and weight loss.[17]

Sensitized employees are at highest risk from continuing or repeated exposure to isocyanates, even at levels below occupational exposure limits or the detection limit of the analytical method. Therefore, air sampling for isocyanates is generally not a useful tool for determining if symptomatic or sensitized individuals are at risk.

Within industries where isocyanates are used, the prevalence of isocyanate-related symptoms may reach 10%.[11-13] Among workers with respiratory symptoms, the predominant clinical diagnosis is bronchial asthma. Rhinitis (runny nose), conjunctivitis (watery eyes), chronic obstructive lung disease, and skin lesions are also observed.[19]

Isocyanates can induce immediate, late, and dual (combined intermediate and late) asthmatic responses; the late asthmatic reaction predominates on inhalation challenge testing.[13] In a study of 29 workers referred for specific inhalation challenges with isocyanates, 7 had an immediate response, 15 had an early late or late response, and 7 had dual reactions.[15] Delayed asthmatic reactions may be missed by cross-shift spirometry, but should be detected by serial measurements of peak expiratory flow rates. In one study, workers currently exposed to MDI had cross-shift changes in forced expiratory volume in one second (FEV_1) that were not significantly different from zero. However, the comparison population of workers with no history of MDI exposure had a mean cross-shift increase in FEV_1, so there was a significant difference between the two groups.[16]

The role of immunologic testing in diagnosing cases of isocyanate-induced asthma is still under investigation. Estimates of the percentage of symptomatic individuals with isocyanate induced asthma who have immunoglobulin-E (IgE) antibodies directed against isocyanates conjugated to human serum albumin have ranged from 14%[12] to 80%.[17] Isocyanates can also cause HP, characterized by shortness of breath and fever for several hours after exposure and the presence of isocyanate-specific immunoglobulin-G (IgG) antibodies. In a study of 29 individuals with positive inhalation challenges to isocyanates, none had isocyanate-specific IgE alone. Thirteen of these subjects had isocyanate-specific IgG only, while eight had both IgE and IgG. Recent evidence suggests that a hypersensitivity pneumonitis type of reaction may be a more frequent consequence of MDI exposure than previously recognized, approaching 5%.[18]

Epidemiologic studies of occupational asthma[19] indicate that, although improvement is often noted after exposure to the precipitating agent is terminated, symptoms and bronchial hyperactivity may persist for many years or indefinitely. Persistence of chronic asthma appears to be related to the duration of an individual's exposure following onset of the disease, and may also be related to the severity of the asthmatic reaction. In a follow-up study of 50 workers with isocyanate-induced asthma, all of whom had avoided isocyanate exposure for at least 4 years, 82% continued to have respiratory symptoms and approximately half of these required inhaled or oral medications for asthma at least once per week.[20] Death has been reported in an isocyanate-sensitized worker who continued to work with polyurethane paint containing isocyanates.[21]

Evaluation criteria are used as guidelines to assess the potential health effects of occupational exposures to substances and conditions found in the work environment. These criteria are generally established at levels that can be tolerated by most healthy workers occupationally exposed day after day for a working lifetime without adverse effects. Because of variation in individual susceptibility, a small percentage of workers may experience health problems or discomfort at exposure levels below these existing criteria. Consequently, it is important to understand that these evaluation criteria are guidelines, not absolute limits between safe and dangerous levels of exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

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 criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure.

The primary sources of environmental evaluation criteria considered in this report are: (1) NIOSH Recommended Exposure Limits (RELs), (2) the 1995-1996 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Permissible Exposure Limits (PELs). The OSHA PEL may be required to take into account the feasibility of controlling exposures where the agents are used; the NIOSH RELs are, by contrast, based primarily on concerns related 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 those levels specified by OSHA. The exposure criteria are reported as: time-weighted average (TWA) exposure recommendations averaged over the full work shift; short-term exposure recommendations for a 10-15 minute exposure period; and ceiling levels not to be exceeded for any amount of time. For dusts, gases, or related substances, these exposure criteria and standards are commonly reported as parts contaminant per million parts of air (ppm), or milligrams of contaminant per cubic meter of air (mg/m^3).

OSHA, NIOSH, and the ACGIH exposure standards and criteria for both MDI and TDI are listed below as TWA concentrations measured over a full work shift or at shorter intervals as specified, or as ceiling exposure limits (C) not to be exceeded at any time.[7-10]

	MDI	TDI
NIOSH-REL	5 ppb (TWA) 20 ppb (10 min. C)	LFL - Lowest feasible limit Potential carcinogen
OSHA-PEL	20 ppb C	20 ppb C
ACGIH-TLV	5 ppb (TWA)	5 ppb (TWA) 20 ppb C

ppb - parts per billion parts air by volume.

Both the NIOSH REL and ACGIH TLV for MDI are a TWA of 5 parts MDI per billion parts air (ppb) for an 8-hour workday (ACGIH) or up to a 10-hour workday (NIOSH).[7-9] NIOSH also recommends a 10-minute ceiling of 20 ppb .

The exposure level at which respiratory sensitization is first initiated in man is unknown. Some studies have suggested that exposure to MDI levels below the exposure criteria may produce isocyanate-induced respiratory sensitization in some workers.[22,23]

The NIOSH recommended exposure levels apply to diisocyanate monomers only, and not to the higher polymers of these compounds. Little is known about the toxicological effects of polymeric isocyanates. No long-term studies of the effects on humans have been conducted.[24] However, it is thought that the inhalation of any species having multiple unreacted isocyanate groups may impair respiratory function or give rise to sensitization.[24-25] In 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. This new control limit is 20 micrograms per cubic meter ($\mu g/m^3$) of isocyanate group (-N=C=O) expressed as an 8-hour TWA, and a 70 $\mu g/m^3$ 10-minute ceiling. This new control limit requires that the analytical methods be applicable to "total isocyanate," which includes the sum of all isocyanate species, both the monomer and polymer components.[26]

Indoor Environmental Quality (IEQ) Parameters

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are: (1) sources of odors or contaminants, (2) problems with the design or operation of the HVAC system, (3) pathways between contaminant sources and the location of complaints, and (4) the activities of building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported high prevalences of symptoms among occupants of office buildings. Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints. Among these factors are imprecisely defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise. Indoor environmental pollutants can arise from either outdoor sources or indoor sources.[27-30]

Problems NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psycho-social stressors. In most cases, however, these problems could not be directly linked to the reported health effects.[27-30]

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, OSHA, and the ACGIH have published regulatory standards or recommended limits for occupational exposures. With few exceptions, air contaminant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[31-32]

Measurement of indoor environmental contaminants has rarely been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature, and RH, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

Temperature and Relative Humidity (RH)

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. American National Standards Institute (ANSI)/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[31-32]

Carbon Dioxide (CO_2)

CO_2 is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality (IAQ), recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, and 15 cfm/person for reception areas, and provides estimated maximum occupancy figures for each area.[31-32]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2

concentrations suggest that other indoor contaminants may also be increased.[33]

RESULTS

Environmental

Isocyanates

Isocyanate measurements collected throughout the J.L. Long Middle School in August of 1994, are shown in Tables 1 through 3. Isocyanates were not detected in any of the air samples during two days of sampling at the school. The minimum detectable air concentration for both TDI and MDI was approximately 2 ppb. Isocyanates were detected by air sampling during a test application of both foam and coating materials (Table 4). This was a brief test application of foam as well as coating agents. This sampling demonstrated that isocyanates were released during the application of both foam and coating agents. None of the isocyanate concentrations exceeded the short term exposure limits or ceiling exposure recommendations of OSHA, NIOSH, or ACGIH. Some of the short term isocyanate concentrations we measured were high by comparison to the TWA exposure standards and criteria of OSHA, NIOSH, and ACGIH. However, the test application and sampling did not include a full work shift. The highest isocyanate concentration (approximately 16 ppb) was measured during the drying of surface coatings applied to the foam; this short term concentration was measured using the isocyanate sampling meter in the programmed setting for MDI. This sampling data indicates the potential for overexposure to isocyanates during the application of roofing materials.

Considering the ventilation practices used at the school during roofing operations, the potential for entrainment of isocyanates into the building would have been possible. However, we were not able to determine this quantitatively or to measure isocyanate concentrations or occupant exposures inside the school building during these times. The entrainment of isocyanates into occupied building spaces could have occurred through open windows, other building openings, or by operation of the HVAC systems. Building roofers indicated that the HVAC systems were routinely shut off during the foam application and during the spraying of coatings. However, the systems could be operated during the application of coating materials by roller brush or during the drying period of the coating materials (approximately 24 hours). This suggests that the HVAC system could be in operation during times when the evaporation of coating materials could produce high concentrations of isocyanates in air; it also suggests a potential mechanism for the entrainment of isocyanates into the building and a potential exposure route for building occupants. The outside air intakes for most of the HVAC systems were located at roof level.

Indoor Environmental Quality (IEQ) Parameters

CO_2, temperature, and RH measurements collected on May 16 - 17, and August 10 - 11, 1994, are shown in Table 5. The range of temperatures inside the school on the days sampled was 70.0 to 80.0 degrees F. RHs inside the school on the days sampled ranged from 40 to 70 percent. CO_2 levels inside the school during the days sampled ranged from 475 to 1850 ppm. Temperature and RH measurements suggest that ASHRAE thermal comfort recommendations were not met in the office and the gym office, with temperature measurements of 78 to 80 degrees F and RHs of 38 to 57 percent at these temperatures on occupied days. Thermal comfort is influenced by temperature and humidity as well as by clothing, activity level, and metabolic heat production. CO_2 concentrations in a majority of the rooms sampled exceeded the maximum recommended comfort level of 800 ppm. Above this level, occupants are more likely to perceive a room as being stuffy or to complain of odors. CO_2 is a constituent of exhaled breath and its concentration is dependent upon the number of room occupants in addition the rate of supply of fresh air. The office, art room, and rooms 3, 4, 7, 8, 11, 14, 15, 17, 106, 110, 111, and 131 showed CO_2 concentrations above this level each time they were sampled while occupied. Rooms 3, 7, 8, 11, 14, 15, 17, 106, and 111 showed CO_2 levels above 1200 ppm each time they were sampled while occupied. Rooms 4, 11, and 106 showed levels above 1400 ppm each time they were sampled while occupied. Rooms 11, 15, and 17 showed levels above 1600 ppm on August 11, 1994. These CO_2 levels suggest a need for additional outside air intake.

Medical

Questionnaires were completed by 85% (87/102) of the school employees. Baseline and periodic spirometry was evaluated on 14 employees. Tenure at J.L. Long Middle School was calculated by subtracting the employee's reported start date from the date of the questionnaire, and rounding the number of elapsed days off to the nearest year. Questions were also asked to determine the number of years spent at other jobs with potential exposures to isocyanates (foundry industry, plastics industry, rubber industry, work with insulation, work with polyurethane paints, work with polyurethane foam, work with any other isocyanates). Questions concerning symptoms, previous and current illnesses, current medication usage, and current medical care for respiratory symptoms were asked. Information on smoking habits was also collected.

The case definition for asthma was based on self report of symptoms consistent with asthma (wheezing, attacks of shortness of breath with wheezing, and use of medications for asthma), as well as self report of physician-diagnosed asthma.

Symptom definitions were derived from responses to specific questions from a standardized survey. Asthma categories were: physician-diagnosed with symptoms; physician-diagnosed, no symptoms; no physician-diagnosis but symptoms present. Surrogates for exposure included current work location (floor), presence in the building during roof repair, and smelling "unusual odors" during at least one episode of roof repair.

Eighty-five percent (74/87) of the participants were female. The age range for 86 of the participants (one declined to give age) was 23-59 years with a mean age of 42 years. Sixteen percent (14/87) of the participants were current smokers, 21% (18/87) were former smokers, and 63% (55/87) claimed to have never smoked. Of those who were current or former smokers. 81% (26/32) smoked 1 pack of cigarettes or less per day, and the remaining 19% (6/32) smoked more than one pack per day. (Table 6)

Seventy-five percent of the respondents were teachers, the remainder either worked in administration, the library, or as clerks, counselors, aides, or interpreters. All areas of the school were represented, through the largest number, 41% (36/87) reported working on the first floor. There were several new teachers, so tenure at the school ranged from 0-24 years, the median was 5 years. Forty-three percent (37/87) had worked at this school 1-5 years, and 25% (22/87) had worked 6-10 years (Table 6).

Three participants (3%) reported that they had worked at other jobs in other industries that had the potential to expose them to isocyanates. One participant reported working with insulation, another worked in the rubber industry, and the third worked in the foundry industry with plastics and polyurethane foam. The tenure for two of these was very short (<1 year), but the third had worked several years in another job with potential exposure. This individual who had a diagnosis of asthma, exhibited a mild obstructive pattern on spirometry and had symptoms of asthma.

Twenty-six percent (23/87) complained of chronic cough and chronic phlegm. Thirty-six percent (31/87) had complaints of dyspnea, though only 5% (4/87) of individuals complained of grade III shortness of breath. Thirty-seven percent (32/87) or slightly more than one-third of the participants complained of wheezing or whistling noises in their chest. When asked about symptoms which employees believed were related to work, 8% (7/87) reported eye and nasal symptoms, and 12% (10/87) complained of chest symptoms.

Twenty-six percent (23/87) of the respondents indicated that they had seen a physician in the last year for a respiratory concern. When asked about respiratory illnesses since childhood, 24 reported hay fever, one had emphysema, 35 reported bronchitis, and 17 reported pneumonia.

Twenty-nine percent (25/87) of participants responded "yes" to the question, "Have you ever had asthma:" Twenty-four percent (21/87) reported that asthma had been diagnosed by a physician. Five had been diagnosed as children. Three of these had seen their asthma resolve and return in their adult years. Four physician-diagnosed individuals reported no symptoms. Five individuals reported symptoms, but had no physician diagnosis of asthma. The prevalence of asthma was 30% (26/87) using the case definition of this study. Twenty three percent (20/87) reported development or worsening of asthma since starting work at the JL Long Middle School.

RAST for isocyanate sensitization was not done. The Baylor Asthma and Pulmonary Clinic center study RAST for "spring allergens" and pigeon were positive in 2 and 1 individual respectively. It is not known if there was improvement in the symptoms after the roofing was completed. However the pulmonary function on half the diagnosed asthmatic group (7/14) worsened with return to the building. Four individuals' methacholine challenge tests became positive with return to work.

Eighty percent (20/25) of those reporting asthma said that they were in the building on at least one occasion when the roof was being repaired. Two failed to respond to the question regarding exposure to roof repair. Of the remaining two who said they were not in the building during roof repair, one had complaints of asthma symptoms.
When the prevalence rates of asthma were compared by job location, no elevated rates were found. The prevalence rate of asthma in those who were present on at least one occasion when the roof was being repaired was 2.6 times (CI .8, 8.5) that in those who had asthma and were never present when the roof was repaired, although this difference was not statistically significant (Table 7).

Thirty six percent (30/83) of the respondents reported smelling "unusual odors" on at least one occasion when the roof was being repaired (Table 8). Four employees did not respond to this question. Of those employees who reported smelling "unusual odors" on at least one occasion when the roof was being repaired 37% (11/30) met the case definition for asthma. The prevalence rate was 1.5 times (CI .7, 3.0) higher in the asthmatics who smelled "unusual odors" during at least one roof repair as compared to asthmatics who did not smell any unusual odors during at least one roof repair. The prevalence rate ratio was not different from one; no significant increase in the prevalence rate of asthma was associated with smelling "unusual odors" during roofing.

Fourteen of 15 employees from the list supplied by the school administration participated in baseline pulmonary function testing. The equipment was set up at a medical facility next to the school building. This was done in an attempt to have the participants perform spirometry before entering the school building for the fall session and after being out of the building for the summer. Twenty-one percent (3/14) of the participants had abnormal pulmonary function. Two exhibited mild obstructive lung patterns, and one had a moderate obstructive lung pattern. These three also reported that they had physician-diagnosed asthma and were symptomatic. All three were over 40 years of age and had worked at the J.L. Long Middle School for 5 or more years. The employee with the moderate obstructive pattern had never smoked cigarettes, while the two with mild obstructive patterns were current or former cigarette smokers. Two of these individuals also reported using medications to control asthmatic symptoms.

In spite of efforts to start the spirometry testing before the participants entered the school building for the fall session, nine of the 14 had already been in the building either the day or week before testing. All 14 were given a belt spirometer and log book and were instructed on how to perform the tests and keep records of times, activities, locations, exposures, use of inhalers, symptoms, and smoking. Instructions were also included in the booklet, and participants were given a phone number to call if problems arose. The participants were instructed to perform the tests every two hours while awake. Eight of the participants performed the tests fairly consistently, but the remaining six had too few tests to draw any conclusions. Of the eight, four had 20% or greater variability in the FEV_1, FVC, and PF values over the testing period. Three of these showed an overall decreasing trend. Two of the four had an obstructive baseline pattern. One subject, who had a normal baseline spirometry, had a 20% drop in peak flow over the first week of work from Monday to Friday and also experienced some chest tightness and wheezing on Thursday and Friday of the first week in the building. Two others had such erratic values that trends could be established and the remaining individual showed some variability in values but without any identifiable trend.

CONCLUSIONS

This evaluation was prompted by reports of an increased prevalence of physician-diagnosed asthma among workers at J.L. Long Middle School. During preliminary walk-through surveys, NIOSH investigators discovered that isocyanate materials were components of the polyurethane foam and coating agents used in school roofing materials. Both MDI and TDI were identified as constituents in the polyurethane roof foam or in the coating materials. These isocyanates were not detected in air samples taken inside the school at a time free of any roofing activities. Isocyanate compounds were measured in air samples during a test application of roofing foam and coating materials; this demonstrated the potential for the release of isocyanates during roofing activities. Based on school HVAC operations and practices, the entrainment of roofing materials and isocyanates into the school was possible and represents a potential source of worker exposure. Further measurements taken to assess indoor environmental quality suggests some deficiencies in the control of temperature and RH. CO_2 measurements taken in many school rooms suggests the need for additional outside air intake.

Reported symptom prevalances were high, with 37% of participants reporting chest wheezing or whistling. Twenty-five (29%) said that they had asthma. Twenty of these 25 said that their asthma was worse since being at J.L. Long Middle School. The prevalence of asthma in the U.S. population is estimated to be 4-10%.[34]

We were not present at the school during roof application or repair activities and, consequently, were not able to determine quantitatively the presence of isocyanates inside the school building or determine if building occupants were overexposed. Further, we were unable to determine conclusively the etiology of the increased prevalence of asthma at the J.L. Long Middle School; however, exposure to isocyanates is suspect for the following reasons:

(1) Isocyanates are potent asthmagens. Exposures to isocyanates can sensitize workers, making them subject to severe asthma attacks if they are exposed again, even at exposure very low levels below the NIOSH REL.[35]

(2) Isocyanates were constituents of the roofing materials used. Sampling results from a test application of roofing foaming and coating/ sealing compounds, at a location remote from the school (so as not to expose children or teachers), indicated that isocyanate compounds were released into air during application of both the foam and coating materials.

(3) Although we were unable to conduct sampling inside the school during roofing operations to determine the intensity of isocyanate exposures, school employee exposure to isocyanates during roofing operations was probable:

The application of roofing materials was done at times when school was in session and teachers / staff were present in the building

Review of reported ventilation practices in place and used during roofing operations and roofing repairs indicate that ventilation systems (with roof level outside air intakes) would have been in operation during portions of the roofing activities (especially while the isocyanate containing sealants were drying) and that windows could have been opened by teachers or by other building occupants.
Many school employees reported the presence of roofing odors inside the school building during roofing operations.

(4) The distribution of asthma cases was throughout the building. There was no significant association with a specific school ventilation system, school area / or room (such as a school art room, shop, or science laboratory).

(5) Eighty percent of the asthma cases indicated that they were in the building on at least one occasion during roofing activities.

RECOMMENDATIONS

Most of the recommendations provided below were included in the interim environmental report for the control of exposures to roofing materials including isocyanates. In addition, recommendations are also included below to address indoor environmental quality problems identified during this survey:

1. **Product Substitution:** When feasible, employers should substitute a less hazardous material for isocyanates. However, substitutes must be selected with extreme care, and possible adverse health effects should be evaluated first.

2. **Roofing Applications:** The application of roofing materials containing isocyanates should be done only when the building is unoccupied. The HVAC systems should be turned off and outside air intakes or other building openings should be closed or covered. Adequate drying time should be provided for all foam products, caulking, or coating materials prior to opening the building or operating the HVAC systems.

3. **Exposure Monitoring:** Each employer who manufactures, transports, packages, stores, or uses isocyanates in any capacity should determine whether a potential exists for any worker to be exposed to these chemicals.

4. **Worker Education:** Equipment maintenance and worker education are vital aspects of a good occupational health and safety program. Workers must be informed of (1) any materials that may contain or be contaminated with isocyanates and (2) the nature of the potential hazard (see 29 CFR 1910. 1200). Employers must transmit this information by means of a hazard communication program, which is to include container labeling, MSDs, and worker training.

5. **Worker Isolation:** The areas in which isocyanates are produced or used should be restricted to workers who are essential to the process or operation.

6. **Protective Clothing and Equipment:** Workers directly involved in polyurethane handling or applications should be provided with and required to use appropriate personal protective clothing and equipment such as coveralls, footwear, chemical-resistant gloves and goggles, full face shields, and suitable respiratory equipment.

7. **Respiratory Protection:** The use of respirators is the least preferred method of controlling worker exposures. Respirators should not be used as the only control for routine operations, but NIOSH recognizes that they may be required to provide protection under certain situations such as implementation of engineering controls, some short-duration maintenance procedures, and emergencies. NIOSH maintains that the most protective respirators should be used for situations involving carcinogens. The respirator recommendations for worker application of isocyanate containing roofing materials would include:

- Any self-contained breathing apparatus with a full face-piece operated in a pressure-demand or other positive-pressure mode, and

- Any supplied-air respirator with a full face-piece operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode.

The respirators should be used as a part of a respiratory protection program. This respiratory protection program must, at a minimum, meet the requirements of 29 CFR 1910, 134. Respirators must be approved by NIOSH. A complete respiratory protection program should include (1) regular training and medical evaluation of personnel and (2) fit testing, periodic environmental monitoring, and maintenance, inspection, cleaning, and storage of equipment. The program should be evaluated regularly. The following publications contain additional information about selection, fit testing, use, storage, and cleaning of respiratory equipment: *Guide to Industrial Respiratory Protection (NIOSH 1987a) and NIOSH Respiratory Decision Logic (NIOSH 1987b).*

8. **Decontamination and Waste Disposal:** Procedures for decontamination, waste disposal, and transport should be established for isocyanate contaminated materials or equipment.

9. **Medical Monitoring:** A medical monitoring program should be established for early detection and prevention of both the acute and chronic health effects among workers exposed to isocyanates (NOTE: This recommendation would apply to the roofing application workers, others directly involved in handling or application of isocyanates, and diagnosed asthmatic employees at J.L. Long Middle School). The worker's physician should be given information about the adverse health effects of exposure to isocyanates and an estimate of the worker's potential for exposure.

10. **Surveillance and Disease Reporting:** NIOSH encourages reporting of all cases of occupational asthma to the State health departments and regulatory agencies such as OSHA and Mine Safety and Health Administration (MSHA). To enhance the uniformity of reporting, NIOSH has developed an asthma surveillance case definition and recommended reporting guidelines. This definition and these guidelines are recommended for surveillance of work-related asthma by State health departments and regulatory agencies receiving reports of cases from physicians and other health-care providers.

11. **Balance and adjust the school HVAC systems** to ensure that they operate according to the ASHRAE recommended standards for outdoor air supply, temperature and relative humidity. The desired air flows, humidities, and temperatures should be verified by engineers qualified to perform such ventilation system work.

REFERENCES

1. Millard MW. J.L. Long Middle School Project, Administration Dallas Independent School District. Baylor Asthma and Pulmonary Rehabilitation Center, Baylor

   University Medical Center, Dallas, TX. May 5, 1994.

2. ACGIH [1995]: *Air sampling instruments for evaluation of atmospheric contaminants*, 8th ed. Cincinnati: OH: American Conference of Governmental Industrial Hygienists, pp 369-510.

3. American Thoracic Society [1987]. Standardization of spirometry-1987 update. Am Rev Respir Dis 136:1285-1298.

4. Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B [1983]. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis 127:725-734.

5. Crapo RO, Hankinson JL, et. al [1995]. American Thoracic Society Standardization of Spirometry: 1994 Update. Am J Respir Crit Care Med 152:1107-1136

6. Lanese RR, Keller MD, Foley MF, Underwood EH [1978]. Differences in pulmonary function tests among whites, blacks, and American indians in a textile company. J Occup Med 20:39-44.

7. ACGIH [1993]. Threshold limit values for chemical substances and physical agents and biological exposure indices for 1993-1994. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

8. NIOSH [1978]. NIOSH criteria for a

recommended standard: occupational exposure to diisocyanates. U.S. Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health. DHEW (NIOSH) Publication No. 78-215.

9. NIOSH [1992]. NIOSH recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

10. Code of Federal Regulations [1989]. OSHA Table Z-1-A. 29 CFR 1910.1000. Washington, DC:U.S. Government Printing Office, Federal Register.

11. Rom WN (editor) [1983]. Environmental and Occupational Medicine. Boston: Little, Brown and Company, pp 240-41 and 621-22.

12. Baur, X [1991]. Isocyanates. Clin Exp Allergy *21*(Suppl 1):241-6.

13. Baur, X [1990]. New aspects of isocyanate asthma. Lung (Suppl):606-613.

14. Chan-Yeung M, Lam S [1990]. Evidence for mucosal inflammation in occupational asthma. Clin Exper Allerg *20*:1-5.

15. Cartier A, Grammar L, Malo JL, Lagier F, Ghezzo H, Harris K, Patterson R [1989]. Specific serum antibodies against isocyanates: association with occupational asthma. J Allergy Clin Immunol *84*:507-514.

16. Liss GM, Bernstein DI, Moller DR, Gallagher JS, Stephenson RL, Bernstein IL [1988]. Pulmonary and immunologic evaluation of foundry workers exposed to methylene diphenyldiisocyanate (MDI). J Allergy Clin Immunol *82*:55-61.

17. Patterson R, Hargreave FE, Grammar LC, Haris KE, Dolovich J [1987]. Toluene diisocyanate respiratory reactions. Int Arch Allergy Appl Immunol *84*:93-100.

18. Vandenplas O, Malo JL, Dugas M, Cartier A, Desjardins A, Levesque J, Shaughnessy MA, Grammar LC [1993]. Hypersensitivity pneumonitis-like reaction among workers exposed to diphenylmethane diisocyanate (MDI). Am Rev Respir Dis *147*:338-346.

19. Becklake MR [1993]. Epidemiology: prevalence and determinants. In: Bernstein IL, Chan-Yeung M, Malo JL, Bernstein DI. Asthma in the Workplace. New York: Marcel Dekker, Inc., pp. 29-60.

20. Lozewicz S, Assoufi BK, Hawkins R, Newman Taylor AJ [1987]. Outcome of asthma induced by isocyanates. Br J Dis Chest *81*:14-22.

21. Fabbri LM, Danieli D, Crescioli S, Bevilacqua P, Meli S, Saetta M, Mapp CE [1988]. Fatal asthma in a subject sensitized to toluene diisocyanate. Am Rev Respir Dis *137*:1494-1498.

22. NIOSH [1985]. Hazard evaluation and technical assistance report: Marion Power Shovel. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 80-073-1589.

23. Baur X, Dewair M, Rommelt H [1984]. Acute airway obstruction followed by hypersensitivity pneumonitis in an isocyanate (MDI) worker. J Occ Med. *26*:285-287.

24. Weyel DA, Rodney BS, Alaire Y [1982]. Sensory irritation, pulmonary irritation and acute lethality of a polymeric isocyanate and acute lethality of 2,6-toluene diisocyanate. Toxicology Appl Pharmacol *64*:423-430.

25. Hardy HL, Devine JM [1979]. Use of organic isocyanates in industry - some industrial hygiene aspects. Ann Occup Hyg *22*:421-427.

26. Silk SJ, Hardy HL [1983]. Control limits for isocyanates. Ann Occup Hyg *27*(4):333-339.

27. Morey PR, Shattuck DE [1989]. Role of ventilation in the causation of building-associated illnesses. Occupational Medicine: State of the Art Reviews 4(4):625-642.

28. Kreiss K [1989]. The epidemiology of building-related complaints and illness. Occupational Medicine: State of the Art Reviews 4(4):575-592.

29. Burge S, Hedge A, Wilson S, Bass JH, Robertson A [1987]. Sick building syndrome: a study of 4373 office workers. Ann Occup Hyg 31:493-504.

30. Mendell MJ, Smith AH [1990]. Consistent pattern of elevated symptoms in air-conditioned office buildings: a reanalysis of epidemiologic studies. Am J Public Health 80(10):1193-1199.

31. ASHRAE [1990]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 62-1989.

32. ASHRAE [1981]. Thermal environmental conditions for human occupancy. Atlanta, GA: American Society for Heating, Refrigerating, and Air-conditioning Engineers. ANSI/ASHRAE Standard 55-1981.

33. Rajhans GS [1983] . Indoor air quality and CO_2 levels. Occup Health in Ontario 4:160-167.

34. McLarty J [1992]. Epidemiology and occupational asthma. In: Bardana EJ, Montanaro A, O'Hollaren MT, eds. Occupational asthma. Philadelphia, PA: Hanley & Belfus, Inc. Publishers, p56.

35. NIOSH ALERT [1996]. Preventing asthma and death from diisocyanate exposure. DHHS (NIOSH) Publication No. 96-111.

Table 1. MDI Sampling Results from School Building J.L. Long Middle School, Dallas, Texas

Time	Room/ Location	MDI (ppm)	Sampling Time (min)
August 10, 1994:			
9:05 am	outside/front	4*	5
9:10 am	outside/front	3*	5
9:15 am	outside/front	3*	5
12:10 pm	outside/front	nd	5
10:15 am	Room 15	nd	5
10:22 am	Room 11	nd	5
10:30 am	Room 4	nd	5
10:38 pm	Room 17	nd	7
10:50 am	Room 8	nd	6
11:10 am	Room 111	nd	5
11:16 am	Room 110	nd	5
11:00 am	Room 106	nd	8
11:22 am	Room 131	nd	5
11:29 am	office	nd	5
11:36 am	auditorium	nd	6
11:46 am	library	nd	5
11:53 am	Room 206 / 207	nd	5
12:01 pm	gym office	nd	6
August 11, 1994:			
11:51 am	office	nd	5
11:57 am	auditorium	nd	5
12:02 pm	outside/front	nd	5
12:08 pm	Room 106	nd	5
12:18 pm	Room 111	nd	5
12:22 pm	Room 110	nd	5
12:30 pm	Room 15	nd	5
12:35 pm	Room 17	nd	5
12:43 pm	Room 8	nd	5
12:49 pm	Room 11	nd	5
12:56 pm	Room 4	nd	5

Table 1. MDI Sampling Results from School Building (Continued)
J.L. Long Middle School, Dallas, Texas

Time	Room/ Location	MDI (ppm)	Sampling Time (min)
August 11, 1994:			
13:06 pm	Room 131	nd	5
13:12 pm	gym office	nd	5
13:16 pm	Room 206/207	nd	5
13:22 pm	Library	nd	5

* The ambient sampling station was selected to provide a background for other MDI measurements taken inside the school or on the school's roof. The positive ambient results likely reflect an interference from oxides of nitrogen generated by morning automobile traffic; oxides of nitrogen are listed as a positive interference for MDI by this sampling method. The positive MDI sampling results from ambient locations are inconsistent with other survey data.

MDI - Methylene bisphenyl diisocyanate.
nd - Below the sampling and analytical detection limit, approximately 2 parts per billion parts air by volume (ppb).

Table 2. MDI Sampling Results from the School Roof J.L. Long Middle School, Dallas, Texas

Time	Location	MDI (ppb)	Sampling Time (min)	Sample Type
August 10, 1994:				
2:50 pm	rooftop	nd	5	ambient
2:55 pm	rooftop	nd	5	ambient
3:00 pm	rooftop	nd	4	ambient
3:05 pm	rooftop	nd	5	aggressive*
3:10 pm	rooftop	nd	5	aggressive*

* Aggressive samples were taken by cutting / agitating the roofing materials during sampling.
MDI - Methylene bisphenyl Isocyanate.

Table 3. TDI Sampling Results from School Building
J.L. Long Middle School, Dallas, Texas

Time	Room/Location	TDI (ppb)	Sampling Time (min)
August 10, 1994:			
2:10 pm	Room 15	nd	5
2:15 pm	Room 8	nd	5
2:25 pm	Room 106	nd	5
2:30 pm	Room 131	nd	5
2:35 pm	Room 206/207	nd	5
2:40 pm	Library	nd	5

* TDI -Toluene 2,4-diisocyanate.
nd - Below the sampling and analytical detection limit, approximately 2 parts per billion parts air by volume (ppb).

Table 4. MDI and TDI Sampling Results During the Application of Roofing Materials*
J.L. Long Middle School, Dallas, Texas

Time of Sampling	MDI (ppb)	TDI (ppb)	Sampling Activity
August 11, 1994:			
10:35 am	nd	--	Before Spraying
10:40 am	3	--	During Foam Application
10:45 am	3	--	During Foam Application
10:46 am	3	--	During Foam Application
10:47 am	6	--	During Foam Application
10:47 am	6	--	During Foam Application
10:49 am	--	nd	Background Away From Application
10:49 am	--	3	During Application of Coating Materials
10:50 am	--	nd	During Application of Coating Materials
11:05 am	nd	--	During Application of Coating Materials
11:07 am	16	--	During Application of Coating Materials
11:11 am	nd	--	Inside Truck Containing Reagents

***** This was a test application of roofing materials done in a parking lot remote from the school on August 11, 1994.
TDI -Toluene 2,4-diisocyanate
MDI - Methylene bisphenyl Isocyanate.
nd - Below the sampling and analytical detection limits, approximately 2 parts per billion parts air (ppb).

Table 5. Indoor Environmental Quality Measurements
J.L. Long Middle School, Dallas, Texas

Time	Room/ Location	Occupants	Temp (^{0} F)	Relative Humid. (%)	CO2 (adj.) (ppm)
May 16, 1994:					
14:15 pm	Outside	n/a	81.0	72	375*
14:15 pm	Office	0	75.1	40	1275*
14:35 pm	Auditorium	0	75.1	48	475*
14:45 pm	Room 106	0	74.6	45	1250*
14:50 pm	Room 131	0	75.5	45	1175*
15:15 pm	Gym office	0	70.0	70	625*
		0			
May 17, 1994:					
10:42 am	Outside	n/a	74.0	84	425*
10:40 am	Art Room	0	71.7	47	1175*
11:17 am	Room 15	16	72.3	46	1300*
11:21 am	Room 4	14	72.9	51	1475*
11:22 am	Room 3	1	73.3	49	1250*
11:28 am	Room 111	18	74.4	48	1350*
11:31 am	Room 110	9	75.0	43	1200*
11:43 am	Room 206	23	75.1	46	775*
11:46 am	Library	1	73.7	46	675*
13:43 pm	Outside	n/a	77.9	77	375*
13:44 pm	Room 14	0	76.2	46	1325*
13:46 pm	Room 15	17	72.6	52	1525*
13:51 pm	Room 4	11	77.0	50	1475*
13:53 pm	Room 3	1	76.7	48	1250*
13:57 pm	Art Room	1	71.3	52	1175*
14:04 pm	Room 111	21	76.1	47	1400*
14:06 pm	Room 110	3	75.6	46	1175*
14:12 pm	Room 207	15	75.6	58	675*
14:14 pm	Library	3	76.4	47	675*
August 10, 1994					
9:25 am	Outside/front	n/a	84.0	51	525

Table 5. Indoor Environmental Quality (IEQ) Measurements (Cont.)

Time	Room/ Location	Occupants	Temp (^{0} F)	Relative Humid. (%)	CO_2 (adj.) (ppm)
August 11, 1994:					
12:49 pm	Room 11	25	75.4	44	1625
12:35 pm	Room 17	27	73.5	41	1825

*Note: Based on post-calibration, 150 ppm was subtracted from instrument readings for CO_2.

Table 6.
J.L. Long Middle School, Dallas, Texas

CHARACTERISTICS OF THE RESPONDENTS	
N=87	
GENDER	
FEMALE	84%(73/87)
AGE	
RANGE	23-59
MEAN	42 (+/- 9)
SMOKING STATUS	
CURRENT SMOKER	16%(14/87)
FORMER SMOKER	21%(18/87)
NEVER SMOKED	63%(55/87)
OCCUPATION	
TEACHER	75%(65/87)
ADMINISTRATION	3%(3/87)
OTHER	22%(19/87)
TENURE (YRS)	
<6MOS	18%(16/87)
1-5	43%(37/87)
6-10	25%(22/87)
11-15	1%(1/87)
16-20	18%(7/87)
MEDIAN	3YRS
LOCATION OF WORK	
GROUND FLOOR	22%(19/81)
1ST FLOOR	41%(36/81)
2ND FLOOR	13%(11/81)
PORTABLES	7%(6/81)
OTHER	11%(9/81)

Table 7
J.L. Long Middle School, Dallas, Texas

ASTHMA				
Present During Roofing		Yes	No	
	Yes	22	45	67
	No	2	14	16
	TOTAL	24	59	83

Prev. Rate for asthma in exposed group = 22/67=32.8
Prev. Rate for asthma in non-exposed group = 2/16=12.5
Prev. rate ratio = 32.8/12.5=2.6

Table 8
J.L. Long Middle School, Dallas, Texas

ASTHMA				
Smell Roofing Materials		Yes	No	
	Yes	11	19	30
	No	13	40	53
	TOTAL	24	59	83

Prev. Rate for asthma in exposed group = 11/30=36.7
Prev. Rate for asthma in non-exposed group = 13/15=24.5
Prev. rate ratio = 36.7/24.5=1.50

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