Case Report

Asthma Death After Spraying Polyurethane Truck Bedliner

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Background *Isocyanate exposure is the most common cause of work-related asthma. In 2003, a male in his mid-40s died of an acute asthmatic reaction approximately 1 hr after he sprayed the inside of a cargo van with an isocyanate-containing truck bedliner. This is the first reported death attributable to this type of isocyanate application.*

Methods *The Michigan Fatality Assessment and Control Evaluation (MIFACE) program investigated this work-related fatality to identify the factors that contributed to his death. The investigation included site visits, personal interviews, and a review of pertinent documents.*

Results *Factors contributing to his death included: the vehicle type; lack of engineering controls; lack of a company safety and health program, including a personal protective equipment program, medical monitoring, and employee training; and a lack of recognition of work-relatedness of the deceased's respiratory problems by a health care provider.*

Conclusions *This work-related fatality investigation demonstrates the need for isocyanate manufacturers/formulators to inform end users of their products of appropriate health and safety work practices associated with new technologies. In addition, health care providers need more education and assistance to recognize and manage work-related asthma.* Am. J. Ind. Med. 48:78–84, 2005. *© 2005 Wiley-Liss, Inc.*

KEY WORDS: occupational asthma; acute asthma fatality; MDI; work-related death; sprayed-on truck bedliner

INTRODUCTION

Spray-on truck bedliners are a new application of isocyanates. Spray-on bedliners have gained popularity in the last 5–6 years due to their protective properties, such as abrasion resistance, insulation, and a watertight seal to the bed of the truck. Spray-on truck bedliners commonly use a two-component system, polyurethane (isocyanate and polyol) or polyurea (isocyanate and amine). Component A is the isocyanate component, Component B is either the polyol (polyurethane) or amine (polyurea) component. The application is performed indoors because no moisture can contact the bedliner during application. Typically, small shops perform the application of the spray-on bedliner as an aftermarket vehicle accessory. Isocyanates are the most common cause of work-related asthma [Gannon and Burge, 1993; Rosenman et al., 1997; Mapp et al., 1999]. Methylene diphenyldiisocyanate, the form of isocyanate used in bedliners, though less volatile than some of the other commonly used isocyanates, has been repeatedly reported to cause

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asthma including one asthma death in a foundry worker [Carino et al., 1997].

Michigan is one of 15 states receiving funds to conduct work-related fatality investigations by the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) program. The goal of the FACE programs is to prevent future occupational fatalities by identifying and investigating workplace occupational fatalities and determining the factors that contribute to the deaths. This information is used to develop prevention strategies that are widely disseminated to employers, industry trade groups, workers, labor unions, and government agencies.

In 2003, a worker died after he sprayed a polyurethane truck bedliner on the floor and partway up the inside walls of a van. This is the first death attributable to isocyanate in the spray-on bedliner industry. This report presents the results of the Michigan Fatality Assessment and Control Evaluation (MIFACE) investigation of this work-related death and the subsequent preventive recommendations that were developed.

MATERIALS AND METHODS

The MIFACE program was notified about the deceased by the county medical examiner 1 day after he died at work. MIFACE received subsequent notification from the Michigan Occupational Safety and Health Administration (MIOSHA) personnel that they would be conducting an enforcement inspection. Approximately 3 months after the incident, a MIFACE researcher interviewed the owner of the vehicle detailing facility at his primary business location; the owner had other business interests and this was his only facility that applied spray-on bedliners. The company owner and MIFACE researcher then traveled to the site of the vehicle detailing facility where the death occurred. The auto detailing facility closed after the death. The material safety data sheets (MSDSs) for the components of the isocyanate-based truck bedliner were obtained and pictures were taken of the facility and of the types of personal protective equipment the deceased was thought to have worn during application of the spray-on bedliner. The deceased's ex-wife, also a coworker, and one of his brothers were interviewed. The deceased's second brother, a primary care physician, declined to be interviewed. Finally, the autopsy report, death certificate, MSDSs, and the MIOSHA citations were reviewed.

MIFACE visited two additional bedliner applicators (Company A and B) located in Michigan to compare work practices and the configuration of area where the bedliner would be applied. The two additional facilities were chosen because they were each franchised to apply the same brand of bedliner as the deceased, their proximity to Michigan State University, and the facility's willingness to participate in the MIFACE study. Company A and B were comparable in the number of employees to the facility where the deceased worked. Air monitoring at these facilities to determine isocyanate exposure was not performed. Michigan State University's Institutional Review Board approved the research protocol, and all participants gave informed consent.

RESULTS

Case History

A man in his mid-forties who had asthma for 10 years developed an acute asthmatic attack at work. On the morning he died, he sent the individual who helped to prepare the van for spraying to do something else while he applied a polyurethane spray-on bedliner inside a van. The deceased used a positive pressure half-mask respirator that supplied fresh air. His helper returned 20 min later to find the work completed, the equipment turned off, and the individual gasping for breath on his knees outside the building. The helper immediately took the individual to an urgent care clinic. The individual collapsed at the door of the urgent care clinic. A nurse at the clinic began CPR. An ambulance arrived 9 min later. Despite attempted resuscitation and transport to a nearby hospital, he was pronounced dead 46 min later. Wheezing was noted on ausculation during bagging. On autopsy, he was found to have mucus in the airways and eosinophils in his bronchial walls and mucosa. He was also noted to have diffuse pulmonary emphysema, numerous macrophages in peribronchial alveoli, and heavy anthracosis. It is possible that his previous diagnosis of ''asthma'' may really have been chronic obstructive pulmonary disease (COPD). There were two possible mechanisms for his death; (1) the isocyanates aggravated his previous lung condition (whether it was asthma or COPD), or (2) he became sensitized to the isocyanate in addition to his previous lung condition. His medical history is consistent with both possibilities. His heart showed coronary arteriosclerosis, calcification, myocardial hypertrophy, and pulmonary fibrosis. Toxicology results indicated that the blood contained pseudoephedrine, dipenhydramine, acetaminophen, and caffeine, none of which were felt to contribute to his death. Toxicology results were negative for ethanol and any illegal drugs. The medical examiners impression was ''Asthmatic reaction due to inhalation of chemicals.''

The deceased had a history of allergies. He had never been hospitalized for his asthma. He had three medical visits in the year prior to his death for: a laceration of his hand; low back pain; and symptoms of shortness of breath and cough. The medical record from that last encounter, 7 months before he died, indicated he inhaled ''chemicals'' 2 days prior at work while working with a bedliner and was not wearing a breathing pack. He was exposed for 10 min, and within 10–

15 min he could not catch his breath. He received a nebulizer treatment. He was prescribed 40-mg prednisone and antibiotics for 7 days, cough syrup with codeine and a Proventil inhaler.

His regular asthma medication consisted only of an albuterol inhaler. He had never had pulmonary function testing. He had smoked two packs of cigarettes per day since his teens but was trying to taper down. The deceased had worked as the manager at a small auto detailing facility, which included himself and three other employees. The shop did vehicle detailing, rustproofing, and spray-on truck bedliners. The deceased was the only individual who applied the truck bed lining but the others would assist him in the preparation and set-up work. The deceased had previously worked at a vehicle paint repair and detailing business, but no information on the type of paint used at his previous job was available. After he died, his coworkers mentioned that he had difficulty breathing after previous spray liner applications and that the deceased sat in his vehicle with the air blowing in his face to get ''fresh air'' or took a walk after spraying the product. There was no history of spills of the isocyanate material. The deceased lived in the basement beneath the customer reception area of his workplace.

Workplace

Four individuals worked at the vehicle detailing facility; a receptionist (the deceased's ex-wife) who worked in the customer reception area, the deceased, and two additional employees who performed vehicle preparation work for the spray-on bedliner application as well as other accessorizing activities, such as vehicle undercoating and rustproofing.

The building had two areas, the general shop area and a customer reception area. The shop area was approximately 40 ft^2 and 12-ft tall. On the west wall there was an overhead door that provided shop access for the vehicles. On the north wall was a pedestrian door, which was adjacent to the undercoating and rustproofing area. The undercoating/rustproofing area had two curtains that could be pulled to enclose the spray area to limit product overspray into the general shop area. Posted on the north wall was the daily startup procedure for the truck bedliner product that detailed the steps to be taken to prepare the spray equipment prior to spraying the bedliner. Next to the east wall was the bedliner spray machine components: 55-gallon isocyanate drum, a container holding polyol/dye mixture, and the pump. A natural gas heater was mounted high on the south wall to provide heat in the winter. A pedestrian door on the south wall permitted entry into the customer reception area.

Bedliner application was performed in the general shop area and was generally performed outside of business hours due to the ''smell.'' The shop area did not have local exhaust ventilation; it was provided by leaving the overhead door raised a few feet and by leaving the pedestrian door open in the rustproofing area while performing the spray-on bedliner application. The employees placed a box fan at this open pedestrian door to assist air movement.

The customer reception area had a storage room where the deceased kept his personal protective equipment, both new and used. A door in the customer reception area led to the basement where the deceased had lived. The basement apartment had no windows. The apartment appeared to be adequately maintained and his ex-wife said he kept his place ''pretty clean.''

The owner paid the employees on a ''per vehicle'' application of the truck bedliner. The frequency of spray-on bedliner application depended upon the orders received and varied from several to no orders per week.

The door to the reception area was closed during application of the spray-on liner if application was performed during company business hours. Only the deceased was permitted in the general shop area when application of the spray-on liner was performed; all other employees were instructed to leave the spray area.

Spray-On Bedliner Application

The isocyanate and polyol were delivered to the facility in 55-gallon drums and stored in the general shop area. The polyol and black dye were manually added to a separate container. The isocyanate and polyol/dye mixture were pumped via separate hoses to a spray gun where they were mixed forming polyurethane and applied to the prepared truck bed under low pressure.

The van was prepared for application of the bedliner the day before the incident occurred. The van area to be sprayed was cleaned, taped/masked to prevent product overspray, hand and power sanded to ensure product adhesion, and then a final clean of the application area was performed. On the day of the incident, the deceased and his helper arrived at approximately 6:30 am. They set up the supplied air system for the respirator and followed the start-up procedure for the bedliner product.

Prior to spraying the liner, the deceased donned his personal protective equipment, which included a positive-pressure, tight-fitting, half-mask supplied-air respirator, a knit ''over-the-head'' cap, a disposable painting hood, and latex gloves. The ambient air pump that supplied air to the half-mask respirator had a high efficiency particulate air (HEPA) filter cartridge. The pump was designed for use with a 40-foot air hose although an 80-foot air hose was attached.

The deceased began the application of the spray-on truck bed liner at approximately 7:00 am. It is unknown *how* the deceased sprayed the inside of the van; whether he crawled in the rear and was in the confined area of the van for most of the spraying time or whether he sprayed most of the van interior while standing on the outside of the van on the shop floor.

The deceased completed the application of the liner and walked to the bedliner mixer to turn off the spray machine. After turning off the spray machine, it appears he walked to the pedestrian door located on the north wall near the rustproofing area. It is unknown where the deceased disconnected his airline from his respirator at his hip; it was found near the pedestrian door. It is also unknown where the deceased took off his respirator. It is thought that he exited the shop through the pedestrian door, and walked outside the building around the north and west walls to the front door of the reception area. His helper found him on his knees with the respirator around his neck.

Facility Safety Program

The company owner had purchased the building and the detailing business a little over a year prior to the incident and did not have a written safety program for this facility. The deceased had received training concerning technical aspects of spray-on bedliner application by the manufacturer of the spray-on truck bedliner; the facility owner did not know if the training included the health and safety aspects related to the isocyanate component of the bedliner. MSDSs for the isocyanate (4,4′-diphenylmethane diisocyanate (4,4′-MDI), 2,4′-diphenylmethane diisocyanate (2,4′-MDI), and modified MDI) and polyol components of the spray-on bedliner were on-site in a MSDS notebook.

Michigan OSHA Citations

The company owner was issued six ''Serious'' citations and five ''Other'' citations as a result of the MIOSHA enforcement inspection, which occurred after the death. The facility had not been previously inspected by MIOSHA. Four of the ''Serious'' citations issued to the owner concerned respiratory protection; the owner was cited for failure to: develop and implement a written respiratory protection program with worksite-specific procedures for employees who are required to wear respiratory protection, provide a medical evaluation, provide an employee fit test, and provide and document employee training regarding respiratory protection prior to using a respirator in the workplace. ''Serious'' citations were also issued for failure to develop, implement, and maintain a hazard communication program and for failure to provide a suitable facility for quick flushing of the eyes within the work area for immediate emergency use where the eyes of an employee may be exposed to injurious corrosive materials. MIOSHA issued the following ''Other'' citations: The owner did not report to MIOSHA orally or in writing within 8 hr after the occurrence of an employment accident or illness which was fatal to one or more employees, the owner did not post the MIOSHA Notice poster in each establishment in a central and conspicuous location; the owner did not provide spray booths or spray rooms to enclose or confine all spray finishing operations; the owner did not verify through a written certification that a workplace hazard assessment had been conducted, and the owner did not verify that each affected employee had received and understood the required training through a written certification that contained all of the following information: the name of each employee trained, the date of training, and the subject of certification.

Factors Contributing to the Death

The investigation of this incident revealed a number of factors that were thought to have contributed to the death.

Vehicle type

This was the first time the deceased had applied the bedliner product to the inside of a cargo van. If the deceased had performed the spraying inside of the van, there would have been confinement of the vapors/aerosols from the spraying that may have increased the deceased's potential exposure to the isocyanate as compared to if he had sprayed a truck bed in the open shop area.

Lack of dedicated spray room and adequate exhaust ventilation

The deceased sprayed the van interior in the general shop area, which had inadequate ventilation. The owner should have provided a spray room or booth equipped with sufficient mechanical exhaust ventilation that had been evaluated to determine its effectiveness and the adequate control of worker exposures.

The two spray-on bedliner companies visited by the MIFACE researcher had dedicated spray areas. Company A had a spray room that was a separate room in the building and was constructed of masonry. Company B had constructed a tarped enclosure within the general shop area using wood framing covered in plastic. A wood door provided access when the tarp was lowered and placed against the vehicle cab. Company A and B had similar exhaust ventilation, a wall fan, in their respective spray rooms. However, neither had evaluated the effectiveness of the exhaust ventilation provided by the fan nor had performed air monitoring.

Lack of comprehensive respiratory protection program

Although the company owner required the deceased to wear a supplied-air respirator while applying the spray-on bedliner, the owner did not have a written respiratory program. The owner did not conduct an exposure assessment to evaluate the respiratory hazard.

The respiratory protection provided to and worn by the deceased may have been inadequate. The ambient air pump, designed for use with a 40-foot airline, was being used with an 80-foot airline. The additional 40 feet of line may have impacted the amount of air that was supplied to the facepiece, thus not providing the expected protection. It is unknown how often the ambient air pump's HEPA filter cartridge was checked and replaced.

The deceased was not properly fitted for the respirator or trained in its use and limitations of use. He had not been fit-tested for the respirator. Also unknown is whether the deceased conducted a user seal check for the respirator on the day of the incident.

The owner did not provide a medical evaluation as required by the respirator standard to determine if the deceased was medically able to wear the respirator and perform work. The deceased, according to the medical examiner's autopsy report, had COPD with emphysema. His medical status may have prohibited him from wearing a respirator and thus performing the spray application.

Similar to the company where the deceased worked, neither Company A nor B had a written respiratory program, evaluated the respiratory hazard(s) in the workplace, evaluated the spray room ventilation, had employees undergo a medical evaluation, fit-tested employees, or had procedures for proper use, storage, cleaning, and inspection of the respirator.

Without evaluation of the respiratory hazards in their respective workplaces, the owner of the facility where the victim worked, and both Company A and B had instituted respiratory protection practices for the steps involved in the application process of the bedliner. The respiratory protection equipment selected may have been inadequate. For example, although Company A required employees to wear a half-mask supplied-air respirator when they re-entered the spray room to remove the taping/masking from the vehicle, the effectiveness of the ventilation in the spray room had not been evaluated and it is unknown whether the level of protection selected was adequate. Similarly, Company B did not evaluate the effectiveness of the ventilation and these employees wore only a dust mask during the removal of the tape and masking material.

Inadequate owner/ employee knowledge

The owner's knowledge of the health hazards of the isocyanate component of the bedliner material was inadequate. The owner failed to recognize that the isocyanate ''smell'' indicated that the exposure was most likely above the MIOSHA permissible exposure limit for MDI. It is unknown whether the deceased or other employees were aware of the respiratory hazards of isocyanates.

The owner did not have a hazard communication program for the facility and did not provide employee training about the health hazards of isocyanates. The deceased did not alert the owner concerning his breathing problems, which may indicate he was unaware that his recurrent breathing problems after applying the bedliner were due to being exposed to the isocyanate component.

Lack of medical monitoring of employees exposed to sensitizers or other asthma-causing agents

Although OSHA has no legal requirement to perform medical surveillance on individuals who work with asthma-causing agents (exception: formaldehyde), the owner did not establish a medical surveillance program for his employees with exposure to isocyanate materials, nor did Company A or B. The deceased had ongoing respiratory problems with spraying that became worse in relationship to the time he began applying the spray-on truck bedliner and with each application he was symptomatic. He had inadequate medical care prior to his death. He never had a pulmonary function test to better characterize his lung condition before or after he began to work with the isocyanate. A medical surveillance program would have identified his breathing problem and allowed intervention that potentially would have prevented his death.

Non-identification of potential work-related illness by medical personnel

The deceased went to an urgent care facility 7 months before he died with breathing problems. There was no recommendation in this urgent care record about the need for additional tests or the advisability of continuing to do this type of work. A bronchodilation inhaler was prescribed, as well as steroids, a common course of treatment of asthma symptoms. Medical personnel in this clinic did not address the advisability of returning to work at this facility.

Lack of a workplace hazard assessment to identify health and safety issues, types of personal protective equipment to be used, and safe work procedures

The owner had not assessed the workplace to determine if hazards were present or likely to be present that required the use of personal protective equipment. The MIOSHA personal protective equipment standard requires an employer to verify through a written certification that the hazard assessment has been performed.

Although safety hazards did not play a role in this work-related death, if the company owner had conducted a workplace hazard assessment, he would have identified potential safety hazards at the facility to which his employees

were exposed, such as sharp edges on vehicles, flammable materials used in conjunction with the application of the bedliner materials, proper bonding and grounding of flammable liquids, location of the space heating appliances (gas powered heater with pilot light) in a spray area where deposits of combustible residues may accumulate, presence of corrosive materials, etc. Potential causes of employee illness or injury can be averted if a hazard assessment coupled with appropriate control measures are instituted.

DISCUSSION

This is the first asthma death from the use of isocyanates from the spray-on application of a truck bedliner. Three asthma deaths have previously been attributed to isocyanates. One of these deaths was from MDI exposure in a steel foundry [Carino et al., 1997]. Two were from exposure to toluene diisocyanate used in car painting [Anonymous, 1985; Fabbri et al., 1998].

Disturbingly, the owners of the three worksites visited did not know what a sensitizing agent was, that isocyanates are sensitizing agents, or that inhalation to isocyanates could cause asthma. None of the facilities had a written hazard communication program, a written respiratory protection program, or had conducted a hazard assessment to determine the personal protective equipment required for each element of the spray operation. None of the individuals conducting spraying operations had received the required health and safety training mandated by these health and safety programs. All facilities posted the instructions for mixing and spraying the product, but written safe work procedures had not been developed. Although relying on respiratory protection as the primary exposure control, the owners had not ensured that applicators of the spray-on liner had proper medical evaluation, were fit-tested with their respirator, and were trained in its use prior to wearing the respirator. The applicators did not know how to perform a user seal check and that they should do this each time they put on the respirator.

In addition, none had a medical surveillance program for their employees. Medical surveillance can be used as a screening tool to identify individuals who may be having breathing problems due to the materials they are working with, and remove them from that exposure before they develop symptoms that may result in a chronic disability or death.

Many spray-on applicators are small business owners who rely on the manufacturer or product distributor for health and safety information. Efforts are needed to ensure that with dissemination of new technology, information about health hazards and safe work practices are also disseminated and implemented. It is imperative that appropriate health and safety information be relayed to the end user by the manufacturer/distributor/supplier to allow the end user to develop and implement safe work procedures. This is especially true for small business owners who, most likely, do not have health and safety expertise ''in-house'' available to them. The training provided by the spray-on bedliner distributor at the deceased's facility and the other facilities visited did not adequately address the health effects of the isocyanate component or the other health and safety aspects of spraying an isocyanate-based product.

Trade groups could be instrumental in assisting manufacturers, distributors, and suppliers to develop comprehensive health and safety training modules for end users of new technology and products, such as spray-on truck bedliners. One possibility is that trade groups could institute a certification program for spray-on bedliner applicators, requiring applicators to institute appropriate health and safety programs. One of the modules should address the importance of medical surveillance when the product contains chemicals that are sensitizers or may cause/aggravate asthma.

Small business owners, because they may lack the expertise to provide a safe and healthful workplace, should seek additional sources for health and safety information. Safety and health efforts should not be considered as an ''extra cost'' but as a part of their business plan. Additional sources of health and safety information and expertise are available from a variety of sources, such as insurance carriers, private consultants, state or federal-OSHA (e.g., MIOSHA Consultation, Education and Training Division) programs, and business/chamber of commerce organizations. These information sources can provide assistance in the development of both required health and safety programs, such as a respiratory protection program and non-required programs, such as a medical surveillance program.

The State of Washington assessed the spray-on truck bedliner industry within their state by examining the Washington State OSHA inspection files, agency laboratory data, and industrial insurance records [Lofgren et al., 2003]. Washington State OSHA found that personal air sampling conducted at 7 of 13 employer worksites resulted in worker exposures in excess of the state and federal OSHA standard of 0.200 mg/m^3. Personal air sampling at one additional company indicated a possible overexposure; the sample time was 30 min and included 15 min with no exposure to MDI.

In Michigan, OSHA had conducted one inspection at another spray-on bedliner company and cited that company for air sample results above the permitted regulatory levels for isocyanate. This company used a different spray-on bedliner process (single line, heated process), had a spray room, but the room did not have mechanical exhaust ventilation.

These findings of inadequate controls are similar to the problems noted in 13 spray-on applicator businesses in the State of Washington. Lofgren et al. [2003] also identified two worker compensation claims for new-onset asthma from MDI from this industry and one for work-aggravated asthma and two for emergency room treatment of a respiratory problem. Additional analysis conducted by the

Washington State Department of Labor and Industries found that the work-related asthma rate in truck bedliner workers is 200/10,000 FTE and the rate for new-onset asthma, 125/10,000 FTE. These rates are appreciably higher than the background rates of work-related asthma up to 6.3/10,000 FTE in Washington [Bonauto et al., 2005].

Increasingly, local urgent care walk-in clinics are being relied upon to diagnose and treat a variety of health conditions, including work-related illness and injury and perform medical surveillance activities. Primary and urgent care physicians do not routinely ask patients about occupational triggers for work-related asthma. A review of HMO medical charts showed that in only 15% of the charts was there a documentation that the physician had asked about work-related symptoms [Milton et al., 1998]. Educational outreach to assist these health care providers as well as all primary care health care professionals in recognizing and managing cases of possible work-related respiratory problems should be ongoing. Education efforts directed at primary care and urgent care health personnel should emphasize the need to take an occupational history to identify possible work exposures contributing to the development of asthma and to include eliminating exposure to work triggers as part of an asthma treatment plan.

In Michigan, the OSHA program has identified over 100 companies applying spray-on bedliners. The Michigan OSHA Consultation, Education, and Training division is currently visiting each of these identified companies and providing both educational and technical health and safety assistance. Similar efforts need to be conducted in other states to prevent additional disease and death among spray-on truck bed applicators.

CONCLUSION

Owners of small businesses often do not have the expertise necessary to recognize, evaluate, and address the health and safety issues in their workplace. This lack of expertise places their employees, and at times themselves, at an increased risk of sustaining a work-related injury or illness. Isocyanates have long been recognized as a sensitizer and cause of asthma by industry, the health and safety, and medical communities. But this knowledge was not present at the facility where the individual died, nor among the individuals in the two other facilities visited. Lack of recognition of the hazards of isocyanates was a major contributor to the death investigated. This adverse outcome is possible for any applicator of a spray-on isocyanate-containing product regardless of industry setting. Spray-on applications of isocyanate materials also occur in the agriculture, marine, and construction settings. Educational outreach efforts are needed by health and safety organizations, and isocyanate manufacturers/distributors to alert users and the medical community of the health and safety issues inherent in isocyanate-containing spray-on applications. It is imperative that developers of new technologies involving applications of isocyanate-containing materials such as spray-on truck bedliners ensure that end users of their products not only know how to use these new technologies but also that end users implement effective safe work procedures to minimize worker exposure.

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