HETA 87-0099-1938
NOVEMBER 1988
LOUISIANA-PACIFIC CORPORATION
OLATHE, COLORADO

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I. SUMMARY

On December 17, l986 the National Institute for Occupational Safety and Health (NIOSH) was requested by the Colorado Department of Health (CDH) to evaluate health problems at the Louisiana-Pacific (L-P) plant in Olathe, Colorado. The request was prompted by local physicians who contacted the CDH after treating several L-P workers with respiratory symptoms consistent with asthma. The company manufactures waferboard using a mixture of wax, 4,4-methylenediphenyl isocyanate (MDI) and similar structure oligomers to bind together wood chips.

NIOSH personnel made initial site visits to the plant in March and July of 1987, during which a medical screening questionnaire was distributed to the workforce. From this information, a group of employees was selected for further medical testing. NIOSH investigators returned to the plant during the week of August 23, l987 to conduct a medical evaluation of the workers and environmental monitoring of the workplace. NIOSH personnel also contacted some employees who reportedly left the workforce due to breathing problems and reviewed their medical records.

Quantifiable concentrations of MDI were found in only two of the 23 personal air samples at time-weighted average (TWA) concentrations of 0.015 and 0.016 milligrams per cubic meter of air (mg/m^3). These results are below the NIOSH recommended exposure limit (REL) of 0.05 mg/m^3 as an 8-hour TWA, and would be below the Occupational Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygienists's (ACGIH) ceiling criteria of 0.2 mg/m^3. Area air samples for isocyanate group, wood dust, aldehydes, and trace organics were also below their respective evaluation criteria.

The medical evaluation identified 13 cases of pulmonary disease (12 cases of asthma, and one case of hypersensitivity pneumonitis) with medical history and diagnostic findings suggesting they were related to isocyanate exposure. These 13 cases were in 3 current and 10 former employees. Most of these cases probably resulted from exposure levels that existed after the introduction of the diisocyanate resin into the plant in June 1986, but before effective engineering controls and personal protection programs were in place.

On the basis of the data collected during this survey, a potential health hazard existed from airborne exposure to diisocyanates. Individuals who perform routine and nonroutine maintenance activities in the areas where MDI is used may face a risk of significant exposure to MDI if the proper personal protective equipment is not used. Individuals already sensitized may continue to react to the diisocyanate at very low or unmeasurable concentrations due to individual susceptibility. Recommendations for environmental and medical monitoring, engineering controls, personal protective equipment, work practices, and employee education are contained in this report.

KEY WORDS: SIC 2493 (Waferboard) 4,4-methylenediphenyl isocyanate (MDI) polymethylenepolyphenylene polyisocyanate (PMPI), asthma, hypersensitive pnuemonitis, aspen, wood dust, isocyanate group.

II. INTRODUCTION

On December 17, l986 the Colorado Department of Health (CDH) requested NIOSH's assistance in evaluating respiratory problems among employees of the Louisiana-Pacific (L-P) plant in Olathe, Colorado. The request was prompted by local physicians who contacted the CDH after treating several L-P workers with respiratory symptoms consistent with asthma.

NIOSH personnel made an initial site visit to L-P on March 13, 1987, to conduct a walk-through survey and collect information on the plant processes. On July 29, l987, a NIOSH medical survey was conducted during which medical screening questionnaires were distributed to the workforce. From these questionnaires, a group of employees was selected for further medical testing. NIOSH investigators returned to the plant during the week of August 23, l987 to conduct a medical evaluation of the workers and environmental monitoring of the workplace. Individual medical results of the August 23, l987 survey were mailed to participants in January, l988. The plant manager was also notified by telephone of the summary medical results in January, l988. An interim letter stating the findings of the NIOSH survey, along with preliminary recommendations, was sent to L-P and the CDH on April 11, 1988.

III. BACKGROUND

A. Plant History

The Louisiana-Pacific Corporation began operation of a waferboard manufacturing plant near Olathe, Colorado in September, l984. The plant processes aspen and pine trees into wafer chips, which are then bound together into waferboard using a heat and pressure cured resin/wax binding material. The facility produces approximately one ton of waferboards per day. The plant has 68,880 square feet (sq ft) under one roof with 10,268 sq ft utilized as warehouse storage and 1,296 sq ft as office space.

The process at the time of plant opening involved coating the wafer chips with a wax and a phenol/formaldehyde resin, with subsequent pressing, under high temperature and pressure, to produce waferboards. Shortly after production began in September l984, the CDH received complaints about mucosal irritation symptoms among nearby residents. In June, l986, L-P switched its binding agent to a wax/diisocyanate combination.

B. Process Description

To begin the manufacturing process, aspen (approximately 90%) and pine logs (approximately 10%), in 8 to 22 feet lengths, are cut and trucked via independent loggers to L-P's property for storage. After drying for 3 to 6 months, the logs are cut into 8 foot sections and loaded into "hot ponds", where they are soaked for one hour in water in order to soften the bark. The logs are then floated into the plant and are guided onto a "jackladder" conveyor: this transports the logs up to the "ring debarker" which strips away the bark. The logs are then cut down to 33 inch lengths by a slasher saw. They next enter the "waferizer" and are slivered into wood chips approximately 2 millimeters thick. The "wet" wafer chips are placed in temporary storage bins. A jackladder, debarker, and waferizer operator are responsible for running the machinery in this area. The production operations up to this point are referred to as the "green end".

The wet wafer chips are then passed through a dryer oven for approximately five minutes in order to reduce their moisture content. The oven temperature ranges from 1400ºF at the entrance to 200ºF at the exit. Following drying, the wood chips are transported to a either the surface dry storage bin or the core dry storage bin. A dryer operator and a utility man, located in air-conditioned enclosed control rooms, were responsible for the operation of the dryer oven, along with the "Konus" unit, which supplies the heat for the press and hot ponds.

The next stage of the production process involves the coating of the wafers with the resin/wax mixture. The resin used for this process is a 50/50 mixture of 4,4-methylenediphenyl isocyanate (MDI) and similar structure oligomers (polymer molecules consisting of only a few monomeric units, e.g., dimers, trimers, tetramers). The resin is delivered to the plant in heated tank trucks, and stored in outdoor heated bulk storage tanks. When needed, the resin is piped into a mixing tank, where it is mixed with a petroleum wax. The resin/wax mixture is then piped to the blenders, where it is distributed onto the wood chips. The entire resin delivery system from the outdoor storage tanks to the blenders is a closed system.

Two different blenders, a "core" blender and a "surface" blender, are used to apply the resin wax mixture to the wafer chips. Each blender is approximately 20 feet long and 8 feet in diameter and deposits the resin/wax mixture onto the wood chips through sprinkler heads in the blenders which rotate between four and five thousand revolutions per minute. The blenders are totally enclosed and are not entered except for the time periods required for routine cleaning or replacement of the spinner heads.

The resin-coated wafers then travel by conveyor from the blenders to the storage bins above the "formers". There are three storage bins: two surface and one core. The two surface bins, which receive coated wafers from the surface blender, supply the wafers to the "surface formers". The core bin, which receives its wafers from the core blender, supplies its wafers to the "core former". The formers consist of a large screen conveyor onto which the wafers are sequentially distributed to form "mats". As the mat's stainless steel screen enters the former, it is sprayed with a release agent (primarily water with polymerized fatty acids and a small amount of an emulsifier). Next, the coated chips are sequentially deposited onto the screen in three layers: two outer surface layers and one core layer. As wafer mat leaves the former, it is cut into 8' x 16' sections, and additional releasing agent is sprayed onto the top surface of the unpressed wafers. The boards are then conveyed to the loader, which loads eight mats into the press at one time. The press operates at approximately 185º C (Range 170 - 200º C) and approximately 2300 lbs/in^2. Retention time in the press varies from four to six minutes, depending on the thickness of the wood and the quality of the board. Finished board thicknesses range from 7/16 to 3/4 inch. A press operator, located in a separately air-conditioned press control room, is responsible for operating the conveyor and press controls.

After leaving the press, the boards are automatically unloaded, their edges trimmed, then cross cut to produce 4' by 4' sheets, and finally stacked at the end of the conveyor. The strapper operator bundles each stack, sprays a protective coating, and stencils the company logo onto the sides of each stack. This process is carried out in a spray booth using water-based paints. The "grader" then stamps the wood with the appropriate grade identifier, and the stacks are moved by forklift to a warehouse area for storage.

C. Maintenance Operations

Several different maintenance activities are conducted in the plant. One "cleanup" employee is responsible for plant-wide general housekeeping duties. Repairs and general preventive maintenance are conducted by a millwright and electrician who have a separate work area, but also work on the equipment throughout the plant as necessary. A "knife grinder" operator works in a separate area of the plant and is responsible for repairing the blades used in the waferizer; this includes babbitting and sharpening. The quality control line technician (and sometimes the quality control supervisor) is responsible for cleaning the spinner heads within the blenders. The cleaning of a spinner head takes approximately 30 minutes: di-2-ethylhexylphthalate (DEHP) is used for this procedure. The changing of spinner heads is also periodically necessary: this operation can take several hours.

D. Workforce

The facility is operated by 4 rotating shifts and employs a total of approximately 100 employees. Each shift employs approximately 18 workers, with the permanent day shift employing an addition 28 employees . Job titles with their descriptions are provided in Appendix A.

E. Personal Protective Equipment

Respirators for protection against wood dust are required to be worn during cleanup work in the forming and blending areas, and are available for other activities during which substantial amounts of wood dust might be generated. The respirators available for these jobs includes half-mask respirator with organic vapor/high efficiency cartridge-filters (TC-23C-204) and single-use dust masks (TC-21C-132). Two different types of respirators are also available for cleaning or entering the blenders. These include air-supplied hoods, Type C-continuous flow class (TC-19C-94) and pressure-demand self-contained breathing apparatus (SCBA) (TC 13F-138). Gloves and coated Tyvec suits are also supposed to be worn during this procedure. The supplied air hoods are also used during the waxing of the conveyor belts to the formers and other non-routine maintenance activities that bring the employee into close contact with material containing the MDI resin.

F. Recent Changes and Process Revisions

As was previously noted, a major change in resin systems (from a phenol-formaldehyde to MDI) occurred in June of 1986. Following this change in resin system, subsequent equipment and procedural changes were made in October, l986. The conveyer belts to the former were enclosed, and an enclosure was built above the press area to capture the emissions released by the steaming boards during and after the press operation. In addition, modifications were underway at the time of the initial survey to decrease the size of the hood above the presses in order to increase the effectiveness of the exhaust fans in this area. The air supply compressor for the continuous flow supplied air respirators was also being modified at the time of the initial survey so that the air intake would be located outside of the plant, instead of in the area between the blenders and the oven. The release agent sprayed onto the forming mat and surface of the unpressed wafers was changed in December 1986, and since that time, four different release agents had been used.

IV. MATERIALS AND METHODS

A. Environmental

An environmental survey was conducted August 26 - 28, 1987. During this survey, personal and area air samples were collected for 4,4-methylenediphenyl isocyanate (MDI), isocyanate group, wood dust, aldehydes, and trace organic compounds. Personal air samples were collected in the vicinity of the employee's breathing zone. General area air samples were collected either in the immediate work area of the employees or in close proximity to portions of the production line ("process" samples). All samples were collected using battery-powered pumps attached via tygon tubing to the appropriate collection media. A brief discussion of the rational for sample collection and the sampling and analytical methods used is presented below.

1. MDI and Isocyanate Group

The isocyanate used in the plant was composed of monomeric and similar structure oligomers. Since members of the isocyanate family are known to cause respiratory irritation and asthma, the collection of samples for these compounds was a major component of the environmental survey.[1] Personal samples for MDI were collected on a glass tube containing two sections of glass wool coated with a reagent, N-(4-nitrophenylmethyl)propylamine. The locations and durations of sample collection are provided in Tables 1 and 2. Following sampling, the tubes were kept refrigerated and shipped on ice to the laboratory. The analysis was conducted in accordance with NIOSH P&CAM 347 using high pressure liquid chromatography and an ultraviolet detector set at 254 nanometers to determine the concentration of MDI.[2]

Current thinking suggests that unreacted isocyanate groups attached to polymeric isocyanate compounds may also cause effects similar to the monomer.[3,4] Therefore, samples were also collected which would allow the determination of the amount of isocyanate group contributed by the polymethylenepolyphenyl isocyanate (PMPI) vapor and aerosol present in the workplace atmosphere. In order to accomplish this, identification and quantitation techniques described in Great Britain's Health Safety Executive Method MDHS 25 (March 1987) for isocyanates were used.[5] This involved the collection of samples in impingers with 15 milliters of toluene containing 1-(2-methoxyphenyl)piper-azine. Due to the flammability and toxicity associated with toluene, only area samples were collected. Samples were collected at a flow rate of 1.0 liter per minute (Lpm), and during sampling, evaporated solution was replaced with only toluene. The solutions were kept refrigerated and shipped cold to the laboratory for analysis. A bulk sample of the isocyanate material used in the plant was also sent to the laboratory under separate cover to aid in the analysis.

The sample analysis was conducted by Method MDHS 25.[5] The reagent 1-(2-methoxyphenyl)piperazine was used to react with isocyanates to form ureas. These were then measured by high-performance liquid chromatography. The ureas were identified and quantitated by using their responses to electrochemical and ultraviolet detectors. The ratio of the responses of the two detectors for each compound was used to identify which compounds that eluted during the analysis were ureas. The electrochemical response of these compounds was used to determine their concentration in the sample by comparing the responses of the identified ureas to the responses of the standards. A more detailed description of the experimental method is provided in Appendix B.

At each area sample location, side-by-side samples were collected to compare the results of Method MDHS 25 and P&CAM 347. The locations of these samples and other information pertinent to sample collection is included in Tables 2 and 3.

2. Wood Dust

The dust from some species of wood are also known to cause respiratory irritation and asthma.[6] Therefore, area samples for total wood dust were collected to determine the relative concentrations of wood dust in the various areas of the plant. Samples were collected at a flow rate of 1.8 Lpm using pre-weighed polyvinyl chloride filters (type FWS-B). The samples were then equilibrated in the laboratory balance room and post-weighed according to NIOSH Method No. 0500.[7] In order to determine the dry weight (less the water content) of the wood dust, the samples were placed in an oven at 40° C overnight and re-weighed the following day. A complete listing of information pertinent to sample collection is contained in Table 5.

3. Aldehydes

Although the current release agent in use did not contain any aldehydes, prior to the NIOSH survey, the CDH had conducted laboratory thermal decomposition studies on two of the previous release agents used in the plant. Samples of these substances were heated to 125° C for one hour. The headspace gases of these samples were then analyzed by gas chromatography/mass spectrometry (GC/MS). The major components were found to be acetaldehyde, propionaldehyde, butyraldehyde, pentanal, and hexanal. Other compounds were also found to be present, but at very low levels.

Since some members of the aldehyde family can cause respiratory irritation, and in rare cases, sensitization, samples for these substances were also collected during the NIOSH environmental survey.[8] Samples were collected at flow rates of 1.0 Lpm (for screening) and 0.070 Lpm (for quantitation) using glass tubes containing 120 mg/60 mg beds of the sorbent Supelpak 20F coated with N-benzylaminoethanol and supplied by Supelco. Samples were analyzed for aldehydes using a gas chromatograph equipped with a flame ionization detector in accordance with a method supplied by the Bureau of Engraving and Printing, with modifications.

4. Trace Organics

Screening samples were also collected to determine if any other organic substances were being emitted from the process as a result of the reaction or thermal decomposition of either the isocyanates, the petroleum wax, the wood, or release agents used in the process. Samples were collected at flow rates of 1.0 Lpm (for screening) and 0.150 Lpm (for quantitation) on charcoal sorbent tubes. All charcoal tubes were desorbed with 1 ml of carbon disulfide. The high volume samples were screened first by gas chromatography and one of the samples was further analyzed by GC with a mass spectrophotometer detector to identify components. All other charcoal tubes were then

analyzed quantitatively by gas chromatography with a flame ionization detector. Thirty-meter DB-1 fused silica capillary columns were used for all analysis (splitless mode).

B. Medical

1. Current Employees

On July 29-30, l987, 97 of L-P's 100 employees completed a screening questionnaire that elicited demographic and symptom information. Respondents were characterized into two groups based on responses to these questions:

a) Within the last month, have you experienced any wheezing, and is this associated with work? (Association with work was defined as symptoms beginning while at work, abating upon leaving the worksite, occurring less frequently while at home, and occurring less frequently on days off-work)

b) Within the last month, have you experienced any shortness of breath or difficulty breathing, and is this associated with work?

c) Within the last month, have you experienced any pain or tightness in the chest, and is this associated with work?

All those who responded "yes" to any of these questions and a like number of randomly chosen participants who responded "no" to all these questions were asked to participate in a follow-up medical evaluation conducted the week of August 23, 1987. This evaluation consisted of:

a) medical questionnaire and a focused physical examination of the pulmonary system. The physician was kept unaware, at the time of examination, of the results from the pulmonary function tests (PFTs), and peak expiratory flow rates (PEFRs),

b) pre- and post-shift PFTs [forced vital capacity (FVC) and one second forced expiratory volume (FEV_1)] using an Ohio Medical Model 822 dry rolling sealed spirometer attached to a Spirotech 220B dedicated computer,

c) serial PEFRs using a mini-Wright's portable peak flow meter for 7 days every 3 hours while awake. Three exhalations were recorded each time, and the maximum of the three was accepted as the PEFR determination,

d) assessment of MDI allergy by measurements of serum IgE and IgG antibody titers to MDI (MDI-RAST and MDI-ELISA, respectively).

A case of occupational induced asthma among current employees was defined as wheezing, shortness of breath, and chest tightness associated with work (as defined above) and either of the following: a) variability of 20% or more in peak expiratory flow rates on any workday, b) a 15% or

more decrement in FEV_1 across a workshift.
Controls were all asymptomatic respondents who participated in the follow-up medical evaluation.

2. Former Employees

To identify potential asthma cases among former employees, we reviewed:
a) the companies' OSHA 200 logs,
b) workers' compensation claims filed against the company,
c) local physician records for any L-P employees, and
d) co-workers knowledge of any current and former workers having breathing problems.

Measuring lung function across a workshift was not possible in former workers, so medical records were used to document airway reactivity, or loss of lung function. We defined a case of occupational asthma among former employees as wheezing, shortness of breath, and chest tightness associated with work (as defined above) and either of the following:

a) an FEV_1 less than 80% predicted, or
b) a positive methacholine challenge test (MCT).

Odds ratios with confidence intervals were calculated using Epiinfo.[9] P-values were calculated using a one-tailed Fisher's exact test or the Student's t-test. Attack rates were calculated for a specified time period using the number of new occupational asthma cases as the numerator, and the total number of workers ever-employed at the plant as the denominator.

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more

recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 (29 USC 651, et seq.) to meet those levels specified by an OSHA standard.

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

Following is a brief discussion of the toxicology and environmental evaluation criteria for the substances evaluated in this survey.

A. MDI and Isocyanate Group

4,4-Methylenediphenyl isocyanate (MDI), chemical formula $C_{15}H_{10}N_2O_2$, is normally a solid material at room temperature with a white to pale yellow color. This odorless substance, with a molecular weight of 250.3, has a low but significant vapor pressure of 0.05 mm/Hg at 20°C (68°F). High molecular weight diisocyanates like MDI present significant vapor hazards when heated or used in exothermic production processes.[6,10]

MDI is an aromatic diisocyanate. Although the majority of studies on aromatic diisocyanates have been done on toluene diisocyanate (TDI), studies done on both chemicals find similar health effects.[10] Exposure to MDI and TDI can occur via ingestion, skin contact, and inhalation. Inhalation of aerosolized isocyanates is responsible for the majority of reported health effects.

The lung is the primary organ affected by inhaled isocyanates. Adverse reactions include:
- upper airway irritation, characterized by cough, and rhinitis;[11,12,13]
- acute asthma, manifested as wheezing, breathlessness, and chest tightness occurring immediately after exposure;[14-19]
- delayed asthma, manifested as wheezing, breathlessness, and chest tightness occurring several hours after exposure;[14-19]
- dual asthma, manifesting as wheezing, breathlessness, and chest tightness occurring in both an immediate and delayed pattern;[14,15,19]
- hypersensitivity pneumonitis, characterized as chronic fever, malaise, dry cough, and progressive dyspnea;[20,21,22]
- asymptomatic permanent loss of lung volumes.[23,24]

Certain individuals may develop diisocyanate sensitization, which is usually manifested as a debilitating asthma-like illness caused by very low, even unmeasurable diisocyanate concentrations.[10] Other adverse health effects in humans due to isocyanates exposure are skin and eye irritation[25,26], skin hypersensitivity[10,26-28], and psychologic symptoms.[10] In animals, isocyanates may cause renal toxicity, and cancer.[10]

The current federal OSHA standard and ACGIH TLV for MDI is a ceiling limit of 0.2 milligrams per cubic meter of air (mg/m^3) [0.02 parts of MDI per million parts of air (ppm)].[29,30] The current NIOSH REL for occupational exposure to MDI is 0.05 mg/m^3 [0.005 ppm] for up to a 10-hour workshift, 40-hour workweek, and a ceiling of 0.2 mg/m^3 [0.02 ppm] for any 10-minute sampling period.[10]

The NIOSH recommended standard applies to diisocyanate monomers only, and not to higher polymers of these compounds. Little is known about the toxicological effects of polymeric isocyanates. No long-term studies of the effects on humans of polymeric isocyanates have been conducted.[31] However, it is speculated that the inhalation of any species having multiple unreacted isocyanate groups may impair respiratory function or give rise to sensitization.[3,4]

On February 2, 1983, the United Kingdom Health and Safety Commission set a "common control limit" for workplace exposure to all isocyanates. This new control limit is 20 ug of isocyanate group per cubic meter of air, expressed as an eight-hour TWA, and 70 ug of isocyanate group per cubic meter of air, as a 10-minute TWA. This new control limit, in units of ug $(NCO)/m^3$, requires that the analytical methods be applicable to "total isocyanate", that is, the sum of all isocyanate species, including monomers and prepolymers.[32]

B. Wood Dust

Exposure to different types of wood dust has been reported to have resulted in numerous health effects, including allergic reactions, chronic nonallergic respiratory disease and nasal sinus cancer.[33-35] Obstructive respiratory effects, development of lung fibrosis, and impairment of the mucocilliary clearance mechanism have also been reported.[34,36,37] In the majority of these studies, a particular type of wood has been identified as the causative agent of the particular health effect. Health effects unique to aspen wood dust has not been described.

The OSHA PEL for total nuisance dust is 15 mg/m^3.[29] The ACGIH TLV for hard wood dust (as in furniture making) is 1 mg/m^3, and for soft wood dust (nonallergenic types) 5 mg/m^3, with an STEL of 10 mg/m^3.[6] There is currently no NIOSH REL for wood dust.

C. Aldehydes

Aldehydes are a highly reactive class of substances. Typically these compounds are irritating to the skin, eyes, and respiratory tract. Acute exposure may result in pulmonary injuries such as edema, bronchitis, and bronchopneumonia. Skin sensitization may develop in some individuals resulting in contact dermatitis, and more rarely, exposure may lead to asthmatic attacks.[8] After hypersensitivity develops, individuals may develop symptoms due to other aldehydes.[8] The environmental criteria differ for various aldehydes.

VI. RESULTS

A. Environmental

1. MDI

The results of the personal samples collected for MDI are presented in Table 1. As evidenced by these results, quantifiable concentrations of MDI were found in only two of the 23 personal samples collected. TWA concentrations of 0.015 mg/m^3 and 0.016 mg/m^3 were found in samples collected on a line technician and dry end utility man, respectively. These results are below the NIOSH REL of 0.05 mg/m^3 as an 8-hour TWA, and would be below the OSHA and ACGIH ceiling criteria of 0.2 mg/m^3. Five of the remaining samples had levels of MDI which were above the limit of detection (LOD) of 0.3 micrograms (ug) per sample, but below the limit of quantitation (LOQ) of 1 ug/sample. MDI levels in the remaining 16 samples were all below the LOD. The 23 personal samples collected encompassed 13 different job categories over a three day period.

The results of the area samples collected for MDI are presented in Table 2. As previously noted, two different sampling and analytical methods for MDI [P&CAM 347 (sorbent tube method) and MDHS 25 (impinger method)] were utilized in the collection of the area samples. At each sample location, side-by-side samples were collected in order to compare the two methodologies. The results of the P&CAM 347 analysis revealed quantifiable levels of MDI in five of the 11 samples collected. TWA concentrations of MDI in these samples ranged from 0.016 to 0.061 mg/m^3, with a mean concentration of 0.036 mg/m^3. In the remaining six samples, five MDI levels were below the LOD of 0.3 ug/sample, and one was below the LOQ of 1.0 ug/sample.

The results of the MDHS 25 analysis revealed quantifiable levels of MDI in eight of 12 samples collected. TWA concentrations of MDI in these samples ranged from 0.0008 to 0.061 mg/m^3, with a mean concentration of 0.019 mg/m^3. In the remaining four samples, one MDI level was below the LOD of 0.086 ug/sample, and three were below the LOQ of 0.28 ug/sample.

With the exception of the sample collected in the press control room, these area samples were "process" samples collected in the immediate vicinity of the production operations. As such, they reflect the relative magnitude of emissions at different locations on the production line and do not reflect personal exposures. As previously described, the production line was totally automated and controlled by employees located in separate control rooms (where no quantifiable levels of MDI were found). Employees would not normally be present in the production areas except for brief periods of time to perform routine maintenance (i.e, waxing of former conveyor belts) or non-routine maintenance activities (unplugging jammed conveyors, repairs, or adjustments). For such brief periods of exposure, the application of ceiling criteria would be most appropriate. Under these circumstances, none of the samples would exceed the NIOSH REL, OSHA PEL, or ACGIH TLV of 0.2 mg/m^3 as a ceiling limit.

While a comparison of the two methods revealed duplicate determinations in some instances, on the average, the impinger results were generally lower than those from the sorbent tube method. Although the exact cause for this discrepancy is not known, it is possible that NIOSH method P&CAM 347 may have had a positive bias, perhaps due to the formation of interfering compounds upon air oxidation or decomposition of the reagent. It is also possible that this discrepancy may be due in part to a greater collection efficiency of the sorbent tube for MDI vapor.

2. Isocyanate Group

The results of the area samples collected for total isocyanates are provided in Table 3, which provides both the number of micromoles (umol) of isocyanate group (NCO) present as MDI and estimates of the umol of NCO group present as PMPI. A combination of the total umol of NCO group present from these two sources is then expressed as a TWA concentration [in micromoles of NCO group per cubic meter of air (umol/m^3)] for each of the samples.

As evidenced by these data, quantifiable concentrations of total NCO groups were found in eight of the 12 impinger samples collected. TWA concentrations ranged from 0.0059 to 0.80 umol NCO group/m^3, with a mean concentration of 0.26 umol/m^3. The amount of NCO groups was below the LOQ of 0.0023 umol in the four remaining samples.

As indicated previously, these samples were process samples, collected at locations where workers are not normally present except for brief periods of time. For such brief exposures, the use of ceiling criteria would be most appropriate. In this case, all exposures would be below the level recommended by the United Kingdom Health and Safety Committee for isocyanate group of 1.7 umol/m^3 as a 10-minute ceiling.

Based on an analysis of the analytical method, the values of PMPI-derived isocyanate group are only estimates of the concentration and are probably somewhat low. These values, added to those for MDI-derived isocyanate group, make the estimates for total isocyanate group also somewhat low. Therefore, when making decisions regarding the needs for engineering controls or personal protection, it would be prudent to view these data as representative of the minimum amounts present.

3. Wood Dust

The results of the eleven area air samples collected for wood dust are presented in Table 4. TWA concentrations of wood dust ranged from 0.02 to 1.7 mg/m^3, with a mean of 0.47 mg/m^3. All of these results would fall below the OSHA PEL of 10 mg/m^3 for nuisance particulate and the ACGIH TLV of 5 mg/m^3 for softwood dusts. Although the ACGIH TLV of 1 mg/m^3 for "certain types" of hardwood dust does not specifically identify aspen, it would be prudent to use this more restrictive criterion as a guideline for controlling dust exposures. During the NIOSH survey, only the area sample collected in the waferizer work area revealed a concentration in excess of the 1 mg/m^3 TLV.

Relatively little moisture content remained in the collected dust on the filters; the weights after equilibration and after heating to 40ºC were very similar (average of 8% less).

The sample collected in the board graders work area was excluded from this discussion due to the fact that a significant amount of paint overspray had accumulated on the filter, and the resulting weight did not accurately reflect the wood dust concentration in this area.

4. Aldehydes

The results of the aldehyde analysis of the two high volume (average 87 liters) and two low volume (average 14 liters) area air samples collected directly adjacent to the press and formers did not reveal detectable concentrations of formaldehyde, acetaldehyde, or butyraldehyde above their LOD's of 2 ug, 3 ug, and 2 ug, respectively. The laboratory method that was used did not allow adequate peak separation to allow for a determination of the presence of propionaldehyde.

5. Trace Organics

The laboratory analysis of the two-high volume (average 94 liters) and two low volume (average 36 liters) air samples collected directly adjacent to the press and formers did not reveal any major components other than toluene. This substance was most likely came from nearby impinger samplers which contained toluene reagent. Trace amounts of some $C_{10}H_{16}$ isomers such as pinene and limonene were also detected, but in amounts too small to quantify.

6. OSHA Inspection Results

Prior to the NIOSH study, OSHA conducted an inspection of the facility. As in the NIOSH study, OSHA found no exposures to MDI above OSHA's PEL, however the company's respiratory protection program had several deficiencies. These included; the lack of a written standard operating procedures, a lack of proper training and instruction for employees using respirators, a lack of fit-testing for adequate facepiece seal, and the use of respirators with conditions such as beard growth, which would prevent a good face seal.

B. Medical

Ninety seven of the 100 plant employees completed the screening questionnaire administered on July 29-31, l987. The three employees not completing the questionnaire were on vacation during our initial visit. Twelve of the 97 employees (12%) answered "yes" to at least one of the asthma symptom questions. All twelve, plus twelve randomly chosen asymptomatic workers agreed to participate in the follow-up medical evaluation during the week of August 24, l987. During the intervening 3 weeks, however, five of the twelve symptomatic employees were fired or quit, and one of the twelve asymptomatic respondents refused participation. Therefore, only 18 of the 24 selected, plus one employee who was on vacation during the screening questionnaire, participated in the follow-up medical evaluation.

Between July l986 and August l987, 93 employees were fired or requested termination from L-P's Olathe plant. Our directed review of these 93 ex-employees led us to contact and review medical records of 20 former workers.

Thirteen workers, three current and ten former, satisfied our case definitions for occupational asthma. Table 5 lists the clinical, PFT, and immunologic results of these thirteen cases. Their ages ranged from 19 to 55, with a mean of 34 years. Males represented 85% (11/13) of the cases. Eleven of the cases were non-Hispanic white (85%), and two were Hispanic (15%). There were no significant differences between the cases and the asymptomatic controls with regard to age, sex, or race (Table 6). The onset of symptoms among the cases began in June l986, peaked in August l986, and continued sporadically over the next nine months (Figure 1). Assuming the introduction of MDI into the plant in June l986 was the beginning of exposure for workers employed prior to May l986, the onset of symptoms after exposure ranged from the same month to nine months later, with a mean latency of 3 months.

The overall attack rate from June l986 through August l987 was 6.7%. Attack rates for this same time period among current employees was 3%, compared to 11% among former employees.

Eleven of the thirteen occupational asthma cases completed the NIOSH questionnaire. There was no association between occupational asthma and family history of asthma, eczema, or hayfever (Table 7).

In addition, there was no association between between cases and controls with respect to smoking, previous history of asthma, eczema, sinusitis, or hayfever (Table 8). The one case who had previous history of asthma described it as childhood asthma with symptoms resolving 10-15 years prior to working at the L-P plant.

Eight cases had MDI-RAST tests performed (IgE). Two of these were positive for a sensitivity of 25%, and none of the controls were positive for a specificity of 100% (Table 9). Six cases had MDI-ELISA tests performed (IgG). Five of these were positive for a sensitivity of 83%, however four of the ten controls were also positive, for a specificity of 60% (Table 10).

Of the ten cases among former employees, five cases had skin testing for atopy performed by their consulting physicians. Three of these were positive for a sensitivity of 60%. Of the ten cases among former employees, four had methacholine challenge testing (MCT) performed by their consulting physicians. Three were positive for a sensitivity of 75%. The one worker with a negative MCT had symptoms more suggestive of hypersensitivity pneumonitis (fatigue, malaise, and night sweats) than asthma. A transbronchial biopsy revealed diffuse fibrosis consistent with hypersensitivity pneumonitis . This individual's MDI-RAST and MDI-ELISA tests, drawn 24 days after the last MDI exposure, were negitive.

No association was found between occupational asthma and job title (Table 11). (The statistically lower risk associated with the job title EFB Donus has no plausible biological interpretation.)

VII. DISCUSSION

A. Medical

NIOSH identified 13 cases of occupational pulmonary disease. This is probably not a complete ascertainment of cases because most of the former employees could not be reached. No workers died or were hospitalized due to asthma, but a few required asthmatic treatment in the local emergency room or physician offices.

Both MDI and wood dust are potential asthmagens, however, only a few particular wood dusts are known to cause asthma[33], neither being aspen or pine used in this plant's operation. The epidemic curve suggests a problem beginning in June l986, coinciding with MDI's introduction into the workplace, while the type of wood (90% aspen and 10% pine) did not change during the plant's three years of operation. Given the known asthmagenic properties of MDI, and the temporal relationship of MDI exposure and the appearance of asthma in the workforce, we conclude that this is MDI-induced asthma.

The mean latency between exposure and onset of symptoms was 3 months. This delay of symptoms, and the low levels of MDI measured in the workplace, suggest the illnesses were due to MDI sensitization, rather than a direct irritant effect. If all the occupational asthma cases represent MDI-sensitized individuals, 6.7% of exposed individuals were sensitized. This prevalence is similar to those in other reports.[15,16,27,38,39]

Identifying susceptible or already sensitized individuals by pre-placement screening examinations would be very useful. Our data does not support using a family history of asthma, eczema, or hayfever, or a personal history of asthma, eczema, hayfever, sinusitis, or smoking to predict MDI-induced asthma. Both skin testing for atopy and MCT had relatively high sensitivities, 60% and 75% respectively, but neither was performed on the control population. (Therefore specificity and predictive value positive could not be calculated.) These two tests are

usually done by specialists (allergists or pulmonologists), are relatively expensive, and carry the potential risk of complications. Because serum immunologic tests are not positive prior to exposure, their potential role in pre-placement screening is limited.

Given our inability to find any predictive pre-employment screening tests or identify any particular area or job title with MDI exposure, monitoring the current workforce for early MDI sensitization is important because the severity and persistence of symptoms appear related to the magnitude and duration of exposure.[42] An ideal screening test has a sensitivity and specificity which approach 100%. The MDI-RAST(IgE) test had a sensitivity of 25%, and a specificity of 100% (Table 90). The MDI-ELISA(IgG) test had a sensitivity of 83.3%, and a specificity of 60% (Table 10). Screening questionnaires, PEFRs, and PFTs were used as part of our case definitions, so sensitivities are, by definition, 100%.

PEFRs showed bronchial lability in 3 cases where the PFTs were normal. The insensitivity of pre- and post-PFTs to diagnosis occupational asthma has been well documented,[28] while the use of PEFRs is becoming more accepted. There are, however, limitations of using PEFRs to diagnose occupational asthma. There are no standardized criteria for a positive response, and the test is effort-dependent and it requires a strongly motivated employee to complete.

Former employees did not have the opportunity to perform PEFRs or pre- and post-shift PFTs. Spirometric evidence of a decreased FEV_1 ($\leq$ 80% of predicted) was present in 9 cases of occupational asthma. Seven of these nine had pre- and post-bronchodilator measurements taken, of which five (75%) demonstrated reversible airway obstruction (15% or more improvement in the FEV_1). The two workers not demonstrating reversiblity had normal FEV_1 readings taken within two weeks. In addition, one had a positive MCT and the other had a positive MDI-RAST.

B. Environmental

The results of the environmental survey did not reveal any exposure to trace organics, aldehydes, wood dust (with the exception of one area sample), MDI, or isocyanate group above the evaluation criteria. In most cases, the results of the personal samples for MDI were below the limits of quantitation or detection for the analytical methods used. This is not surprising, considering the high degree of automation of the production line. The employees who operate the line in these areas are located in separate air-conditioned control rooms. The only time workers enter these areas are when it is necessary to conduct routine (e.g., waxing of the former conveyor belts) or non-routine (e.g., equipment malfunctions or conveyor clogs and jams) maintenance operations.

In the case of the two personal samples which revealed quantifiable levels of MDI, both employees (a line technician and a dry end utility man) had been involved in these types of activities sometime during the workshift. Emphasis should be placed on reducing the exposures during these maintenance activities.

The results of the area samples showed the airborne MDI and isocyanate group exposure at several points along the production line. While employees performing work in these areas for short periods of time would still not have been exposed to these substances above the ceiling environmental criteria, the samples do provide useful information on the relative isocyanate concentrations at various areas of the production line. The highest concentrations of MDI and isocyanate group were noted in the area by the formers, followed by the rear entrance to the blender and the bottom of the conveyor to the core former. Concentrations in samples collected directly alongside of the press were found to be very low or nondetectable, indicating that the exhaust ventilation above the press appeared to be operating effectively. The ventilation above the press had undergone major modifications prior to the NIOSH environmental survey, so these results may not accurately reflect the prior

airborne concentrations that may have existed previously in this area or their resulting effect on exposures in other areas of the plant. In addition, a certain number of operational problems would have been expected to occur during the initial period of production with the isocyanate binding agent. This probably resulted in personnel spending more time in the area for the adjustments and maintenance, which could have led to an increased potential for exposure. In addition, deficiencies in the companies respiratory protection program probably compromised respirator effectiveness. Therefore, while the environmental data is not available to accurately determine the historic exposures, it is probable that isocyanate levels were higher in the past which diminished with enviromental controls installed in October l986, and subsequent modification to the press exhaust hood. However, four cases of isocyanate induced pulmonary disease reported symptoms occuring after Janurary l988, suggesting continued, though perhaps minimal, exposure.

VIII. CONCLUSIONS

Although personnel exposures were not found to exceed the NIOSH REL, the evaluation identified 13 epidemiologically defined cases of occupational pulmonary disease: 12 cases of asthma, one of which may have actually been hypersensitivity pneumonitis. It is likely that most of these cases resulted from the higher MDI exposure levels that may have existed shortly after the introduction of the material into the plant, when engineering controls and personal protection programs were not in place. Individuals who perform routine and nonroutine maintenance activities in the areas where isocyanates are used still face a risk of significant exposure if the proper personal protective equipment is not used. In addition, due to individual susceptibility, some individuals within the plant may continue to react to the isocyanates at very low or even unmeasurable concentrations. Therefore, it is important to reduce diisocyanate exposures as low as possible through ongoing emphasis on engineering controls and the appropriate use of personal protection.

IX. RECOMMENDATIONS

In order to further reduce occupational exposures to isocyanates and to prevent additional cases of sensitization, the following recommendations are provided.

A. Engineering Controls and Work Practices

Engineering controls, such as process enclosure or local exhaust ventilation, should be used where needed to maintain environmental concentrations of diisocyanates at or below the recommended limits. These systems should be designed to prevent the accumulation or recirculation of diisocyanates in the workplace environment and to effectively remove diisocyanate vapors or aerosols from the breathing zone of the employees. The ventilation systems should be periodically checked, including airflow measurements, to ensure that the systems are working properly. Exhaust ventilation systems discharging to outside air must conform to applicable local, state, and Federal air pollution regulations and must not constitute a hazard to employees or to the general public.

Good housekeeping in the workplace is of prime importance in reducing exposure to diisocyanates. Adequate facilities for handling spills and leaks of diisocyanates should be provided, and workers should be thoroughly trained in cleanup procedures. Spills should be promptly cleaned up, and all equipment used in the exposure areas, such as buckets, weighing containers, and funnels, should be decontaminated and cleaned immediately after use. To reduce the possibility of leaks, plastic or rubber hoses which become brittle from contact with diisocyanates should be checked and replaced regularly.

Storing, handling, dispensing, and consuming food should be prohibited in work areas, regardless of the concentrations of diisocyanates. In addition, employees who work in areas that use diisocyanates should wash their hands thoroughly before eating or using toilet facilities. Smoking should not be permitted in areas where diisocyanates are stored or used because of the possibility that smoking materials may become contaminated with diisocyanates.

Signs warning of the danger of exposure to diisocyanates should be posted in any area where occupational exposure to the diisocyanates is likely. Access to areas of potential high exposure should be restricted to employees equipped with appropriate protective gear.

B. Monitoring

A regular program of air monitoring of diisocyanate concentrations should be implemented. This will permit engineering controls to be modified or improved to keep the concentrations of diisocyanates at or

below the recommended limits. Monitoring should also be performed whenever there is a change in the process or materials used that could increase the exposure of employees.

C. Personal Protective Equipment and Clothing

Where engineering controls are used to keep diisocyanate concentrations at or below the recommended exposure limits, minimal protective clothing is needed to safeguard workers. Under these conditions workers should wear coveralls and rubber or polyvinyl chloride gloves. Where liquid diisocyanates may be present on floors, protective shoe coverings should be worn. If the potential exists for splashes or contact with aerosols of diisocyanates, employees should be provided with face shields (20-cm minimum) with goggles, rubber or polyvinyl chloride gloves and aprons, rubber boots, and appropriate respiratory equipment. All protective clothing that becomes contaminated with diisocyanates should be replaced or thoroughly decontaminated in a solution of 8% ammonia and 2% liquid detergent in water and cleaned before reuse.

In instances where engineering controls are not feasible and respirator use is necessary (e.g., maintenance work, tank cleaning, or other infrequent short periods of exposure), employees should be provided with a properly selected and fitted respirator. A respiratory protection program which meets the requirements provided in the OSHA "General Industry Standards", 29 CFR 1910.134 should be put into place.[29] Because diisocyanates have poor warning properties, the use of chemical cartridge respirators or gas masks is not recommended. At present, air-purifying respirators with an end-of-service-life indicator are not available for the diisocyanates. Demand-type (negative pressure) supplied-air respirators are not recommended because of the possibility of facepiece leakage. The NIOSH criteria document should be consulted for further information regarding the selection of the proper respiratory protection for MDI.[10]

D. Informing Employees of Hazards

At the beginning of employment, all employees should be informed of the hazards from exposure to diisocyanates. Brochures and pamphlets may be effective aids in informing employees of hazards. A continuing education program, which includes training in the use of protective equipment, such as respirators, and information about the value of the periodic medical examinations, should be available to the employees. Employees exposed to diisocyanates should be informed that symptoms of exposure, such as nocturnal dyspnea, may occur several hours after the end of the workshift. Because of the possibility of sensitization to the diisocyanates, employees should be warned that the improper home use of polyurethane products, such as foam kits and varnishes that contain diisocyanates, may increase their risk of developing isocyanate health problems. Employees should be

instructed in their own responsibility for following work practices and sanitation procedures to help protect the health and provide for the safety of themselves and their fellow employees.

E. Medical Screening

A program for medical screening of workers potentially exposed to isocyanates should be instituted. For new employees this should include (1) a medical history to seek pre-existing respiratory symptoms and disease, especially asthma, and an occupational history to seek evidence of previous exposure to isocyanates; and (2) baseline PFTs including, FEV_1 and FVC (and calculation of the FEV_1/FVC ratio). All employees should be interviewed and have PFTs at least annually. Any worker reporting symptoms such as persistent cough, cough at night, wheezing, shortness of breath or difficulty breathing, and anyone with abnormal PFT's, should have further medical evaluation. Anyone with documented hypersensitivity to isocyanate should not have a work assignment involving exposure to isocyanates, and may even be unable to work in the general area of isocyanate use.

For proper performance of spirometry, a number of technical considerations should be addressed, including the use of a spirometer and test procedures meeting ATS specifications,[41] a trained and enthusiastic technician, and, to the extent feasible, doing the tests with same machine, technician, and time of day from year to year. Other features of an occupational pulmonary disease surveillance program include education of workers, maintenances of medical records and records of environmental exposure, and epidemiologic evaluation of data.

The document NIOSH Criteria for a Recommended Standard...Occupational Exposure to Diisocyanates should be consulted for more detailed information regarding these recommendations.[10]

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XII. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to:

A. Colorado Department of Health
B. Louisiana-Pacific Corporation
C. U. S. Department of Labor, OSHA - Region VIII
D. NIOSH Regional Offices/Divisions

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

TABLE 1

Results of Personal Air Samples Collected for MDI

HETA 87-099

Louisiana- Pacific, Olathe, Colorado

Sample Date	Employee Job Title	Sample Time (minutes)	Sample Volume (Liters)	TWA Concentration MDI (mg/m3)
8/26/87	Line Technician	514	98.4	0.015
8/26/87	Board Grader	510	112	< LOD (0.0027)
8/26/87	Dryer Operator	477	96.9	< LOD (0.0031)
8/26/87	Electrician	455	95.8	< LOD (0.0031)
8/26/87	Slasher Operator	501	113	< LOD (0.0027)
8/26/87	Board Grader	502	109	< LOD (0.0028)
8/26/87	Dryer Operator	499	112	< LOD (0.0027)
8/26/87	Cleanup (press pit)	356	66.6	< LOD (0.0045)
8/27/87	Line Technician	510	108	< LOQ [0.0056]
8/27/87	Millwright	501	109	< LOD (0.0028)
8/27/87	Electrician	510	112	< LOQ [0.0036]
8/27/87	Warehouseman	488	88.5	< LOD (0.0034)
8/27/87	Mobile Equip. Operator	506	119	< LOD (0.0025)
8/27/87	Line Technician	506	109	< LOQ [0.0055]
8/27/87	Board Grader	472	102	< LOD (0.0029)
8/27/87	Electrician	470	96	< LOD (0.0031)
8/28/87	Line Technician	513	110	< LOQ [0.0045]
8/28/87	Trucker/Strapper*	381	84.6	< LOD (0.0035)
8/28/87	EFP Konus Operator	331	72.4	< LOQ [0.0069]
8/28/87	Utility Man, Dry End	412	90.2	0.016
8/28/87	Waferizer	430	95.3	< LOD (0.0031)
8/28/87	Dryer Operator	558	129	< LOD (0.0023)
8/28/87	Board Grader	490	108	< LOD (0.0028)

Evaluation Criteria: MDI

NIOSH REL 0.05 mg/m^3 10 hour TWA / 0.2 mg/m^3 10-min ceiling

OSHA PEL 0.2 mg/m^3, ceiling

ACGIH TLV 0.2 mg/m^3, ceiling

Abbreviations and Key

MDI - 4,4-methylenediphenyl isocyanate

TWA - Time-Weighted Average Concentration for duration of sample collection mg/m^3 - milligrams per cubic meter of air

< LOD - Sample was less than the limit of detection of 0.3 micrograms per sample. Values expressed in parenthesis reflect the minimum detectable air concentrations at each sample volume; however, the actual air concentration was below this value.

< LOQ - Sample was less than the limit of quantitation of 1.0 micrograms per sample. The value contained in brackets should only be considered an estimate of the actual air concentration.

*This sample was collected in the employees immediate work area and would be expected to closely reflect the personal exposure.

TABLE 2

Results of Area Air Samples Collected for MDI

HETA 87-099
Louisiana- Pacific, Olathe, Colorado

Sample Description	Sample Time (minutes)	P&CAM 347 Sample Volume (Liters)	MDHS 25 Sample Volume (Liters)	P&CAM 347 TWA Concentration MDI (mg/M3)	MDHS 25 TWA Concentration MDI (mg/m3)
(Collected 6/26/87)					
Press Pit	223	223	223	< LOD (0.0013)	< LOQ [0.0010]
Above Press Loaders	215	215	215	< LOQ [0.0028]	0.0037
Press Control Room	212	212	212	< LOD (0.0014)	< LOQ [0.0010]
Side of Press	210	210	210	< LOD (0.0014)	< LOQ [0.0011]
Above Core Former	212	212	212	0.061	0.061
Conveyor to Core Former	207	207	207	0.016	0.012
Rear Platform of Blender	206	206	206	0.053	0.026
(Collected 6/28/87)					
Press Pit	389	87.1	389	< LOD (0.0034)	< LOD (0.0002)
Rear Platform of Blender	375	NA	375	NA	0.032
Conveyor to Core Former	376	69.9	376	0.021	0.0085
Above Core Former	381	75.6	381	0.030	0.014
Side of Press	384	84.5	384	< LOD (0.0036)	0.0008

Evaluation Criteria: MDI

NIOSH REL 0.05 mg/m^3 10 hour TWA, 0.2 mg/m^3 10-min ceiling
OSHA PEL 0.2 mg/m^3, ceiling
ACGIH TLV 0.2 mg/m^3, ceiling

Abbreviations and Key

MDI - 4,4-methylenediphenyl isocyanate
TWA - Time-weighted average concentration (for duration of sample collection) mg/m^3 - milligrams per cubic meter of air
< LOD - Less than the limit of detection of 0.3 micrograms(ug)/sample P&CAM 347, 0.086 ug/sample MDHS 25. Values in parenthesis reflect the minimum detectable air concentrations at each sample volume; however, the actual air concentration was below this value.
< LOQ - Less than the limit of quantitation of 1.0 ug/sample P&CAM 347, 0.28 ug/sample MDHS 25. The values contained in brackets should only be considered estimates of the actual air concentration.
NA - Sample not analyzed due to sample pump failure.

TABLE 3

Results of Area Air Samples Collected for Isocyanate Group

HETA 87-099
Louisianna Pacific, Olathe, Colorado

Sample Description	Sample Time (minutes)	Sample Volume (Liters)	MDI NCO Group (umols)	PMPI* NCO Group (umols)	TWA Concentration Total NCO Group* (umols/m3)
(Collected 6/26/87)					
Press Pit	223	223	< LOQ [.0017]	< LOQ [.002]	< LOQ [0.017]
Above Press Loaders	215	215	0.0064	0.007	0.062
Press Control Room	212	212	< LOQ [0.0017)	< LOQ [0.002]	< LOQ [0.017]
Side of Press	210	210	< LOQ [0.0019]	< LOQ [0.002]	< LOQ [0.019]
Above Core Former	212	212	0.11	0.06	0.80
Conveyor to Core Former	207	207	0.020	0.01	0.14
Rear Platform of Blender	206	206	0.043	0.03	0.35
(Collected 6/28/87)					
Press Pit	389	389	< LOD (0.00069)	< LOQ [0.002]	< LOQ [0.005]
Rear Platform of Blender	375	375	0.099	0.05	0.40
Conveyor to Core Former	376	376	0.026	0.02	0.12
Above Core Former	381	381	0.042	0.03	0.19
Side of Press	384	384	0.0023	< LOQ [0.002]	0.006

Evaluation Criteria - Isocyanate Group: UK HSC 0.48 umol/m^3 8-hour TWA, 1.7 umol/m^3 10-min ceiling

Abbreviations and Key
MDI - methylene bisphenyl isocyanate
PMPI - Polymethylenepolyphenyl isocyanate
TWA - Time-weighted average concentration (for the duration of sample collection)
NCO Group - Isocyanate Group
umols - micromoles
umoles/m^3 - micromoles per cubic meter of air
< LOD - Less than the limit of detection of 0.00069 umol/sample
< LOQ - Less than the limit of quantitation of 0.0023 umol NCO group/sample. Therefore, the values contained in brackets should only be considered estimates of the actual amounts present.
* All values listed are only estimates.

TABLE 4

Results of Area Air Samples Collected for Wood Dust
(samples collected 6/28/87)

HETA 87-099
Louisianna Pacific, Olathe, Colorado

Sample Location	Sample Time (minutes)	Sample Volume (Liters)	TWA Concentration Wood Dust* (mg/m3)
Forming Line	380	684	0.15
Board Grader - Work Area	221	398	1.4**
Below Core Blender	297	535	0.28
Below Wood Chip Storage Bins	225	405	0.35
Below Dust Percipitator	156	281	0.71
Below Dryer Entrance	290	522	0.63
Waferizer - Work Area	211	380	1.7
Debarker - Work Area	303	545	0.18
Below Waferizer	298	536	0.45
Yard - Slasher Cab	310	558	0.02
Yard - Forwarder Cab	315	567	0.25

Evaluation Criteria: Wood Dust (measured as total particulate)
OSHA PEL 10 mg/m^3, 8-hour TWA (nuisance dust)
ACGIH TLV 5 mg/m^3, 8-hour TWA (softwood dust)
1 mg/m^3, 8-hour TWA (certain hardwood dusts)

Abbreviations and Key
TWA - Time-Weighted Average Concentration for duration of sample collection
mg/m^3 - milligrams per cubic meter of air
* Wood Dust - measured as total particulate
** This sample contained a substantial amount of overspray from a paint sprayer, and therefore does not accurately reflect the the wood dust concentration in this area.

Table 5

Occupational Asthma Cases

HETA 87-099
Louisiana-Pacific, Olathe, Colorado

ID#	Asthma Sxs	MD's Dx	Smoke (Pk-yr)	MCT Pos.	FEV_1 <80% Pred.	>20% drop FEV1	>20% drop PEFR.	MDI RAST (IgE)	MDI ELISA (IgG)
Current Employees									
01	Y	A	14	NA	N	N	Y	N	Y
02	Y	A	5	NA	N	N	Y	N	Y
03	Y	A	0	NA	N	N	Y	N	N
Former Employees									
04	Y	HP	0	N	Y	NA	N	N*	N*
05	Y	A	12	NA	Y+	NA	NA	Y	Y
06	Y	A	0	NA	Y	NA	NA	NA	NA
07	Y	A	0	Y	Y	NA	NA	N	Y
08	Y	A	8	NA	Y	NA	NA	N	NA
09	Y	A	1	NA	Y	NA	NA	N	Y
10	Y	A	NA	Y	Y+	NA	NA	NA	NA
11	Y	A	1	Y	N	N	N	NA	NA
12	Y	A	NA	NA	Y	NA	NA	NA	NA
13	Y	NA	2	NA	Y	NA	NA	Y	NA

Y = Yes
N = No or normal
NA = Not Available
A = Asthma
+ = No bronchodilator response
HP = Hypersensitivity pneumonitis
* = Drawn four weeks after exposure

Table 6

Comparing Age, Sex, and Race between Asthma Cases and Controls

HETA 87-099
Louisiana-Pacific, Olathe, Colorado

Number(N)	Case N = 13	Control N = 10	P Value
Age (mean)	34	32	0.650*
Sex (% Male)	85%	90%	1.000+
Race (% White)	85%	90%	1.000+
(% Hispanic)	15%	10%	

* = Student's t-test
+ = Fisher's exact test, 2 tailed

Table 7

Comparing Family History Between Cases and Controls

HETA 87-099
Louisiana-Pacific, Olathe, Colorado

Number(N)	Case N = 11	Control N = 10	O.R.*	P Value**
Family History of:				
Asthma	1	1	0.90	.738
Eczema	0	1	0.00	.476
Hayfever	4	7	0.57	.425

* O.R. = Odds ratio
** P Value calculated using one tailed Fischer's Exact Test

Table 8

Comparing Personal History of Cases and Controls

HETA 87-099
Louisiana-Pacific, Olathe, Colorado

Number(N)	Case N = 11	Control N = 10	O.R.*	P Value**
Personal History of:				
Asthma	1	0	Undefined	.524
Eczema	1	0	Undefined	.524
Hayfever	1	4	.15	.126
Sinusitis	2	5	.22	.140
Ever Smoked	7	6	1.17	.608

* O.R. = Odds ratio
** P Value calculated using one tailed Fischer's Exact Test

TABLE 9

HETA 87-099
LOUISIANNA-PACIFIC, OLATHE COLORADO

RAST as Screening Test
for Occupationally-Induced Respiratory Disease

MDI RAST (IgE)	Case	Control	
+	2	0	2
-	6	10	16
	8	10	18

Sensitivity = 25%
Specificity = 100%

TABLE 10

HETA 87-099
LOUISIANNA-PACIFIC, OLATHE COLORADO

ELISA as Screening Test
for Occupationally-Induced Respiratory Disease

MDI ELISA (IgG)	Case	Control	
+	5	4	9
-	1	6	7
	6	10	16

Sensitivity = 83%

Specificity = 60%

Table 11

Relationship Between Occupational Asthma Cases and Job Title

HETA 87-099
Louisiana-Pacific, Olathe, Colorado

Job Title:	Number(N)	Case N = 13	Control N = 10	O.R.*	P Value**
Trucker/Straper		4	l	4.00	.25l
Mob. Equip. Oper.		5	2	2.50	.3l3
Log Retrieval		l	l	0.75	.692
Board Grader		3	4	0.45	.337
Dryer Operator		l	2	0.33	.398
Line Technician		l	3	0.l9	.200
Press Operator		0	0	0.78+	.904++
Prod. Electrician		0	l	0.0	.435
Prod. Maintenance		0	0	0.78+	.904++
Green End Relief		2	0	4.57+	.308
Knife Grinder		0	l	0.0	.435
Waferizer		l	0	2.52+	.565
Utility		3	0	7.00+	.l62
EFB Konus		0	4	0.0	.024
Millwright		l	0	2.52+	.565
Tongue & Groove		0	0	0.78+	.904++
Foreman		l	0	2.52+	.565
Debarker		0	0	0.78+	.904++

* O.R. = Odds ratio
** P Value calculated using one tailed Fischer's Exact Test
+ = 0.5 added to each cell to determine odds ratio.[43]
++ = P-value calculated using unadjusted Chi-Squared test

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Appendix A

A. Shift job titles with their job descriptions:

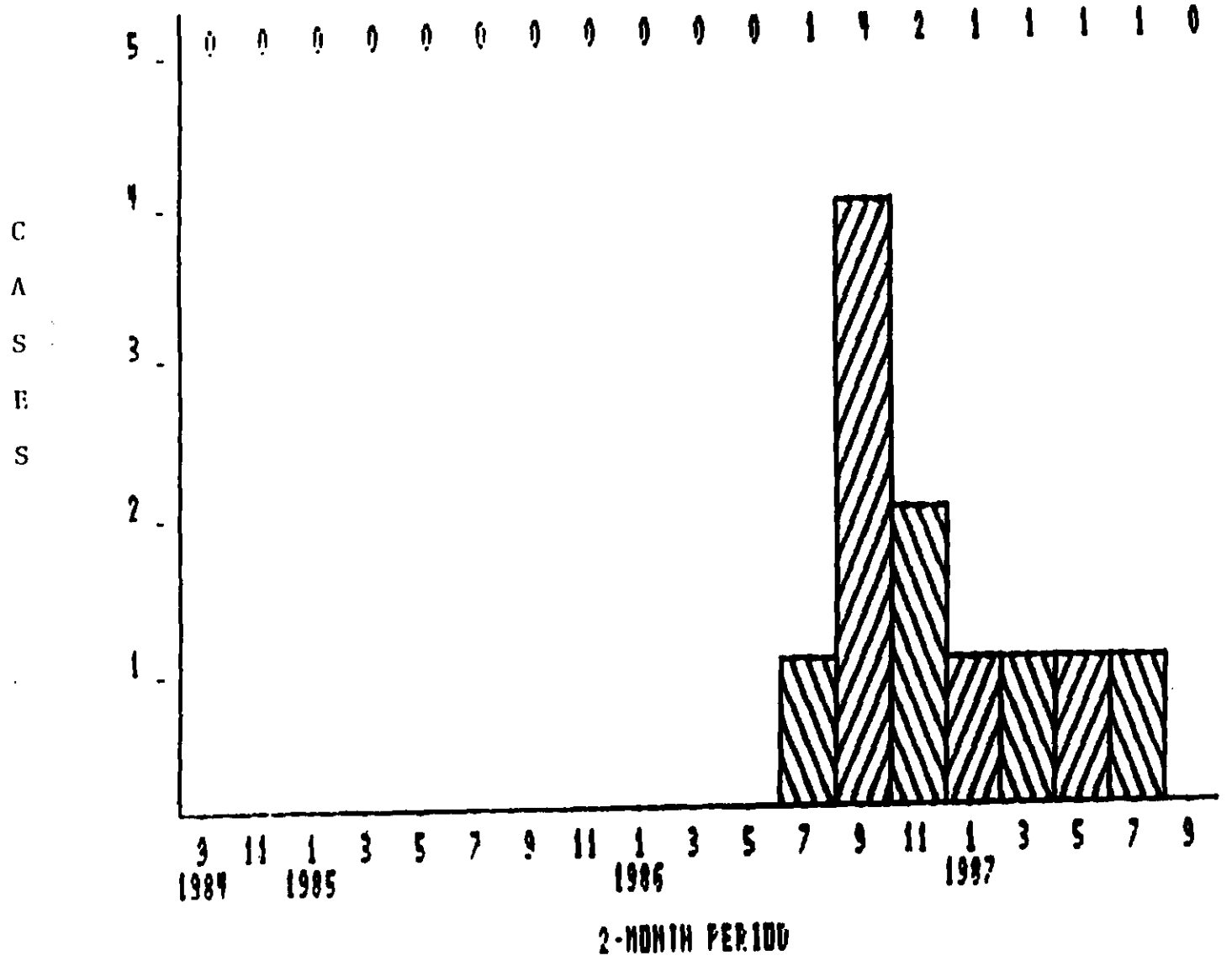
Mobile Equipment Operators (3) - transporting, cutting and loading the logs into the hot ponds.
Log Retrieval (1) - Once inside the plant, removing the logs from the hot ponds.
Debarker (1) - controls the machine which strip the bark off the logs.
Waferizer (1) - controls the machine which cuts the wood into wafers.
Knife grinder (1) - sharpens the knives which cut the wood into wafers.
Dryer Operator (1) - controls flow of the wafers into the dryer and blenders.
Line Technician (1) - trouble shoots the proccess from the blenders until the wafers are pressed into boards.
Press Operator (1) - controls the flow of boards into and out of the press.
Board Grader (1) - trims the edges of the newly formed boards as they come out of the press.
Trucker/Straper (1) - stacks, paints and prepares the boards for storage.
Production Electrician (1) - trouble shoots the whole plant for electrical problems, but spends most of the day around the press area.
Production Maintenance (1) - trouble shoots the whole plant.
Green End Relief (1) - janitorial services for the whole plant, but spends a large share of the day sweeping up the accumulated dust under the press area.
Utility (1) - trouble shoots the whole plant.
EFB Konus (1) - responsible for operating the furnaces which provide the electricity and heat for the plant.
Supervisor (1) - management responsible for that shift.

B Permanent day job titles with their job descriptions:

Plant Manager (1) - overall plant operations
Secretary (3) - office clerical responsibilities
Purchasing Agent (1) - buying and receiving of raw materials
Laboratory Technician (1) - checks for quality control of the product
Technical Director (1) - maintains production flow
Production Superintendent (1) - oversees the production process
Maintenance Superintendent (1) -oversees the maintenance process
Millwrights (4) - responsible for the electrical systems in the plant
Yard Leadman (1) - maintains the flow of logs outside the plant
Mobile Equipment Mechanics (2) - maintenance of the yard vehicles
Mobile Equipment Operators (2) - operates the yard vehicles
Tongue and Groove Operators (3) - puts tongues and grooves on the edges of the finished boards.
Warehouseman (2) - transports the finished boards throughout the plant
Plant Oiler (1) - oils the machinery
Dryer Utility Operator (1) - assists the dryer operator
EFB Konus Assistant (1) - Assists the EFB Konus operator.

FIGURE 1

Occupational Asthma Cases
HETA 87-099 Louisiana-Pacific, Montrose, Colorado



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Appendix B

Analytical Method for Isocyante Group (MDHS 25)

The impinger samples were analyzed for 4,4'-methylenediphenyl isocyanate (MDI) and polymethylenepolyphenyl isocyanate (PMPI) using identification and quantitation techniques described in Great Britain's Health Safety Executive Method MDHS 25 (March 1987) for isocyanates, with the following modifications.

The samples were stored in glass scintillation vials in the refrigerator for 11 days before they were acetylated with acetic anhydride and the toluene evaporated on a hotplate (60°C) and under a stream of nitrogen. The dry samples were then stored in the refrigerator for 11 weeks.

The samples were analyzed using the HPLC conditions described in Method MDHS 25, except that the samples were acetylated before evaporation of the toluene, the sample residues were dissolved in 5 mL of methanol instead of 1 mL of acetonitrile, the mobile phase was 67% acetonitrile and 33% sodium acetate buffer, and the flowrate was 1mL/min rather than 2 mL/min. The analysis of the bulk sample and the impinger samples indicated that two compounds were ureas, one of which was the MDI urea. Therefore, only one polyisocyanate compound was observed in the samples. Under these conditions, the capacity factor (k') for MDI urea was 2.2 and 3.7 for the PMPI urea. Some samples were cloudy and contained visible particulate after addition of the methanol. These samples were filtered wtih Gelman Acro discs to remove the particulate.

Standard solutions of MDI urea in methanol were used to generate the calibration curve for the electrochemical detector. This curve was used to determine the concentration of MDI urea and PMPI urea in the samples. The responses of the ultraviolet and electrochemical detectors to the MDI urea in the standards were used to determine the value of the ratio used for identification of the polyisocyanate ureas.

The LOQ for these samples as determined from the MDI urea calibration curve was estimated to be 0.0023 umol of isocyanate group per sample and the LOD was 0.00069 umol of isocyanate group per sample.

Before the analysis of the samples was undertaken, an evaluation of Method MDHS 25 was done using the bulk, MF184, which had been sent with the samples. The results from these experiments suggest that the estimate of polymethylenepolyphenyl isocyanate using Method MDHS 25 may be low.