HEALTH HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT

HETA 93-0436

Trus Joist MacMillan
Deerwood, Minnesota

March 1996

Preface

The Hazard Evaluation and Technical Assistance Branch 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 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 and technical 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.

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TRUS JOIST MACMILLAN
DEERWOOD, MINNESOTA

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SUMMARY

In December 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from employees at the Trus Joist MacMillan (TJM) parallel strand lumber plant in Deerwood, Minnesota. The request indicated that several workers had developed occupational asthma, apparently related to isocyanate exposure at the plant. The company manufactures lumber products using long strands of aspen wood bound together with a 4,4-methylenediphenyl diisocyanate (MDI) resin.

In February 1993, a NIOSH team made an initial site visit of the facility. A NIOSH interim report dated October 20, 1993, summarized the medical records review for 12 individuals identified by the company as potentially having occupational respiratory problems. Ten of these individuals had a physician's diagnosis of occupational asthma attributed to MDI exposure.

During the week of February 13, 1994, NIOSH conducted an environmental and medical survey at the facility. The environmental survey consisted of area air sampling for MDI, total functional isocyanate group (NCO), 4,4'-methylenedianiline (MDA), and wood dust. During the medical survey a health, symptoms, and occupational history questionnaire was administered to current employees. The questionnaire was designed to distinguish between workers who developed symptoms prior to a major change in the plant ventilation in February 1993 and development of symptoms in those who began their employment after the ventilation change was made. Analysis of the questionnaire indicated that respiratory symptoms were developing in workers who began their employment after the ventilation change was made.

Two area air samples had monomeric MDI concentrations that exceeded the NIOSH recommended exposure level (REL) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for personal exposure of 50 micrograms per cubic meter of air ($\mu g/m^3$). The samples were from an area that is primarily unoccupied but is used for access to the blenders. The samples also had NCO concentrations that exceeded the United Kingdom (UK) control limit of 20 $\mu g/m^3$. Three area concentrations of wood dust exceeded the REL and TLV of 1 milligram per cubic meter of air (mg/m^3).

At least 18 employees of TJM have developed respiratory illness that meet the NIOSH case definition for occupational asthma since the plant began production in October 1991. Although changes in ventilation took effect in February 1993, 9 (50%) of these 18 cases developed after this change; 4 of these cases were in workers who began their employment after the ventilation changes were made.

Based on the information collected during this evaluation, NIOSH investigators conclude that a health hazard existed from exposure to isocyanates at the Trus Joist MacMillan parallel strand lumber plant in Deerwood, Minnesota. Area air sampling conducted by NIOSH indicated the potential for employee exposure to isocyanates and wood dust above the NIOSH RELs and ACGIH TLVs. At least 18 employees of TJM have developed symptoms that meet the NIOSH surveillance case definition for occupational asthma since the plant began production in October 1991. Cases of occupational asthma continued to develop after ventilation system modifications. Recommendations include utilization of traditional industrial hygiene practices to eliminate the hazards and establishment of a medical monitoring program. The recommendations can be found in the Recommendations section of this report.

Keywords: SIC 2493 (Reconstituted wood products - oriented strand boards), 4,4-methylenediphenyl diisocyanate (MDI), functional isocyanate group (NCO), 4,4'-methylenedianiline (MDA), aspen, wood dust, lumber, asthma, hypersensitivity pneumonitis.

INTRODUCTION

In December 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from employees at the Trus Joist MacMillan (TJM) parallel strand lumber plant in Deerwood, Minnesota. The requestors asked that their identities remain confidential. The request indicated that several workers had developed occupational asthma, apparently related to isocyanate exposure at the plant. The company manufactures lumber products using long strands of aspen wood bound together with a 4,4-methylenediphenyl diisocyanate (MDI) resin.

In February 1993, a NIOSH team consisting of an occupational medicine physician and an industrial hygienist visited the facility. On February 16, a confidential meeting was held with the requesters. On February 17, an opening conference was held with plant management, followed by a walk-through evaluation of the plant and review of the company's air sampling data, safety manual, OSHA 200 logs and medical records.

A NIOSH interim report dated October 20, 1993, summarized the medical records review for 12 individuals identified by the company as potentially having occupational respiratory problems. Ten of these individuals had a physician's diagnosis of occupational asthma attributed to MDI exposure.

During the week of February 13, 1994, NIOSH conducted an environmental and medical survey at the facility.

BACKGROUND

Construction on the Deerwood plant began in 1990 and was completed in the spring of 1991. The first production employees were hired in April 1991, and the first successful board pressing was in October 1991. During the NIOSH visits, the plant production ran 24 hours a day. Employees worked either 8-hour shifts for 5 days per week or 12-hour shifts for 3 to 4 days per week. Thursdays were used for maintenance and tooling changes, with work lasting 8-12 hours. The plant had approximately 100 employees — referred to as “associates” at TJM — with about 70 in production and the remainder in support positions and in peripheral areas such as the wood yard.

At the Deerwood facility, TJM manufactures parallel strand lumber products from long wood strands and MDI resin. Aspen logs are delivered by truck to the log yard, from which the logs are fed into warm water ponds for rinsing and thawing. Inside the mill, on the “green end,” a ring debarker strips the bark from the logs, which are then trimmed and slashed into 12 in. x 1 in. x 1/32 in. pieces called long strands. The bark and other wood residue are used to fuel the plant energy system. The wet strands are dried in rotary dryers before entering one of two blenders.

The blenders are under negative pressure and vent through a bag house to the outside. In the blenders, the strands are coated with molten wax and atomized MDI. Sometimes zinc borate is added as a wood preservative for some products. MDI resin arrives at the plant by rail car and is pumped into one of four 12,700-gallon storage tanks, where it is blanketed by nitrogen to prevent moisture or air contact with the MDI. The resin is pumped directly from these tanks into the blenders; in the winter, it may need to be heated slightly to lower the viscosity enough to permit pumping. Approximately seven million pounds of MDI are used at the plant each year. The wax is maintained in a molten form, pumped as a liquid, and

sprayed into the blender. The blenders are cleaned weekly by individuals who enter the blender to scrape the wax, wood dust, and resin that have accumulated inside.

The MDI-coated strands leave the blender and fall across former heads, which orient them in a parallel alignment to form a continuous wood-fiber mat. Up to 35-foot sections of the mat are cut to form billets. Curing of the billets takes place in a steam injection press, which is totally enclosed. Although the press is not cleaned routinely, loose strands are removed on a weekly basis. The thickness of the pressed billet can be varied from 1-1/2 to 3 inches, depending on customer needs. Upon exiting the press, the edges of the billets are trimmed with saws, and the billets are stacked prior to delivery to the finishing area to be sanded and sawn to specific dimensions. The final product is packaged into finished bundles for shipment by rail or truck.

In 1992, TJM began a major modification of their plant ventilation system. In February 1993 the modified ventilation system began functioning in the plant. The modifications included enclosure of the billet formers, forming line, blender outfeed conveyors, and the first pass saws and conveyor located adjacent to the press outlet. In addition, the entire ventilation system was modified to put the MDI-processing areas under negative pressure with respect to the rest of the building to prevent migration of MDI-laden air from these areas.

The company's medical surveillance program consists of two components. Newly hired employees receive pulmonary function testing to establish a baseline reading, audiometric testing, and a chest x-ray. For follow-up, employees receive single-session pulmonary function testing (PFTs) every 6 months. Employees are routinely given the results of these PFTs if they are abnormal. Employees with "abnormal" results receive further clinical evaluation. Semi-annual testing is performed by a local practitioner who determines whether a test is "abnormal" and reports the results to TJM. The local physician would refer suspect cases of occupational asthma to a pulmonologist in St. Paul, Minnesota, for further clinical evaluation. Company medical records include any records from company referrals to medical practitioners. Medical records from the visits to the local physician and pulmonologist were kept in files at TJM.

EVALUATION METHODS

A. ENVIRONMENTAL

The environmental survey of February 16-19, 1994, consisted of area air sampling for MDI, total functional isocyanate group (NCO), 4,4'-methylenedianiline (MDA), and wood dust. Baskets containing sampling instruments were placed in several locations throughout the facility. Sampling was conducted during a full-production shift, a maintenance (cleaning) shift, and the start-up production shift following cleaning. A few area air samples were also collected during the start-up shift to measure 10-minute time-weighted average (TWA) concentrations of MDI and NCO.

MDI and TOTAL FUNCTIONAL ISOCYANATE GROUP (NCO)

Area air samples were collected for MDI using a NIOSH interim test method for isocyanates. The samples were collected in impingers containing a solution of tryptamine in dimethyl sulfoxide (DMSO). Some of the samples were collected in impingers containing a solution of

tryptamine in 20:80 acetonitrile:DMSO. Acetonitrile was added to the solution because the samples were collected in areas where the ambient temperature was near 60°F, the freezing point of DMSO. Personal sampling was not practical because of the danger of skin contact with the impinger solutions. Air was sampled at a rate of 1 liter per minute (lpm) using battery-powered sampling pumps. A few samples were collected at 2 lpm for a 10-minute period to evaluate ceiling concentrations. The samples were analyzed with high performance liquid chromatography (HPLC) with fluorescence detection for monomer and isocyanate-based oligomers of MDI. The limits of detection and quantitation were 0.2 and 0.8 micrograms (µg) of MDI per sample. The monomeric and oligomeric MDI air sampling results were used to make total functional isocyanate group (NCO) calculations. A conversion factor of .34 grams of NCO per gram of MDI was used.

Because the sampling/analytical method was an interim method and had little field testing prior to this evaluation, a few verification samples were collected for the laboratory with NIOSH Method 5521 for monomeric isocyanates.[1] These samples were collected in impingers that contained a solution of 1-(2-methoxyphenyl)-piperazine in toluene. Air was sampled at a rate of 1 lpm. The samples were analyzed with HPLC with electrochemical and ultraviolet detection for monomeric MDI. The limit of detection (LOD) and limit of quantitation (LOQ) for these samples were 0.30 and 0.95 µg/sample, respectively. The laboratory reported that the sample measurements corresponded well with those collected using the interim method, which has since been approved for publication in a future supplement to the NIOSH Manual of Analytical Methods as Method 5522.

An MDA Scientific Model TLD-1 Toxic Gas Detector® with a detection tape (colorimetric paper tape) for isocyanates was also used. This instrument provides average concentrations over 2-minute intervals. It was used in this survey to determine the potential and duration of isocyanate exposure during stacking of heated billets subsequent to their discharge from the press.

MDA

Samples were collected for MDA because it was suspected that MDI could possibly hydrolyze to MDA in the presence of water (or steam). They were collected in accordance with NIOSH Method 5029 for MDA.[1] Samples were collected on 37-mm diameter glass-fiber filters (sulfuric acid-treated) at a rate of 1 lpm and were analyzed with HPLC with electrochemical and ultraviolet detection for MDA. MDI is an interference in this method in that it converts to MDA on the acid-treated filter, so laboratory analysis of the sample will measure the combination of both the MDA and the MDI that has converted to MDA

(i.e., MDA+MDI). To obtain MDA results, the value from the adjacent MDI sample in each basket was to be subtracted from the value obtained in the MDA+MDI sample.

WOOD DUST

Because there could be potential for elevated concentrations of wood dust in the facility, especially in areas where wood products were sanded and sawed, several samples were collected for wood dust. These samples were collected on 37-mm diameter, 5-micrometer (µm) pore size, tared polyvinyl chloride (PVC) filters behind a circum-ferential inlet which was used to avoid collection of stray particles thrown from the saws. Samples were measured gravimetrically in accordance with NIOSH Method 0500 for total dust.[1]

B. MEDICAL

The medical survey of February 1994 consisted of a health, symptoms, and occupational history questionnaire that was administered to current employees. The questionnaire was designed to distinguish between development of symptoms in workers who began work prior to a major change in the plant ventilation in February 1993 and development of symptoms in those who began their employment after the ventilation change was made. This information could provide the company with a quantifiable assessment of whether or not their ventilation change had sufficiently controlled employee exposures in order to prevent development of new cases of occupational illness. The date the employee began work at TJM served as the basis for exposure classification. Workers who began work at TJM prior to February 1993 were in one exposure group and those who began work during or after February 1993 were in the other exposure group. All current employees were invited to complete the questionnaire. The questionnaire was administered by a NIOSH investigator and directly entered into a computer program (Epi-Info) for analysis.

The presence of respiratory symptoms, nasal, and eye irritation was assessed by the questionnaire. Chronic cough was defined as cough occurring on most days for as much as three months during the year. Chronic phlegm was defined similarly. Grade I dyspnea was defined as shortness-of-breath when hurrying on level ground or walking up a slight hill. Grade II dyspnea was defined as shortness-of-breath while walking on level ground with people of one's own age, and Grade III was defined as having to stop for breath when walking at one's own pace on level ground.

In November 1994, copies of the Occupational Safety and Health Administration (OSHA) log and summary of occupational injuries and illnesses (form 200) were requested, as were company medical records for all employees who had initial respiratory complaints since the opening of the plant.

NIOSH has developed an occupational asthma surveillance case definition and recommended reporting guidelines for surveillance of work-related asthma by State health departments.[2] This occupational asthma case definition (Figure 1) was used to define occupational asthma in this study.

EVALUATION CRITERIA AND TOXICOLOGY

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental evaluation criteria. These criteria suggest exposure levels to which most workers may be exposed for a working lifetime without experiencing adverse health effects. However, because of wide variation in individual susceptibility, some workers may experience occupational illness even if exposures are maintained below these limits. The evaluation criteria do not take into account individual hypersensitivity, pre-existing medical conditions, or possible interactions with other workplace agents, medications being taken by the worker, or environmental conditions.

The primary sources of evaluation criteria for the workplace include the following: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[3] the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[4] and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).[5] The objective of these criteria for chemical agents is to establish levels of inhalation exposure to which the vast majority of workers may be exposed without experiencing adverse health effects.

Occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimental data, or epidemiologic studies. Differences between the NIOSH RELs, OSHA PELs, and ACGIH TLVs may exist because of different philosophies and interpretations of technical information. It should be noted that RELs and TLVs are guidelines, whereas PELs are standards that are legally enforceable. OSHA PELs are required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are present. The NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected industries and as such tend to be conservative. A Court of Appeals decision vacated the OSHA 1989 Air Contaminants Standard in AFL-CIO v OSHA, 965F.2d 962 (11th cir., 1992); and OSHA is now enforcing the previous 1971 standards. However, some states which have OSHA-approved State Plans continue to enforce the more protective 1989 limits. The Minnesota Department of Labor and Industry has an OSHA-approved State Plan. The limits enforced under their plan will be discussed below. NIOSH encourages employers to use the 1989 limits or the RELs, whichever are lower.

Evaluation criteria for chemical substances are usually based on the average personal breathing zone (PBZ) exposure to the airborne substance over an entire 8- to 10-hour workday, expressed as a TWA. Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). To supplement the 8-hr TWA where there are recognized adverse effects from short-term exposures, some substances have a short-term exposure limit (STEL) for 15-minute peak periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be absorbed through direct contact of the material with the skin and mucous membranes.

It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, previous exposures, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking, etc.) to produce health effects even if the occupational exposures are controlled to the limit

set by the evaluation criterion. These combined effects are often not considered by the chemical specific evaluation criteria. Furthermore, many substances are appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

ASTHMA

Asthma is a clinical syndrome characterized by increased responsiveness of the tracheal-bronchial tree to a variety of stimuli.[6] Symptoms of asthma include episodic wheezing, chest tightness, and dyspnea, or recurrent attacks of cough and sputum production, often accompanied by rhinitis.[7] The primary physiologic manifestation of airways hyper-responsiveness is variable or reversible airflow obstruction, which may be demonstrated by significant changes in the forced expiratory volume in 1 second (FEV_1) or peak expiratory flow rate (PEFR). Airflow changes can occur spontaneously, with treatment, with a precipitating exposure, or with diagnostic maneuvers such as nonspecific inhalation challenge.

ISOCYANATES

Isocyanates are a class of low molecular weight compounds containing the isocyanate group -NCO. They are widely used in the manufacture of polyurethanes which are used to make such products as rigid and flexible foams, resins, adhesives, coatings, sealants, binders, and elastomers.

Within industries where isocyanates are used, the prevalence of isocyanate-related symptoms may reach 10%.[8] Symptoms that have been described from exposure to isocyanates include upper respiratory, lower respiratory, and skin (usually allergic contact dermatitis). Among isocyanate-exposed 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.[9]

Probably the most debilitating health effects from workplace exposure to isocyanates occur in workers with specific respiratory and skin sensitization. Isocyanate exposures can lead to sensitization depending on the exposure concentration, duration of exposure, the route of exposure, and individual susceptibility. Skin sensitization can result in such symptoms as rash, itching, hives, and swelling of the extremities.[10,11] Respiratory sensitization from exposure to isocyanates results in the typical symptoms of asthma. Estimates of the prevalence of isocyanate-induced asthma in exposed worker populations vary considerably from 5% to 10% in isocyanate production facilities[12,13] to 25% in polyurethane production plants[12,14] and 30% in polyurethane seatcover operations.[15]

Isocyanates can induce immediate, late, and dual (combined intermediate and late) asthmatic responses; the late asthmatic reaction predominates on inhalation challenge testing.[16] 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.[17] Delayed asthmatic reactions may be missed by cross-shift spirometry but should be detected by serial measurements of peak expiratory flow rates done during working hours and while away from work. In one study, workers currently exposed to MDI had a mean cross-shift change in forced expiratory volume in one second (FEV_1) that was not significantly different from zero. However, the comparison population of workers with no MDI exposure had a mean cross-shift increase in FEV_1, so there was a significant difference between the two groups.[18]

Typically, the diagnostic criteria for isocyanate-induced asthma are similar to the criteria for asthma.[7,11,19,20] The physical examination and chest auscultation may be unremarkable in mild cases, whereas the physical distress of asthma is apparent in more advanced cases of the disease. Chest x-rays will either be normal or show signs of hyperinflation. Spirometry will show evidence of reversible airways obstruction; i.e., decreases in FEV_1, in forced expiratory flow between 25 and 75% (FEF_{25-75}) of forced vital capacity (FVC), and in the ratio of FEV_1 to FVC. When airflow limitation is present, i.e., FEV_1/FVC is less than the lower limit of normal, which is defined as the lowest 5% of the reference population[21], spirometry should be repeated after the administration of an inhaled β-adrenergic agonist. An improvement in FEV_1 of 12% or greater, with an absolute change of at least 200 ml, from the baseline level, confirms that there is significant reversibility, and together with the appropriate history, the diagnosis of asthma[21]. Measurements of serial peak expiratory flow over several days may show decreases and recovery in flow rate. Bronchoprovocation with methacholine or histamine may demonstrate non-specific bronchial hyperresponsiveness. Most sensitized individuals will exhibit eosinophilia.[20,22-24]

After a diagnosis of reversible airways obstruction has been determined, the next step is to determine whether it is work-related and/or related to isocyanate exposure. This determination can be made according to the following criteria. First, the work/exposure history is very important in determining if the worker has been exposed to isocyanates. Second, pulmonary function testing should be performed in the workplace in an attempt to establish the temporal relationship between isocyanate exposure and an asthmatic reaction. Workers with isocyanate-induced sensitization may exhibit decrements in pulmonary function (FEV_1, FEV_1/FVC) across the work shift. Serial peak expiratory monitoring is more sensitive to the temporal pattern of work-related asthma. (Pre- and post-shift spirometry will miss the late reaction and may miss an immediate reaction if recovery occurs before the end of the shift.) Third, provocative inhalation challenge testing with a specific isocyanate also provides a means of determining if a worker's asthma is related to isocyanate exposure. In this test, the worker is exposed to controlled concentrations of a specific isocyanate, and his/her pulmonary function is monitored for 24 hours post-exposure. It is important to note that inhalation challenges must be carried out in facilities equipped to handle adverse reactions, and the reasons and need to perform such tests are considered controversial. Fourth, serial non-specific inhalation challenge tests (e.g., using methacholine or histamine) are often used to demonstrate bronchial responsiveness that varies over time in a pattern consistent with exposure to isocyanates. Finally, immunologic testing (blood or skin testing) for either monoisocyanate or isocyanate protein conjugates will determine if workers have been exposed to isocyanates and may be an indicator of sensitization in some workers. Immunologic tests, by themselves, neither confirm nor rule out the presence of isocyanate-induced asthma and should be used to augment other information such as a work/exposure history, pulmonary function testing, and/or inhalation challenge testing. 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%[8] to 80%.[25] Smoking history and allergy do not appear to be risk factors for the development of isocyanate-induced asthma.[22,26]

Studies of the natural history of occupational asthma[27] indicate that, although improvement is often noted after exposure to the precipitating agent is terminated, symptoms and bronchial hyperresponsiveness 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 four years, 82% continued to have respiratory symptoms, and approximately half of these required inhaled or oral medications for asthma at least once per week.[28] Death from occupational asthma has been reported in an isocyanate-sensitized worker who continued to work with polyurethane paint containing isocyanates.[29]

The percentage of workers with isocyanate induced asthma who have persistent symptoms of asthma years after discontinuing occupational exposure may be 50% or higher. Studies have shown that workers with persistent asthma have a significantly longer duration of symptoms prior to diagnosis, larger decrements in pulmonary function, and a severe degree of nonspecific bronchial hyperresponsiveness at diagnosis.[7] These data suggest that prognosis is improved with early diagnosis of isocyanate-induced respiratory sensitization and early removal from isocyanate exposure. This emphasizes the need for active medical surveillance of all workers potentially exposed to isocyanates, in addition to the need for control of workplace exposures.

Isocyanates can also cause hypersensitivity pneumonitis (HP), characterized in its acute form by shortness of breath and fever with onset several hours after exposure. Chronic HP results in pulmonary fibrosis. Isocyanate induced HP is associated with 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 immunoglobulin-E (IgE) alone. Thirteen of these subjects had isocyanate-specific IgG only, while eight had both IgE and IgG. Recent evidence suggests that a HP type of reaction may be a more frequent consequence of MDI exposure than previously recognized, approaching 5%.[30]

Both the ACGIH TLV and NIOSH REL for MDI are a TWA of 5 parts MDI per billion parts air (ppb) [equivalent to 50 $\mu g/m^3$] for an 8-hour workday (ACGIH) or up to a 10-hour workday (NIOSH).[3,5] NIOSH also recommends a 10-minute TWA ceiling of 20 ppb (200 $\mu g/m^3$). The OSHA PEL for MDI is a 20 ppb ceiling level that should not be exceeded during any part of the workday.[4] Under the OSHA-approved Minnesota State Plan, the OSHA PEL for MDI is enforced.

The NIOSH REL was designed to prevent adverse health effects only to unsensitized workers;[10] however, some studies have suggested that exposure to MDI levels below the exposure criteria may produce isocyanate-induced respiratory sensitization in some workers.[31,32]

The NIOSH recommended levels apply to isocyanate monomers only and not to the oligomers of these compounds. Little is known about the toxic effects of oligomeric forms of isocyanates. However, it is thought that the inhalation of any isocyanate compound having multiple unreacted isocyanate groups may impair respiratory function or give rise to sensitization.[33,34] In 1983, the United Kingdom (UK) Health and Safety Commission set a "control limit" for workplace exposure to all isocyanates. The control limit is 20 $\mu g/m^3$ of isocyanate group (NCO) expressed as an 8-hour TWA, and 70 $\mu g/m^3$ NCO as a 10-minute TWA. The control limit requires that the analytical methods be applicable to "total isocyanate," that is, the sum of all isocyanate species, including monomers and oligomers.[35]

MDA

Workers may be exposed to MDA through ingestion, dermal absorption, and/or inhalation. Because it is a high molecular weight compound with a low vapor pressure, airborne exposure at room temperature is most likely to be in the form of airborne particulate; however, heating MDA can result in vapor and particulate exposures. MDA is of occupational health concern as a liver toxin (hepatotoxin), exhibiting

both acute and chronic effects. Skin contact has been associated with contact dermatitis. It is also highly suspect as a bladder carcinogen.[36]

OSHA has established PELs for MDA of 10 ppb as an 8-hour TWA and 100 ppb as a STEL.[37] In addition, an "action level" of 5 ppb TWA (8-hour) has been established at which employee medical surveillance programs must be initiated. These PELs are enforced by the Minnesota Department of Labor and Industry. The ACGIH TLV for MDA is 100 ppb as an 8-hour TWA.[5] Both authorities consider MDA to be a suspected human carcinogen, as does NIOSH, which recommends that exposure to the substance be limited to the lowest feasible concentration.[3]

WOOD DUST

Exposure to different types of wood dust has been reported to result in numerous health effects, including eye and nose irritation, dermatitis, and respiratory disorders. Respiratory effects include impairment of mucociliary clearance, lung fibrosis, chronic obstructive lung disease, asthma, and nasal cancer.[38-42] In the majority of the studies, a particular type of wood was identified as the causative agent. Health effects unique to aspen wood dust were not described. Microbiological contamination of the wood may have been the causative agent in some of the disorders.

Until the OSHA 1989 air contaminant limits were vacated in 1992, OSHA enforced PEL's for all wood dust except western red cedar of 5 mg/m^3 as an 8-hour TWA and 10 mg/m^3 as a STEL.[43] There is currently no OSHA PEL for wood dust;[7] however, under the OSHA-approved Minnesota State Plan, the vacated limits are enforced with the allowance of supplementing engineering controls with personal respiratory and administrative controls. The ACGIH TLV for hardwood dust is 1 mg/m^3, and for softwood dust it is 5 mg/m^3 as a TWA with a STEL of 10 mg/m^3.[5] Aspen is a hardwood. NIOSH recognizes all softwood and hardwood dusts as potential occupational carcinogens and recommends that exposure be limited to a 1 mg/m^3 TWA.[3]

RESULTS AND DISCUSSION

A. ENVIRONMENTAL

The industrial hygiene survey of February 16-19, 1994, consisted of area air sampling for MDI, NCO, MDA, and wood dust. Sampling was conducted during a full-production shift, a maintenance (cleaning) shift, and the start-up production shift following cleaning. Samplers were operated during the maintenance shift only from the time workers entered the blender room until they completed cleaning of the blender. During the start-up shift, samplers were activated after the facility started production.

MDI and TOTAL FUNCTIONAL ISOCYANATE GROUP (NCO)

During the full-production shift, morning and afternoon samples were collected for MDI in 11 areas of the facility (See Table 1) and the results of both periods were used to determine the TWA concentration. Monomeric MDI was detected in seven of the areas. The highest concentrations, 18.6 $\mu g/m^3$ and 54.2 $\mu g/m^3$, were measured in the blender room and in the conveyor belt access area beneath the blender room, respectively. The latter concentration exceeded the NIOSH REL and ACGIH TLV of 50 $\mu g/m^3$ TWA; however, the area is primarily a

landing on the stairway to the blender room so occupancy duration is very limited. The morning TWA concentration in this area was 103.9 $\mu g/m^3$ which indicates the potential exists for very high concentrations in this area. Eleven areas were also sampled during the start-up production shift, and the same two areas had the highest concentrations of monomeric MDI - 15.4 $\mu g/m^3$ and 81.8 $\mu g/m^3$, respectively. Again the belt access area concentration exceeded the REL and TLV. Monomeric MDI was not detected in three of the areas. Of the three samples collected during the cleaning of the blenders, detectable concentrations of monomeric MDI were found only inside the blender (9.4 $\mu g/m^3$) and immediately outside the blender (35.2 $\mu g/m^3$). Workers left the area when the cleaning operation was completed. None of the three 10-minute samples collected during the start-up shift detected monomeric MDI. The minimum detectable concentrations (MDC) and minimum quantifiable concentrations (MQC) for the samples of MDI collected during this evaluation are presented in Table 2.

Table 1 also presents the oligomeric MDI concentrations. These values were used to calculate NCO concentrations and are included in the table to illustrate the contribution the oligomeric MDI makes to the NCO concentrations. As can be seen for some samples where monomeric MDI was not detected, the oligomeric form was measured, and vice versa.
It should be noted that testing of the interim method used in the study revealed excellent recovery for monomeric MDI but not for oligomeric MDI. Oligomeric MDI concentrations, as well as those calculated for NCO, are thus considered probable underestimations (i.e., actual concentrations are likely higher than reported.)

The NCO concentrations reported in Table 1 indicate that almost every sample measured isocyanate (either monomeric or oligomeric MDI, or both). The samples that exceeded the REL and TLV for monomeric MDI also exceeded the UK control limit of 20 $\mu g/m^3$ for isocyanate group (NCO). Although none of the samples collected over 10-minute periods measured monomeric MDI, with the contribution made by oligomeric MDI on one of the samples, the total NCO concentration of 54.9 $\mu g/m^3$ approached the UK 10-minute limit of 70 $\mu g/m^3$.

An observation made while the billets were being stacked after they emerged from the steam press was the release of plumes of hot vapors from small areas on the billets (emitted continuously for several minutes and sometimes as bursts). Area air sampling was performed with a paper tape monitor during the stacking of a few billets. The monitor was activated as each billet approached the stacker and continued to monitor for approximately 10 minutes. The TWA concentrations reached as high as 180 $\mu g/m^3$ MDI during the monitor's initial 2-minute reporting intervals and quickly dropped to concentrations of 40-90 $\mu g/m^3$ during the next few intervals before measurements of 0-20 $\mu g/m^3$ were indicated at the end of the 10-minute periods. (Units of "ppb" are indicated for MDI on the monitor, but the reported concentrations have been converted to "$\mu g/m^3$" for consistency throughout this report.) When MDI is heated, the vapor pressure increases and MDI vapor evolves. As it cools to the ambient temperature, this vapor readily condenses to aerosols[44,45] which may not always register on paper-tape monitors or may produce erroneous results.[46,47] Accordingly, the results of the paper-tape sampling for MDI concentrations are considered to be qualitative (not quantitative) in value.

TJM utilized two stationary paper-tape monitors in the plant with output transmittal to the press control room. One monitor was near the press outlet and the other near the forming heads. In

addition, hand-held paper-tape monitors were used by workers for measurements anywhere in the plant.

Routine air sampling at the plant has been conducted by the MDI supplier. MDI samples have been collected on treated glass-fiber filters. In the results reviewed by NIOSH, all personal samples were less than 50 $\mu g/m^3$ MDI (concentrations are again converted from "ppb"). The highest 1- to 5-hour TWA MDI area concentrations were historically in the blender room, floors beneath the blenders, and around the forming line. Most of the concentrations in those areas were below 100 $\mu g/m^3$. Concentrations within the press enclosure, usually unoccupied during operation, were found as high as 600 $\mu g/m^3$. Company records of direct reading measurements from a hand-held paper-tape MDI monitor taken in March 1992 indicated many readings above 140 $\mu g/m^3$ near the blenders, formers, and the finishing area. Many exceeded 200 $\mu g/m^3$ near the blenders and forming line.

MDA

Results from NIOSH sampling for MDA are not available due to technical difficulties with the method. The NIOSH laboratory indicated the possibility of incomplete conversion of MDI to MDA on the filters, so concentration calculations could not be made reliably. Since the ventilation system modifications, the MDI supplier has also conducted MDA sampling at the facility. Personal samples did not exceed 5 ppb. Four-hour TWA area concentrations have reached as high as 0.7 ppb in the trim saw area, 0.9 ppb around the formers, 13 ppb near the blenders, and 37 ppb on levels beneath the blenders. Within the press enclosure, concentrations as high as 400 ppb were measured during 1-hour sampling periods. Because the supplier did not feel the environmental conditions around the blenders were conducive to the formation of MDA, they made plans to evaluate their sampling technology and conduct further sampling. It is not known if their sampling suffered the same problem as that performed by NIOSH since it also relied on conversion of MDI to MDA, but if so, then some of their results could be underestimations.

WOOD DUST

Table 1 also presents area wood dust sampling results. Ten samples were collected during the full production shift, 13 during the startup shift, and 3 during blender cleaning. During the full production shift, the TWA concentrations ranged from 0.03 mg/m^3 to 1.43 mg/m^3. The only sample with a concentration that exceeded the REL and TLV of 1 mg/m^3 was collected near the wood flaker. Concentrations ranged from 0.04 mg/m^3 to 1.25 mg/m^3 during the start-up shift sampling. The samples collected between the drying bins and in the blender room exceeded the REL and TLV with concentrations of 1.25 mg/m^3 and 1.12 mg/m^3, respectively. Samples taken during the blender cleaning did not exceed 0.16 mg/m^3.

OBSERVATIONS AND UPDATES

Work Locations

Most of the operators work in enclosed control rooms. The main control room operators for the blenders, forming line, and press reported that they spend approximately 1/4 to 1/3 of each day

outside the control room and "on the floor" to monitor equipment operation. Their helpers spend more time performing these tasks. Workers who are almost always on the floor include maintenance and finishing end workers. On the finishing end, workers were observed operating saws and sanders and preparing products for shipment.

Work Schedules

During a phone call of February 1995, the plant manager reported that 12-hour work shifts had recently been eliminated and all workers were working 8-hour work days and 40-hour work weeks. This change was intended to decrease exposure duration each day.

Personal Protective Equipment (PPE)

The TJM safety and health manual available to the investigators at the time of the survey (October 30, 1992, revision) specified that workers were required to utilize personal protective equipment (PPE) when accessing the blenders, the blender outfeed and infeed conveyors, blender forming bin, second and third levels of the forming line, and press enclosure. Prior to entry, a portable MDI monitor was to be used to measure the concentration in the area. If the concentration was less than 5 $\mu g/m^3$, workers were required to wear an air purifying respirator with an organic vapor cartridge and a particulate prefilter. If the concentration was at or above 5 $\mu g/m^3$ or an accurate measurement was not possible or available, a self-contained breathing apparatus (SCBA) or supplied air respirator (SAR) was required for entry. Workers were required to wear a SCBA or SAR when maintaining or cleaning the blenders and anytime they were working around the formers on the second level. Long-sleeved clothing, gloves, and eye goggles were required in all these areas during maintenance and cleaning operations. A full Tyvek® suit with hood was also required while performing these tasks inside the blender.

During the environmental investigation, workers throughout the plant were voluntarily wearing organic vapor/particulate respirators. However, workers were wearing this type of respirator while cleaning the blender although the TJM safety manual specified a SCBA or SAR be worn during this task. These same workers changed into their PPE within several feet of the open blenders in the blender room. This practice presents the risk of exposure to airborne MDI and through contamination of their PPE.

The plant manager reported some changes in personal protective equipment requirements during the February 1995 telephone conversation. He confirmed that SAR is required during cleaning and maintenance tasks in the blender. In addition, workers must wear a SAR anytime they are in the blender room, at the hogger and pretrim saws, or within the immediate areas of the forming heads while the equipment is operating. Air purifying respirators with an organic vapor cartridge and a particulate prefilter must be worn near boards that are warm. Full Tyvek® suits are still required in the blender. At the beginning of each shift, all workers are given, for voluntary use, clean cotton/rayon uniforms which are collected at the end of the shift for laundering.

Process and Ventilation

Some of the ventilation ducts at the facility historically became plugged with MDI resin accumulations. Cyclone collection systems and inspection and maintenance portholes were installed on some of these ducts as a preventative measure. Their effectiveness was still being tested at the time of the evaluation.

The plant manager also reported in February 1995 that, since the major ventilation modifications completed in February 1993, minor changes to the systems were ongoing. Plans were being made for the installation of an enclosed billet cooler behind the press in an attempt to decrease volatile emissions from hot billets coming from the press and to decrease the waiting time required before billets could proceed to the finishing area.

B. MEDICAL

OSHA LOGS

The plant began production in October 1991. The OSHA 200 log for 1991 showed no lost work time due to injuries or illnesses. The 1992 log included 39 reportable events; 11 (28%) entries were for respiratory symptoms. In 1993, there were 28 reportable events, with 3 (11%) cases concerning respiratory symptoms. The 1994 log through October 1994 had 47 entries, with 13 (28%) involving respiratory symptoms. The respiratory events reported in the OSHA 200 logs represented 27 individual workers.

MEDICAL RECORDS

By January 1995, TJM company medical records for 29 employees had been received by NIOSH. Records from all individual workers identified in the OSHA 200 logs as having a respiratory condition were included in the information sent to NIOSH. Eighteen of the 29 TJM employees with respiratory illness met the NIOSH surveillance case definition for occupational asthma (OA) by having a physician diagnosis of asthma, an association between asthma symptoms and work, and a workplace exposure to an agent (MDI) previously associated with occupational asthma. Eight additional workers were categorized as “suspect cases” because the records did not mention one of the criteria needed to fit the case definition or the result of the examination was listed as "borderline." The remaining three workers were being evaluated by a physician at the time the records were sent to NIOSH (November 1994 through January 1995).

Nine cases which met the requirements of the NIOSH surveillance case definition of OA occured in workers prior to the time the ventilation change took effect. An additional four employees in the pre-ventilation change category were classified as suspect cases. From the time the ventilation changes took effect in February 1993 through December 1994, nine additional cases of OA developed; four of these cases were in workers who began their employment after the ventilation change was made. Four additional workers who began their employment after the ventilation change was made were classified as having "suspect” OA.

Twenty-one individuals had a positive methacholine challenge test, although criteria for defining the results as positive were not provided by the diagnosing physician.

The length of employment of the 29 workers at TJM prior to onset of respiratory symptoms ranged from 1 to 40 months (mean 11 months).

According to the company medical records, only 1 worker out of the 29 who reported symptoms of OA had a previous history of asthma - this worker was 1 of the 18 who met the NIOSH case definition. A request from a physician for removal of the worker from work areas with possible exposure to MDI was recorded in the records for 24 of the workers. Nineteen of the 29 workers no longer worked at TJM. The remaining 10 workers were relocated to different areas of the plant.

QUESTIONNAIRE

Demographics

The questionnaire was completed by 65 workers (65% response rate) from office, support, and production areas of the plant. Workers ranged from 21 to 53 years of age, with a median age of 35 years. The median employment tenure at TJM was 2 years. A large amount of formal mobility between different jobs and work areas in the plant was reported by workers on the questionnaire. Thirty-one of the 65 workers who were interviewed had been assigned to more than one area during their tenure at TJM; 3 workers had been assigned to 4 different areas. There was also a large amount of informal job mobility where workers would be pulled from one area of the plant to other areas for short periods of time. Due to these factors, no analysis concerning job title or work area was done.

Exposure

To evaluate the effectiveness of the new ventilation system, employees were divided into the following two exposure categories: those who began work prior to the ventilation change in February 1993, and those who began work during or after February 1993. Table 3 details the reporting of symptoms in the two groups of workers from the questionnaire analysis. Of those surveyed, 55% began work at TJM before February 1993 and 45% began work during or after February 1993. The questionnaire showed that some workers who began their employment after the ventilation change was made experienced respiratory symptoms (see Table 3). Lower respiratory symptoms, which include chronic cough, chronic phlegm, dyspnea, chest tightness, wheezing, and shortness-of- breath were reported both before and after the ventilation change was made.

Previous Exposure

Occupational histories revealed that 28 (43%) of the participants had a possible exposure to isocyanates other than at TJM. In the “pre-February 1993" exposure group, 44% of surveyed employees had possible pre-employment exposure to isocyanates. The “February 1993 and after” exposure group had 41% of employees who had possible pre-employment exposure to isocyanates.

Prior Asthma

Fifty percent (3 out of 6) of workers who reported they had prior asthma said they have worsening asthma symptoms since they began work at TJM. Seventy-five percent (3 out of 4) of those who stated they developed asthma during adulthood had respiratory symptoms that became worse since they began employment at TJM.

CONCLUSIONS

Area MDI concentrations that exceeded the NIOSH REL and ACGIH TLV for personal exposure were found at the conveyor located one level beneath the blenders. The samples at this location also exceeded the UK control limit for NCO. Results from NIOSH sampling for MDA are not available due to technical difficulties with the method, but area sampling conducted by the MDI supplier indicated concentrations may have exceeded occupational exposure limits in some areas of the facility. NIOSH and ACGIH consider MDA to be a suspected human carcinogen. Area air sampling for wood dust revealed three samples that exceeded the REL and TLV for personal exposure. NIOSH also recognizes wood dust as a potential carcinogen. Some workers indicated that the production rate during the NIOSH sampling survey was less than usual, which may have resulted in underestimation of air contaminant concentrations.

There is some concern over whether MDI that is attached to wood dust particles is reactive. If so, it could contribute to the dermal and respiratory exposures; however, it is not known whether the available sampling methods can measure it. Most of the sampling detected MDI, both monomeric and oligomeric. It is important to note that concentrations of monomeric MDI below the evaluation criteria are suspected of causing sensitization in some workers, and there is also suggestion that oligomeric forms of MDI also contribute to sensitization.

At least 18 employees of TJM have developed respiratory illness that meets the NIOSH surveillance case definition for OA since the plant began production in October 1991. In all of these cases, OA was attributed to MDI exposure. This figure is neither an incidence nor a prevalence as it does not reflect a systematic survey of all workers at risk for developing isocyanate-induced occupational asthma. Cases of occupational asthma continued to develop after the ventilation system was modified even among employees who began employment at TJM after the ventilation system was modified.

Based on the information collected during this evaluation, it is concluded that a health hazard existed at the facility from exposure to isocyanates. A potential health hazard existed from wood dust exposure.

RECOMMENDATIONS

1. Whenever there is a potential for a hazardous exposure to isocyanates, traditional industrial hygiene practice dictates that the following hierarchy of controls, in decreasing order of desirability and effectiveness, be implemented to protect worker health:

    a. Elimination of the toxic substance from the workplace.

    b. Substitution of the toxic substance with a less toxic substance.

    c. Installation of engineering controls to reduce exposure.

    d. Use of administrative controls to reduce exposure.

    e. Use of personal protective equipment to reduce exposure.

    In many instances, it is not possible to eliminate or substitute an isocyanate from a production

process without altering the integrity of the desired product. Thus, most strategies for reducing isocyanate exposure center on the use of engineering controls and personal protective equipment. Local exhaust ventilation and/or process isolation are commonly used controls for isocyanate exposure reduction. Personal protective equipment should only be used when engineering controls are not feasible, in the interim when engineering controls are being installed or repaired, or when engineering controls have not sufficiently reduced exposures. NIOSH recommends that whenever there is a potential for occupational exposure to isocyanates, including concentrations below the NIOSH REL, that the employer provide the worker with SAR protection.[10] Air-purifying respirators are not appropriate because isocyanates have poor odor warning properties. Personal protective equipment should also be used to prevent skin and eye contact with isocyanates.

2. The higher MDI concentrations found at the conveyor located one level beneath the blenders indicate a ventilation system problem. Although the area is primarily unoccupied, it is used by those who access the blender room. Ideally the conveyor ventilation system should be at a negative pressure with respect to the area to prevent release of MDI that could migrate to occupied areas.

3. Ventilation systems will not work effectively as their ducts become obstructed. Those ducts that have historically become plugged and have since been retrofitted with cyclone collection systems should be inspected and maintained on a routine basis.

4. Workers should store and don their personal protective clothing and respiratory protective equipment in a clean area away from the production areas to avoid the risk of exposure to airborne MDI and through contamination of their PPE.

5. Sources of wood dust generation should be investigated. Existing local exhaust ventilation systems should be evaluated and improved where necessary. Where they do not exist, they should be installed.

6. The MDI supplier's sampling for MDA showed the potential for overexposures to MDA in areas, but they did not feel the environmental conditions were conducive to the formation of MDA. Their plan to evaluate their sampling technology and conduct further sampling is recommended.

7. The company should establish a medical monitoring program for the early detection of adverse health effects of exposure to MDI and to assess the adequacy of controls implemented to decrease exposures.

    a. Each current and new employee with potential exposure to isocyanates and/or wood dust should undergo the following:

- A careful medical history paying special attention to respiratory conditions and symptoms.

- Physical examinations with particular attention to the respiratory system.

- Lung function tests, including measurement of FVC and FEV_1.

Under the Americans with Disabilities Act (Public Law 1-1-336 [S. 993]; July 26, 1990), unless these examinations reveal a disabling condition which would prevent the applicant from performing the essential functions of the job, even if "reasonable accommodations" were made, the applicant may not be refused employment.[48]

b. Employees should receive a follow-up examination every six months. This examination should include a brief questionnaire screening for upper and lower respiratory symptoms and allergic contact dermatitis. The examination should also include lung function testing. Workers with either abnormal lung function or symptoms such as persistent cough, cough at night, wheezing, shortness-of-breath, difficulty breathing, or skin symptoms associated with isocyanate exposure should receive a more thorough medical evaluation.

c. Employees found to have medical conditions that could be directly or indirectly aggravated by exposure to isocyanates (e.g., respiratory allergy, chronic bronchitis, chronic obstructive pulmonary disease, or evidence of isocyanate sensitization) should be counseled on their increased risk from working with isocyanates. Those with histories of allergy other than respiratory disease should be counseled that they may be at increased risk of adverse health effects from isocyanate exposure.

d Employees should receive written reports of all medical surveillance tests performed by the company or by a physician to whom the company makes referal, regardless of the results of such tests.

e. Pertinent medical records should be maintained. Records of environmental exposures applicable to an employee should be included in the employee's medical records. Such records should be kept for at least 30 years after the employee terminates employment.

f. Prior to any worker examinations, the worker's physician should be given information about the adverse health effects of exposure to MDI and an estimate of the worker's potential for exposure.

g. Individuals who become sensitized to MDI should be advised of the health risks of continued exposure to isocyanates and given the opportunity to transfer to an area where they will have no exposure to MDI. Isocyanate sensitization could last the lifetime of the worker. Requiring sensitized individuals to wear respirators and to

continue to work in areas of potential MDI exposure is NOT an acceptable measure for health protection although it may be an appropriate accommodation for a disabled worker who would like to continue such work.

8. Worker training should include the following:

   - Health effects of isocyanates.

   - Recognition of symptoms of OA and other chronic respiratory disorders. Workers who develop any such symptoms in the period between the semi-annual exams should be referred promptly for further medical evaluation.

   - Employees should be advised that isocyanate exposure may result in delayed effects, such as coughing or difficulty breathing when they are away from work.

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

Table 1
Air Sampling Results

Trus Joist MacMillan, Deerwood, Minnesota
HETA 93-0436
February 16-19, 1994

Date	Sampling Activity	Location	Sampling Time (minutes)	Monomeric MDI TWA (µg/m³)	Oligomeric MDI TWA (µg/m³)	Total NCO TWA (µg/m³)	Wood Dust TWA (mg/m³)
16-Feb-94	Full-Production	Flaker Control Booth	472	nd*	0.8	0.3	0.18
16-Feb-94	Full-Production	Flaker Deck (near Flaker #2)	474	nd	3.8	1.3	1.43
16-Feb-94	Full-Production	Belt Access - one level beneath Blenders	461	54.2	22.8	26.2	0.46
16-Feb-94	Full-Production	Blender Room	467	18.6	8.0	9.0	0.79
16-Feb-94	Full-Production	Forming Heads #2 Catwalk	470	0.9	nd	0.3	0.44
16-Feb-94	Full-Production	Flying Cutoff Saw (just before Press)	464	0.9	1.8	0.9	0.14
16-Feb-94	Full-Production	Press Control Room	477	nd	0.8	0.3	..
16-Feb-94	Full-Production	Crossover at Pretrim Hogger Saws	482	4.4	3.8	2.8	0.30
16-Feb-94	Full-Production	Finishing Line Grader Station (near Ripsaw)	458	0.9	3.5	1.5	0.03
16-Feb-94	Full-Production	Lumber Wrap Station	470	0.9	nd	0.3	0.42
16-Feb-94	Full-Production	Maint Shop (near blender cleaning dumpster)	470	nd	2.4	0.8	0.06
19-Feb-94	Startup Shift	Between Drying Bins	356	nd	0.6	0.2	1.25
19-Feb-94	Startup Shift	Belt Access - one level beneath Blenders	363	81.8	23.5	35.8	0.59
19-Feb-94	Startup Shift	Blender Room	357	15.4	7.0	7.6	1.12
19-Feb-94	Startup Shift	Press Control Room	358	nd	0.6	0.2	0.04
19-Feb-94	Startup Shift	Press Exit	353	0.6	0.6	0.4	..
19-Feb-94	Startup Shift	Press Inlet	355	0.6	0.6	0.4	0.17
19-Feb-94	Startup Shift	Crossover at Pretrim Hogger Saws	362	..**	..	..	0.98
19-Feb-94	Startup Shift	Billet Stacker	353	0.6	0.6	0.4	0.06
19-Feb-94	Startup Shift	Finishing Line Grader Station (near Ripsaw)	377	0.5	0.5	0.4	0.25
19-Feb-94	Startup Shift	First Pass Saw (Control Panel)	349	..	..	..	0.15
19-Feb-94	Startup Shift	Hogger Saw Cutter/End Product Stacker	359	3.9	3.7	2.6	0.37
19-Feb-94	Startup Shift	Lumber Wrap Station	325	0.6	nd	0.2	0.35
19-Feb-94	Startup Shift	Second Pass Saw (Control Panel)	346	..	..	..	0.29
19-Feb-94	Startup Shift	Maint Shop (near blender cleaning dumpster)	360	nd	0.6	0.2	0.07
16-Feb-94	Cleaning	Blender Room (inside Face Blender)	127	9.4	1.6	3.7	0.16
16-Feb-94	Cleaning	Blender Room (outside Face Blender)	122	35.2	nd	12.0	0.16
16-Feb-94	Cleaning	Maint Shop (near blender cleaning dumpster)	116	nd	nd	nd	nd
19-Feb-94	10-minute sampling	Near Press Inlet Basket	10	nd	nd	nd	..
19-Feb-94	10-minute sampling	Near Hogger Saw Cutter Basket (by Stacker)	10	nd	nd	nd	..
19-Feb-94	10-minute sampling	Under Hogger Saw Cutter (level beneath)	10	nd	161.4	54.9	..

* nd = not detected
** .. = not sampled

Table 2
Minimum Detectable Concentrations (MDC) and Minimum Quantifiable Concentrations (MQC) for MDI Samples (in µg/m^3)

Trus Joist MacMillan
Deerwood, Minnesota
HETA 93-0436
February 16-19, 1994

Sampling Activity	Duration	Monomeric MDI		Oligomeric MDI	NCO	
		MDC	MQC	MDC & MQC	MDC	MQC
Full-Production Shift *	8 Hours	0.8	3.3	Same as Monomeric MDI	0.3	1.1
Startup Shift	6 Hours	0.5	2.3		0.2	0.8
Cleaning Shift	2 Hours	1.6	6.3		0.5	2.1
Short-Term	10 Minutes	20.0	80.0		6.8	27.2

* MDC and MQC are for each 1/2-shift sampling period during the full-production shift

Table 3
Report of Respiratory Symptoms, Nasal and Eye Irritation
by Exposure Category

Trus Joist MacMillan
Deerwood, Minnesota
HETA 93-0436

Respiratory Symptoms	Exposure Category	
	Hired Before February 1993 N = 36	Hired Since February 1993 N = 29
	Yes %	Yes %
Chronic Cough	13 36	5 17
Chronic Phlegm	13 36	5 17
Dyspnea		
Grade I	8 22	9 31
Grade II	2 6	0 0
Grade III	2 6	0 0
Chest Tightness	17 47	10 34
Wheezing/Whistling in Chest	9 25	6 21
Attacks of Shortness of Breath w/ Wheeze	6 17	2 7
Nasal Irritation	16 44	13 45
Eye Irritation	13 36	16 55

Figure 1

NIOSH Surveillance Case Definition for Occupational Asthma[2]

A. A physician diagnosis of asthma

and

B. An association between symptoms of asthma and work and any one of the following:

1. Workplace exposure to an agent or process previously associated with occupational asthma.

or

2. Significant work-related spirometry changes in forced expiratory volume in one second (FEV_1) or peak expiratory flow rate (PEFR).

or

3. Significant work-related changes in airways responsiveness as measured by nonspecific inhalation challenge.

or

4. Positive response to inhalation provocation testing with an agent to which patient is exposed at work. Inhalation provocation testing with workplace substances is potentially dangerous and should be performed by experienced personnel in a hospital setting where resuscitation facilities are available and where frequent observations can be made over sufficient time to monitor for delayed reactions.

Patterns of work related disease association can vary. The following examples are patterns that may suggest an occupational etiology: symptoms of asthma develop after a worker starts a new job or after new materials are introduced on a job (a substantial period of time may elapse between initial exposure and development of symptoms); symptoms develop within minutes of specific activities or exposures at work; delayed symptoms occur several hours after exposure, during the evenings of workdays; symptoms occur less frequently or not at all on days away from work and on vacations; symptoms occur more frequently on returning to work. Work-related changes in medication requirements may have similar patterns, also suggesting an occupational etiology.

Many agents and processes have been associated with occupational asthma,[7,49] and others continue to be recognized. Changes in nonspecific bronchial hyper-activity can be measured by serial inhalation challenge testing with methacholine or histamine. Increased bronchial reactivity (manifested by reaction to lower concentrations or methacholine or histamine) following exposure and decreased bronchial reactivity after a period away from work are evidence of work-relatedness.