The Evaluation Of Employee Exposure To Isocyanates During A Painting/Sealing Process At An Airline Maintenance Facility

by:

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ABSTRACT

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The Evaluation of Employee Exposure to Isocyanates During a Painting/Sealing Process at an Airline Maintenance Facility

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Exposure levels to methylene biphenyl isocyanate (MDI) and toluene diisocyanate (TDI) were quantified using industrial hygiene monitoring for two groups of aircraft maintenance employees. Results indicated levels between 0.18 and 0.24 parts per billion (ppb) for one group and were not detectable for the other group.

Literature review highlighted past studies showing negative health affects, including occupational asthma and several other respiratory system problems in hypersensitive individuals working in various industries.

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CHAPTER I
Statement of the Problem

Introduction

Numerous aircraft maintenance related activities require the use of products that contain isocyanates. For example, in the machine shop a process requires metal deposition to the surface of a breaking mechanism that has fallen below tolerance. The newly deposited metal requires painting and sealing. Aircraft manufactures such as Airbus and Boeing require specific products be used. The specific product used in this painting and sealing operation contains methylene bisphenyl isocyanate (MDI).

Another process in the hydraulics shop requires 747 and A320 generator housings be heat sealed after repair and immediately repainted and sealed. The product prescribed for this process contains toluene diisocyanate (TDI).

The airline at which this study was completed has not experienced any losses due to isocyanate sensizitation, but realizes the potential for loss and has devoted a great deal of effort to maintain it's current level of losses. The completion of this study is just one of those efforts.

This is an important topic because over exposure to one of these variations of isocyanates can cause serious health problems and financial loss to all parties concerned. It is essential to prevent or reduce employees' and the companies' losses due to hazardous conditions and acts.

Purpose of the Study

The Purpose of this study is to describe the level of risk associated with isocyanate exposure as measured by Industrial Hygiene personal air monitoring for aircraft mechanics working in a painting/sealing process.

Goals of the Study

This study focuses on the following objectives:

1.0 To determine the negative health effects related to isocyanate exposure.

2.0 Determine the current level of employee exposure to isocyanates.

2.1 Determine if exposure to levels below the government and industry recommended standards may still result in negative health effects.

Background and Significance

Isocyanates are characterized by the N=C=O group that contains two double bonds and exhibits strong chemical reactivity. There are many different prefixes for the term isocyanate that will come up in this paper. However, they are all variations of the same base functional group N=C=O. However, they do exhibit unique properties.

On the night of December 2 and 3, 1984, nearly forty metric tons of methyl isocyanate (MIC) were released from the Union Carbide pesticide plant at Bhopal, India. Over 3000 people residing in areas adjacent to the plant died of

pulmonary edema within three days. The Bhopal accident is the world's worst industrial disaster (Varma and Guest, 1993).

Employees at an airline maintenance facility expressed their concern about working with a product they had found to contain isocyanates. Members of the union-run safety committee and the corporate safety and health department immediately began to investigate the issue. The ensuing investigation would become the basis for this study.

Isocyanates are a key factor in the production of polyurethane's. Isocyanates are combined with a hydroxyl (OH) through polymerization. Polyurethane's are used in numerous products. Including flexible foam products used in furniture and bedding, rigid foams for various insulating processes, automotive applications, specialized paints and sealants used on products ranging from wood to metal.

The worldwide production of isocyanates is about 5 million tons, with approximately 500,000 exposed subjects (Kampen, Mergert, and Baur, 2000).

The most relevant isocyanate products in addition to MIC are; hexamethylene diisocyanate (HDI), toluene diisocyanate (TDI), and 4,4'-diphenylmethane diisocyanate (MDI) (Raulf-Heimsoth and Baur, 1998). MIC is primarily used in pesticide production. HDI is mostly used in the production of polyurethane paints. TDI and MDI are mainly used in the production of rigid and flexible foams as well as rubbery plastics, but they are used in paints as well.

Previous studies have linked isocyanates to occupational asthma, bronchial asthma, bronchitis, conjunctivitis, dermatitis, and sensitization.

The previous listed health problems and illnesses when occurring in the workplace mean financial losses to the company. These types of health problems are long-term and are not curable, therefore, not only will they result in financial loss, but long-term financial losses.

The uses of isocyanates are not industry specific. Isocyanates play an important part in many aspects of society today.

The benefits of doing this study are obvious. If the results show that employee exposure is at an acceptable level (to be defined later), the benefit is knowing that employees are not working in an uncontrolled environment. High exposure levels will result in the implementation of either engineering or administrative controls.

Limitations of the Study

The information and recommendations contained in this study are based on information and data available at the time of the study. The study is limited to selected employees in a specific aircraft maintenance facility and may not be applicable to employees in other maintenance settings.

Definition of Terms

≤: Less than.

>: Greater than.

MDI: Methylene Bisphenyl Isocyanate

TDI: Toluene Diisocyanate

ND: None detected.

ACGIH TLV-TWA: Threshold Limit Value, 8-hour time-weighted average (TWA) recommended by the American Conference of Governmental Industrial Hygienists.

OSHA PEL: Permissible Exposure Limit, 8-hour time-weighted average, mandated by the Federal Occupational Safety and Health Administration.

CHAPTER II
Review of Literature

Introduction

The review of literature describes isocyanates as a chemical family and show how and where they are used in industry. The main area of focus is previous studies and previous reviews of literature showing various negative health effects related to the use of isocyanates. The review also summarizes previous industrial hygiene sampling results. The current government and industry permissible exposure levels are also presented in detail.

Background

Isocyanate is the general term given to a group of chemicals characterized by the highly reactive N=C=O group. Isocyanates are chemical intermediates in the manufacture of polyurethane foam, plastics, adhesives, coating materials, pesticides, and paints. The most commonly used isocyanates are toluene diisocyanate (TDI), hexylmethylene diisocyanate (HDI), diphenylmethane 4,4'-diisocyanate (MDI), and Methyl isocyanate (MIC)(Varma and Guest, 1993). More than 90% of the total world production of isocyanates is accounted for by MDI and TDI (Ulrich, 1996).

Polyurethane's were invented in Leverkusen, Germany, 1935. TDI and HDI became major commercial diisocyanates.

The following timeline lists some highlights in polyurethane development (Ulrich, 1996).

1950-Cast polyurethane elastomers introduced

1956- Du Pont introduced polyether polyols

1959- Polymeric MDI was introduced

1960s- Polyurethane flexible foam in landing pads of the lunar module touched the surface of the moon.

1970s- Thermoplastic polyurethane elastomers were developed

1980s- A polyurethane artificial heart was developed at the University of Utah

1983- First fully plastic commercial automobile body (Pontiac Fiero) appeared on the market in the United States

1984-2001- Used in products such as polyurethane foam, insulation materials, surface coatings, car seats, furniture, foam mattresses, under-carpet padding, packaging materials, laminated fabrics, and adhesives

Isocyanates chemically react to form solid polyurethane foam or a plastic coating. The finished product is almost non-toxic, unless it is burned or caused to generate a dust. Isocyanates are also used in a liquid form or dissolved in other liquids. TDI and HDI are especially hazardous, because they can evaporate quickly to produce harmful levels in the air (California Department of Health, online).

Methods of Exposure

Exposure to isocyanates may occur during their production from primary amines and phosgene, in their transport, in the production of polyurethane products, in the application of isocyanate-containing paints and varnishes, and as a result of the combustion of isocyanate-containing materials (Musk, Peters and Wegman, 1988).

Dermal Exposure

Several studies have reported that dermal contact with isocyanates can induce respiratory symptoms in animals, indicating that isocyanates may be dermally absorbed. Biological monitoring via urine samples were taken in a study involving five motor vehicle repair shops. The study showed that workers can absorb isocyanates during spraying operations despite wearing full-face air fed respirators and using ventilated spray booths or extracted work areas. The evidence of exposure despite precautions highlights the continued need to improve control procedures (Williams, Jones, and Cocker, 1999). Employees in the airline maintenance industry use a thin liquid that is applied to various parts with a paintbrush, which almost completely eliminates dermal exposure. All fuselage-painting actives at Northwest Airlines have been contracted to a painting contractor according to Troy Schon, Corporate Safety and Health (Personal communication, May 14, 2001).

Toxicity

The earliest documented toxicity of isocyanates in humans deals with effect on firefighters exposed to liquid and fumes during a fire at a polyurethane foam manufacturing plant in England. Respiratory, ophthalmic, and neurological symptoms occurred either immediately or within three days. The majority of cases cleared up within a week, but about one third of those exposed experienced increased incidence of the symptoms over the next several years. Cough, chest tightness, breathlessness, nausea, vomiting, and gastric pains occur frequently in firefighters exposed to smoke from burning polyurethane (Varma and Guest, 1993).

Respiratory Effects

Asthma resulting from TDI exposure in a polyurethane plastic manufacturing plant was reported in 1951 and again in 1955. The process of "sensitization" or hypersensitivity to isocyanates was recognized when asthma induced by TDI was noted to improve with removal from exposure, and return in the form of an "acute attack" upon renewed exposure (Musk et al, 1988).

Isocyanates induce sensitization and stimulate production of antibodies to protein-isocyanate conjugates (Varma and Guest, 1993).
Hypersensitivity is classified by an exaggerated response to an antigen; prior exposure to the antigen (sensitization) is required for response. The antigen triggers release of histamine, which causes bronchioconstriction (asthma), itching sensation, edema, and drop in blood pressure (anaphylactic shock).

Isocyanates are known as a sensitizing chemical, which causes occupational asthma (Van Kampen, Mergert, and Baur, 2000).

Numerous studies have shown the TDI workers experience changes in lung function (airflow obstruction) during the course of a work shift. The degree of this acute change is correlated with long-term changes in pulmonary function and also correlates with the severity of exposure (Musk et al., 1988).

The typical dose-response relationship applies to employees involved with isocyanate products, unless they have been sensitized, which requires a much smaller dose to cause the effect.

Neurological Effects

Neurological complications (euphoria, ataxia, and loss of consciousness) have been described as occurring immediately after a single severe exposure to TDI. Headache, difficulty in concentration, poor memory, and confusion may persist for up to four years (Musk et al., 1988).

Relevant Studies

A comprehensive survey summarizing industrial hygiene monitoring of 457 samples collected from 47 different operations using HDI based polyisocyanate was divided into two groups; non-spray situations and spray situations. Only 5 of 85 samples taken in non-spray situations showed any detectable level of isocyanate. The survey did show that there is potential for overexposure of the unprotected worker (Myer, O'Block and Dharmarajan,

1993). Another study was completed on construction workers during the process of insulating buildings with sprayed polyurethane foam. The study concluded that while the work was completed outdoors there was not an exposure problem, but indoors there was a possibility of exposure (Crespo and Galan, 1999). The majority of studies completed dealing with isocyanate exposure seems indicate inhalation as the primary route of exposure. The problem with all of the previously mentioned studies is that even though results show low levels of exposure there are still symptoms of exposure.

The exposure to isocyanates is not limited to industrial exposures. The management of a large metropolitan school district contacted NIOSH for assistance after a university study documented asthma in 13 of approximately 85 staff members from a middle school in 1994. The report further concluded that as many as 34 staff members may be asthmatic. Investigation revealed large quantities of polyurethane foams and isocyanate-coating materials had recently been applied to the school roof on several occasions (Center for Disease control, 1996). The relevance of the case studies listed above is evident in the discrepancy in exposure levels and symptoms. Air monitoring alone may not be enough evidence to make a conclusion on employee exposure levels to isocyanates.

Regulations

Some countries are beginning to implement steps to reduce employee exposure to isocyanates. Since, 1979, Ontario government regulations require

that companies whose workers have potential exposure to isocyanates must have a medical surveillance program, including a screening questionnaire at time of hire and after every six months (Kraw and Tarlo, 1998). Worldwide, there is a rigorous scientific activity concerning the further development of work safety regulations involving airway-sensitizing substances. The European Union has established a code for several occupational substances, now labeled R 42 ("may cause sensitization by inhalation"); isocyanates are one of those substances. This label is commonly combined with the label R 43 ("may cause sensitization by skin contact")(Van Kapen et al, 2000). Currently the United States does not require a similar label. The United States does have several standards concerning isocyanate exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a 0.005 ppm (0.005ppm = 5ppb = 0.034mg/$m^{3)}$ time-weighted average (TWA) threshold limit value (TLV) for HDI. The Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL) for both TDI and MDI are 0.020ppm. The National Institute of Safety and Health (NIOSH) recommended exposure limit (REL) for MDI has been set at 0.005ppm (Center for Disease Control, 1996). These limits were intended to prevent acute and chronic irritation and sensitization of workers but not to prevent responses in workers who are already sensitized. Available data do not indicate a concentration at which TDI vapor fails to produce adverse reactions in sensitized persons.

Airline Industry Controls

The aircraft maintenance industry has actively put control measures in place to prevent isocyanate related losses, including, product substitution and periodic air monitoring. One of the problems risk control manager's face are the strict regulations mandated by the Federal Aviation Administration (FAA). The FAA requires that companies who produce aircraft, aircraft engines, and aircraft parts use products they [FAA] determine to be “flight worthy." Risk control managers must work closely with chemical producers and aircraft manufactures to determine acceptable products that satisfy the airline maintenance industry as well as its’ regulators. Currently it is not possible to completely remove isocyanates from use in the airline industry, but they can be significantly reduced. This has been achieved through product substitution, periodical air monitoring and proactive management techniques according to John McMurtry, Corporate Safety and Health Manager (Personal communication, May 14, 2001).

Summary

A review of research literature indicates that negative health effects related to isocyanate exposure may occur at levels below the current standards. Isocyanates have been proven to cause sensitization with the primary effect being occupational asthma and other similar respiratory effects.

This review provided a guideline concerning the industrial and domestic uses of isocyanates. Although no research was found specifically concerning

the airline maintenance industry, many closely related applications were evaluated.

CHAPTER III
Methodology

Introduction

The potential employee exposures to methylene bisphenyl isocyanate (MDI) and Toluene Diisocyanate (TDI) are quantified using industrial hygiene sampling. The Wisconsin State Laboratory of Hygiene at the Wisconsin Occupational Health Laboratory was contacted to determine the proper sampling protocol. The protocol was reviewed by the researcher and discussed with the companies' certified industrial hygienist. Employees were contacted several weeks prior to sampling to explain the sampling method and what would be required of them. Their respective managers were also contacted to ensure the required process was available on the day the sampling was to be performed.

General Selection

The employees working in the hydraulics shop were sampled while performing the painting/sealing of aircraft generator housings. This process includes placing several generators on a cart, wheeling them to the exhaust booth and painting them using a standard paintbrush.

The employees working in the machine shop also performed their painting/sealing process in an exhaust booth. Three area samples were taken in proximity to the drying parts.

Specific Sampling Selection

The air sampling test group consisted of four breathing zone air samples taken from mechanics working in the Hydraulics Shop, Additionally, one breathing zone, and three area samples (set up within near proximity of the painting/sealing operation) were taken from mechanics working in the Machine Shop. Although these samples were taken in different shops they represent similar processes required on different parts of the aircraft. A mechanic is required to paint/seal several parts at a time, this is a limited operation and is only required twice a week.

Instrumentation

MSA ESCORT ELF sampling pumps were used to collect all air samples in this study. A BIOS DRY CAL DC-1 pump calibrator was used to calibrate each pump prior to and after sampling. Sampling media included, three piece cassettes containing glass fiber filters treated with 1-(2-Pyridyl) piperazine (PP), PP forms a derivative with isocyanate compounds, which stabilizes the collected sample for shipment and analysis, and a desorbing solution consisting of 90% acetonitrile/ 10% dimethylsulfoxide. The Wisconsin Occupational Health Laboratory provided all sampling media.

Procedures

The Wisconsin Occupational Health Laboratory (WOHL) in accordance with the Occupational Safety and Health Administrations (OSHA) method for

isocyanate sampling prescribed the following procedures. The MSA ESCORT ELF personal sampling pumps were calibrated to a flow rate of one liter per minute using the BIOS DRY CAL DC-1 pump calibrator prior to sampling. Calibration was always done with a filter cassette in line. Upon arrival to the desired maintenance shop a sampling pump and filter was attached to a selected subject. The filter was clipped to the subject's shirt lapel to as closely represent the breathing zone as possible. The sampling pump ran for exactly fifteen minutes while the subject was completing the painting/sealing process. The area samples were completed in the same manner except the pump and filter were placed in close proximity to the part being painted/sealed instead of on the subject. After the fifteen minutes had expired the filter was removed from the cassette and placed into a vial of the desorbing solution. The vials were sealed, properly labeled, and mailed to the WOHL for analysis. The sampling pumps were then checked for proper calibration after the sampling process to ensure validity of the sample volumes.

Sampling Analysis

All air samples were analyzed by WOHL using method LC48.mth [WHOL internal numbering system] based on OSHA protocol methods #42 and #47. The Wisconsin Occupational Health Laboratory is an American Industrial Hygiene Association (AIHA) accredited laboratory. Once the results were returned the values needed to be extrapolated from the fifteen-minute samples to an eight-hour workday, all standards were expressed in terms of an eight-

hour average. The air monitoring results are summarized in Table 4-1 and 4-2 and are compared against the OSHA PEL and ACGIH TLV exposure limits.

CHAPTER IV
Data Analysis

Introduction

This chapter outlines the completed air sampling results for methylene bisphenyl isocyanate (MDI) and toluene diisocyanate (TDI) conducted on July 20, 2000 and August 16, 2000 respectively and compares the results to the OSHA PEL and ACHIH TLV exposure limits.

Isocyanate Levels Detected

The first isocyanate air sampling was performed during the first shift (7 am to 3 p.m.) on July 20, 2000 in the plasma spray booth in the Machine Shop at Building B. The specific form of isocyanate sampled was methylene bisphenyl isocyanate (MDI). Previous employee contact highlighted the nature of the testing. The employees were asked to save multiple units that required the prescribed sealing process for the test day. Eye protection and half mask respirators with HEPA filters were worn during this operation. Half mask respirators with HEPA filters are prescribed for another process employees complete in the area. The sampled employees chose to wear the same protection. [Note: An Organic Vapor filter would be the necessary filter for isocyanates, but because of company policy respirators are only allowed in areas that have been shown to need them. This particular area only requires the use of a HEPA filter.]

Considering the results from the air monitoring, reported in Table 4.1 below, none of the samples were above the OSHA PEL or the ACGIH TLV-TWA. In fact, the results were all in the none detected (ND) range (Appendix A).

Table 4.1

Summary of Personal Air Sampling for Methylene Bisphenyl Isocyanate
At
Airline Maintenance Facility
Machine Shop
Minneapolis, Minnesota

Sampling Date: July 20, 2000

Sample Number	Sample Description	Sample Volume (Liters)	(MDI) (ppb)
90	Brake Assy. Paint	16.71	ND <0.058
91	Area Sample Brake Assy. Paint	16.22	ND <0.060
92	Area Sample Brake Assy. Paint	15.11	ND <0.065
Blank	Field Blank	--	ND

Notes

ACGIH TLV-TWA= 5ppb
OSHA PEL= 20ppb

The second isocyanate air sampling was performed during the first shift on August 16, 2000 in the Hydraulics Shop of Building B. The specific form of isocyanate sampled was toluene diisocyanate (TDI). Again, previous contact informed employees of the exact testing procedure and allowed ample time to accumulate enough units so the proper testing could be completed. No personal

protective equipment was worn during this process. It is company policy to only allow respirators to be used if they are necessary.

Considering the results from the air monitoring, reported in Table 4.2 below, none of the four samples were above the OSHA PEL or the ACGIH TLV-TWA. The highest recorded sample was more than 20 times below the TLV (Appendix B).

Table 4.2

Summary of Personal Air Sampling for Toluene Diisocyanate
At
Airline Maintenance Facility
Hydraulics Shop
Minneapolis, Minnesota

Sampling Date: August 16, 2000

Sample Number	Sample Description	Sample Volume (Liters)	(TDI) (ppb)
70	747 Generator Paint	15.8	0.24
71	A320 Housing Paint	19.8	0.18
72	Paint	15.2	ND <0.092
73	Paint	15.2	0.24
Blank	Field Blank	--	ND

Notes

ACGIH TLV-TWA= 5ppb
OSHA PEL= 20ppb

Chapter four outlined the results of the air monitoring completed for methylene bisphenyl isocyanate (MDI) and toluene diisocyanate (TDI) in the machine and machine shops respectively. The protocol outlined in chapter

three was used for both sets of samples. The results revealed none detectable isocyanate levels for MDI and levels ranging from 0.18 to 0.24 parts per billion (ppb) for TDI. The ACGIH TLV is 5ppb and the OSHA PEL is 20ppb for both MDI and TDI. Several conclusions can be drawn from the results, leading to the appropriate recommendations that are beneficial to the company and employees.

CHAPTER V
Conclusions & Recommandations

Introduction

The purpose of this study was to describe the level of risk associated with isocyanate exposure as measured by industrial hygiene personal air monitoring for aircraft mechanics working in a painting/sealing process.

The goals of the study were to:

1.0 Determine the negative health effects related to isocyanate exposure.

2.0 Determine the current level of isocyanate to which employees are exposed

2.1 Determine if exposure to levels below the government and industry recommended standards might result in negative health effects.

Conclusions

Upon completion of this study, the following conclusions were drawn from the results.

1.0 Health effects related to isocyanates exposure include occupational asthma, respiratory problems, neurological problems, heart attacks, and can irritate human eyes, nose, throat, skin, and even death.

2.0 Isocyanate measurements are shown in Tables 4.1 and 4.2.

3.0 Isocyanate levels measured were all significantly below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL) and the American Conference of Governmental

Industrial Hygienists (ACGIH) Threshold Limit Values (TLV). The highest recorded level was 0.24 ppb while the ACHIH TLV-TWA is set at 5.0 ppb.

The small exposure levels do not simply indicate that there is no exposure to loss. Studies indicate that sensitive individuals may still experience negative health affects including, occupational asthma and other respiratory system problems due to minimal exposure.

Recommendations

After analyzing the results and drawing conclusions from them, several recommendations were developed related to this study.

1. The risk would be eliminated if the isocyanate-containing product were replaced with one, which did not contain isocyanates, but currently no such product is available.
2. From a pure risk control perspective, the most viable course of action is to make sure employees and local management are aware of the potential problems and utilize the current state of the art engineering in personal protective equipment, ventilation and administrative controls
3. Continued air monitoring should be performed to be certain exposure levels are not increasing and if an increased workload should arise.

APPENDIX A

To: Jim Kraft, Hydraulics Shop Manager

From: Ryan Hanson, Corporate Safety and Health

Date: August 25, 2000

Subject: MSPB Machine Shop Air Monitoring

Attached you will find the results of the air monitoring for methylene bisphenyl isocyanate (MDI) completed July 20, 2000, in the MSPB machine shop, during the brake assembly painting process in the plasma spray booth area.

All sample results were well below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV).

Isocyanates can cause asthma and other lung problems, even at minimal exposure levels. Isocyanates can also irritate human eyes, nose, throat and skin. The product used in this facility contains the smallest amount of isocyanates possible, however, hypersensitive individuals may be affected. Please report any symptoms to management immediately.

Please share this information with your employees and document that you have done so. If you have any questions, please contact me a 612-700-4681.

cc: John McMurtry
Rick Luth
Tom Griffith
Sandea O'Bryant
Charlie Gumbert

APPENDIX B

To: Warren Warmka, Hydraulics Shop Manager

From: Ryan Hanson, Corporate Safety and Health

Date: September 18, 2000

Subject: MSPB Hydraulics Shop Air Monitoring

Attached you will find the results of the air monitoring for Toluene Diisocyanate (TDI) completed August 16, 2000, in the MSPB hydraulics shop, during the painting process at the east end of the hydraulics shop.

All sample results were well below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).

Isocyanates can cause asthma and other lung problems, even at minimal exposure levels. Isocyanates can also irritate human eyes, nose, throat and skin. The product used in this facility contains the smallest amount of isocyanates possible, however, hypersensitive individuals may be affected. Please report any symptoms to management immediately.

Please share this information with your employees and document that you have done so. If you have any questions, please contact me a 612-700-4681.

cc: John McMurtry
Rick Luth
Tom Griffith
Sandea O'Bryant
Charlie Gumbert

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