NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2004-0349-2970
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin

May 2005

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Mark Methner, Ph.D., CIH, Chandran Achutan, Ph.D., and Ayodele Adebayo, M.D., M.P.H., of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Analytical support was provided by DataChem, and Ardith Grote, Robert Streicher and Kathleen Ernst of the Division of Applied and Research Technology. Desktop publishing was performed by Robin Smith. Editorial review was performed by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at Kewaunee Fabrications, LLC, the International Brotherhood of Boilermakers, and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

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

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Fire/Rescue Vehicle Ladder Finishing

In December 2004, NIOSH conducted a health hazard evaluation of paint spraying operations at Kewaunee Fabrications, LLC. Employees and management were concerned about exposure to hexamethylene diisocyanate (HDI) paints during fire/rescue vehicle ladder finishing.

What NIOSH Did

- We took air samples for hexamethylene diisocyanate (HDI), volatile organic compounds (VOCs), silica, and particulates.
- We measured air flow in the spray booth used in the East and West paint shops.
- We observed glove and respirator use.
- We observed work practices.
- We reviewed the OSHA injury/illness log.
- We conducted employee interviews.

What NIOSH Found

- Air concentrations of HDI monomer were very low and within recommended levels.
- Some air concentrations of Total Reactive Isocyanate Group (TRIG) exceeded the United Kingdom-Health and Safety Executive (UK-HSE) time-weighted average (TWA) criteria.
- Spray painters wore the correct respirators but not the correct gloves.
- Workers sometimes used methyl ethyl ketone (MEK) to clean their skin.
- One worker's particulate level exceeded the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) during sanding/prep of ladders. No silica was found.
- Most sanding/prep workers did not wear a respirator.
- The ventilation rate in the East paint shop was below the recommended minimum face velocity for controlling paint overspray.

What Kewaunee Fabrications Managers Can Do

- Use nitrile and butyl rubber gloves, which provide better protection than latex gloves. Do not use latex gloves for protection from HDI and MEK.
- Make sure workers wear an appropriate NIOSH-certified respirator when they perform sanding/prep operations.
- Increase the face velocity of the exhaust ducts inside the East paint shop spray booth.
- Tell workers not to use MEK to clean their skin.

What Kewaunee Fabrications Employees Can Do

- Make sure you wear the required PPE for the job you are performing. Do not use latex gloves.
- Do not use MEK to clean your skin.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2004-0349-2970

Health Hazard Evaluation Report 2004-0349-2970
Kewaunee Fabrications, LLC
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SUMMARY

On September 3, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the management at Kewaunee Fabrications, LLC, Kewaunee, Wisconsin. The request asked NIOSH to evaluate employee exposures to hexamethylene diisocyanate (HDI) during spray painting. Additionally, exposure to volatile organic compounds (VOCs), particulates, and silica was measured. Two ventilation systems were examined and confidential medical interviews with 13 employees were performed.

Full-shift air samples for HDI, VOCs, particulates, and silica were collected between December 13–15, 2004. No air samples collected for HDI monomer exceeded the NIOSH Recommended Exposure Limit (REL) of 35 micrograms per cubic meter ($\mu g/m^3$). There is no Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for HDI monomer or other species of HDI. However, the United Kingdom Health and Safety Executive (UK-HSE) does publish a Total Reactive Isocyanate Group (TRIG) 8-hour time-weighted average (TWA) criteria of 20 $\mu g/m^3$ and a Ceiling Limit criteria of 70 $\mu g/m^3$. Of the 15 painters sampled for HDI exposure, six workers' had PBZ levels that exceeded the UK-HSE TRIG 8-hour TWA criteria of 20 $\mu g/m^3$ while four workers' HDI levels exceeded the UK-HSE TRIG Ceiling Limit criteria of 70 $\mu g/m^3$. Workers wore supplied air respirators, full-body Tyvek® suits, boot covers, and latex gloves while spray painting, so actual exposure to airborne HDI may be lower. However, latex gloves do not provide adequate protection against HDI and other solvents used in the paint shops.

Two sanding/prep workers' particulate exposure levels exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV), (10 milligrams per cubic meter of air [mg/m^3]). Levels for another worker engaged in the same activity also exceeded the OSHA PEL of 15 mg/m^3. No silica (quartz and cristobalite) was found in these samples. Disposable filtering-facepiece respirators were available on a voluntary basis and sporadically used by some workers engaged in sanding/prep activities. All samples collected for VOCs were well below relevant occupational exposure criteria.

Air velocities, measured at the exhaust outlets, were three to seven times higher in the West paint shop than in the East paint shop. This likely accounted for the lower airborne concentration of HDI in the West paint shop.

No consistent respiratory symptoms were noted among the 13 workers interviewed, and symptoms reported were not those commonly found among workers exposed to HDI. However, a common work practice reported by workers involved the use of methyl ethyl ketone (MEK) to wash their skin and remove paint. This practice should be discontinued because MEK can be absorbed through the skin.

NIOSH investigators conclude that a health hazard exists from exposure to particulates during the sanding/prep work activity and the use of solvents such as MEK to clean skin. Recommendations to increase the level of protection for workers engaged in sanding/prep activities include mandatory use of NIOSH-approved, single-use filtering-face piece N-95 respirators. Additionally, exhaust ventilation in the East paint shop should be increased to at least 100 feet per minute (fpm), as an average air velocity across the exhaust outlet to reduce the potential health hazard from exposure to isocyanates.

Keywords: SIC 3599 (Industrial and Commercial Machinery and Equipment, Not Elsewhere Classified), Hexamethylene diisocyanate, HDI, spray painting, metal fabrications, isocyanate paints, volatile organic compounds, dust, silica, Quartz, Cristobalite

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INTRODUCTION

On September 3, 2004, the National Institute for Occupational Safety and Health (NIOSH) received a request from the management at Kewaunee Fabrications, LLC, to conduct a health hazard evaluation (HHE) at their facility in Kewaunee, Wisconsin. The request asked NIOSH to evaluate employee exposures to hexamethylene diisocyanate (HDI) during spray painting operations in the East and West paint shops. Additionally, management representatives were concerned about exposure to volatile organic compounds (VOCs), particulates, and silica during spray painting and sanding operations.

NIOSH representatives, management officials, and the on-site union steward from the International Brotherhood of Boilermakers attended an opening conference on December 13, 2004. On December 13–15, 2004, NIOSH investigators conducted air sampling and medical evaluations. An evaluation of the spray paint booth ventilation systems used in the East and West paint shops was also conducted.

BACKGROUND

Kewaunee Fabrications LLC, founded in 1941, is among the largest heavy steel fabrication specialists in the Midwest. The company initially served as a shipbuilding and engineering company but evolved into heavy fabrications for other industries such as crane and lift manufacturers, heavy construction equipment, fire and rescue vehicles, and the forestry industry. Currently, Kewaunee Fabrications operates two 8-hour shifts with 250 heavy metal fabrication specialists who are machine operators, welders, and painters. The fabrication and painting area of the facility covers approximately 200,000 square feet.

One aspect of Kewaunee Fabrications operation involves fabricating and painting ladders and other components used on fire and rescue vehicles and other heavy equipment. The East paint shop is used for painting ladders and includes a large side-draft paint booth, drying oven, prep and finish area and a separate room for touch-up work. The West paint shop is used for all other painting (mainly smaller parts) and includes two side-draft paint booths.

Prior to painting in the East paint shop, ladders are taped, caulked, and sanded in an area outside the spray booth. Once painting and drying are complete, the ladders are rolled out of the paint booth and examined for paint flaws. Additionally, parts of the ladders that were in contact with the racks used for support are touched up using small quantities (approximately 1 pint) of paint propelled by compressed air.

The West paint shop handles smaller pieces of equipment that often traverse the shop on hooks attached to a slow-moving overhead trolley system. Painters apply paint to the parts as the parts slowly move down the trolley line. They try to conduct spraying while the parts are in front of the paint mist exhaust ventilation system. Because irregularly shaped parts are difficult to paint, painters routinely position themselves between the part being sprayed and the exhaust ventilation.

All large-scale painting operations are conducted via a spray gun/hose combination connected to an automatic paint-mixer system, which in turn is attached to a compressed air source. All painters working in a spray booth wear supplied air hood-type respirators, Tyvek® full-body suits and boot covers, and latex gloves. When painters use small quantities of paint, as in touch-up work, they use half-mask respirators equipped with organic vapor cartridges and paint mist pre-filters along with the Tyvek® full-body suits, boot covers, and latex gloves.

METHODS

Industrial Hygiene Evaluation

Personal breathing zone (PBZ) and general area air samples (samples collected at fixed locations within the work area) were collected for HDI, VOCs, particulate, and silica. All sampling

pumps were calibrated before and after each sampling period.

HDI was sampled and analyzed according to the NIOSH Manual of Analytical Methods (NMAM) Method 5525.[1] HDI airborne concentrations were measured using impingers containing 15 milliliters (mL) of 3% 1-(9-anthracenylmethyl) piperazine in butyl benzoate. The impingers were placed in leather holders and pinned to the workers' lapels, at a position that approximated their breathing zone. The impingers were connected to a battery-operated personal sampling pump via chemical-resistant Fluran® tubing. The pump was then attached to the workers' belts. The pumps were set to operate at a flow rate of 1 liter per minute.

Air samples for VOCs were collected during spray painting and touch-up work using thermal desorption tubes (TD) for qualitative analysis and charcoal tubes for quantitative analysis. Thermal desorption tubes were sampled at a flow rate of 50 milliliters per minute (mL/min) and analyzed per NIOSH Method 2549.[1] The charcoal tubes were run at a flow rate of 200 mL/min, and analyzed by NIOSH Method 1501.[1] Based on the TD sample results, the charcoal tubes were analyzed for the following VOCs: methyl ethyl ketone (MEK), methyl propyl ketone (MPK), methyl isobutyl ketone (MIBK), methyl amyl ketone (MAK), methyl isoamyl ketone (MIAK), 1-methoxy-2-propanol, xylenes, toluene, butyl acetate, propylene glycol methyl ether acetate (PGMEA), ethylbenzene, trimethylbenzene, butanol, and butyl benzoate.

During sanding/prep work and painting, air samples for particulate and silica were collected on polyvinyl chloride (PVC) filters attached to pumps operating at 2 Lpm, according to NIOSH Method 0500 and NIOSH Method 7500, respectively.[1]

Air velocity measurements were made within each side-draft style paint booth in a grid fashion at the face of each paint-arresting filter inlet (ten measurements per filter) using a Velocicalc® Model 8360 thermal anemometer (TSI Inc., St. Paul, Minnesota).

Medical Evaluation

Union and management staff notified employees that NIOSH was conducting an HHE. Employees met confidentially with NIOSH representatives (medical and industrial hygiene) to discuss their concerns about workplace hazards and medical conditions that might result from exposure to substances they use in their jobs. Of the 14 employees, NIOSH representatives interviewed 13; one employee declined an interview. In addition, the NIOSH medical officer reviewed the Occupational Safety and Health Administration (OSHA) Illness and Injury logs for the past 3 years and results of the latest respirator clearance examinations.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing 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 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 become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor OSHA Permissible Exposure Limits (PELs).[4] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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 STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Isocyanates

The feature common to all diisocyanates (monomers) is the presence of two -N=C=O (isocyanate) functional groups attached to an aromatic or aliphatic parent compound. These compounds are widely used in surface coatings, polyurethane foams, adhesives, resins, elastomers, binders, and sealants.

In general, the types of exposures encountered during isocyanate use (i.e., monomers, prepolymers, polyisocyanates, and oligomers) in the workplace are related to the vapor pressures of the individual compounds. The lower molecular weight isocyanates tend to volatilize at room temperature, creating a vapor inhalation hazard. Conversely, the higher molecular weight isocyanates such as the type used at this facility do not readily volatilize at ambient temperatures, but still present an inhalation hazard if aerosolized or heated in the work environment. This is important because many reactions involving isocyanates are exothermic, thus providing the heat for volatilization. As exposure limits decrease, the volatility of solid materials becomes an issue. To reduce the vapor hazards associated with the lower molecular weight diisocyanates, prepolymer and polyisocyanate forms of these diisocyanates were developed and have replaced the monomers in many product formulations. An example is the biuret of HDI, which consists of three molecules of HDI monomer joined to form a higher molecular weight oligomer with similar characteristics to those of the monomer. Many prepolymer and polyisocyanate formulations contain a small fraction (usually less than 1%) of unreacted monomer.

Isocyanates exist in many physical forms in the workplace. Not only are workers potentially exposed to the unreacted monomer, prepolymer, polyisocyanate, and/or oligomer species found in a given product formulation, they can also be exposed to partially reacted isocyanate-containing intermediates formed during polyurethane production. In addition, isocyanate-containing mixtures of vapors and aerosols can be generated during the thermal degradation of polyurethane coatings and plastics. The capability to measure all isocyanate-containing substances in air, whether they are in monomer, prepolymer, polyisocyanate, oligomer, and/or intermediate forms, is important when assessing a worker's total airborne isocyanate exposure.

Exposure to isocyanates irritates the skin, mucous membranes, eyes, and respiratory tract.[5,6] The most common adverse health outcome associated with isocyanate exposure is asthma due to sensitization; less prevalent are contact dermatitis (both irritant and allergic forms) and hypersensitivity pneumonitis (HP).[7,8] Contact dermatitis can result in symptoms such as rash, itching, hives, and swelling of the

extremities.[6,9] The traditional symptoms of acute airway obstruction:, *e.g.*, coughing, wheezing, shortness of breath, and tightness in the chest tightness may indicate isocyanate-induced asthma/sensitization.[6,8] An isocyanate-exposed worker may first develop an asthmatic condition (i.e., become sensitized) after a single (acute) exposure, but sensitization usually takes a few months to several years of exposure.[6,8,9,10,11] The asthmatic reaction may occur minutes after exposure (immediate), several hours after exposure (late), or a combination of immediate and late components after exposure (dual).[8,11] The late asthmatic reaction is the most common, occurring in approximately 40% of isocyanate sensitized workers.[12] After sensitization, any exposure, even to levels below an occupational exposure limit or standard, can produce an asthmatic response that may be life threatening. Diagnosis of isocyanate induced asthma requires a thorough occupational history. As with other asthmatic conditions, pulmonary function tests may be within normal limits between episodes. However, in controlled laboratory environments, provocation testing may be used in diagnosis.

Experience with isocyanates has shown that monomeric, prepolymeric and polyisocyanate species can produce respiratory sensitization in exposed workers.[13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29] Because the intermediates may be chemically similar to these compounds, it is reasonable to assume that they may also produce this condition. Prevalence estimates for isocyanate-induced asthma in exposed worker populations vary considerably: from 5% to 10% in diisocyanate production facilities[10,30] to 25% in polyurethane production plants[30,31] and to 30% in polyurethane seat cover operations.[32] The scientific literature contains a limited amount of animal data suggesting that dermal exposure to diisocyanates may also produce respiratory sensitization.[33,34,35,36] However, this finding has not been tested in dermally exposed workers.

Hypersensitivity pneumonitis has been described in workers exposed to isocyanates.[37,38,39,40] Currently, the prevalence of isocyanate-induced HP in the worker population is unknown. HP is considered rare compared to the prevalence rates for isocyanate-induced asthma.[9] As an obstructive respiratory disease, asthma usually affects the bronchi whereas HP, a restrictive respiratory disease, affects the lung parenchyma (bronchioles and alveoli). The initial flu-like symptoms associated with isocyanate-induced HP include shortness of breath, non-productive cough, fever, chills, sweats, malaise, and nausea.[8,9] After the onset of HP, prolonged and/or repeated exposures may lead to an irreversible decline in pulmonary function and lung compliance, and to the development of diffuse interstitial fibrosis.[8,9] Early diagnosis is difficult because HP's flu-like symptoms and changes in pulmonary function are manifestations common to many other respiratory diseases and conditions.

The only effective intervention for workers with isocyanate-induced sensitization (asthma) or HP is cessation of all isocyanate exposure. This can be accomplished by removing the worker from the work environment where isocyanate exposure occurs, or by providing the worker with supplied-air respiratory protection and preventing dermal exposures.

The NIOSH REL of 35 micrograms per cubic meter of air ($\mu g/m^3$) is a TWA average exposure for the monomeric fraction that should not be exceeded during any work period of up to 10 hours. Similarly, the ACGIH has established a TLV of 34 $\mu g/m^3$ as a TWA not to exceed 8 hours. There is no OSHA PEL for the monomeric fraction. The United Kingdom Health and Safety Executive (UK-HSE) has developed a non-specific exposure limit based on the total number of reactive isocyanate groups (TRIGs) in a volume of air. The UK-HSE full-shift TWA criteria is 20 $\mu g/m^3$, with a ceiling limit criteria of 70 $\mu g/m^3$.

VOCs

Volatile organic compounds describe a large class of organic chemicals (*i.e.*, containing carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. Many paints are formulated with VOCs, including

toluene, MIBK, PGMEA, MEK and xylene. Routes of exposure to solvents include inhalation of vapors (lungs), direct contact with the liquid (skin), and ingestion or swallowing (gastrointestinal tract). Because many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors can be a significant route of exposure. Additionally, many solvents can be absorbed through the skin.

Particulates

Often the chemical composition of the airborne particulate has no established occupational health exposure criterion. The convention has been to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate is now "particulates, not otherwise regulated" (n.o.r.) for the OSHA PEL. The OSHA PEL for total particulate, n.o.r., is 15 mg/m^3, determined as an 8-hour TWA.[4]

RESULTS

In addition to comparing HDI monomer air concentrations to NIOSH RELs and ACGIH TLVs, results were also compared to the UK-HSE exposure criterion for TRIG. First, -N=C=O monomer and -N=C=O oligomer concentrations are summed to obtain the total weight of isocyanate-containing compounds in a given sample. Next, the molecular weight of the isocyanate functional groups in the parent compound is divided by the molecular weight of the parent compound. This yields a numerical constant that reflects the percentage of a compounds' molecular weight contributed by the TRIGs. For HDI and HDI-based oligomers, the TRIGs constant is 0.5. Finally, the total weight of isocyanate-containing compounds in a given air sample is multiplied by the TRIGs constant, and the product is the concentration of TRIGs in air.

Fifteen full-shift PBZ samples were collected for HDI during painting operations (Table 1). Sampling times ranged from 163 minutes to 514 minutes. No PBZ sample exceeded the NIOSH REL of 35 µg/m^3 or the ACGIH TLV of 34 µg/m^3 for HDI monomer. Six workers' levels exceeded the UK-HSE TRIG 8-hour TWA of 20 µg/m^3, while four workers' levels exceeded the UK-HSE TRIG Ceiling Limit of 70 µg/m^3. More painters' levels in the East paint shop exceeded the TRIG criterion than those in the West paint shop.

Nine general area air samples for HDI were collected (four in East and five in West); the results are presented in Table 2. The samples were collected in the area where workers conducted spraying operations. None of these samples exceeded the NIOSH REL or ACGIH TLV for HDI monomer. However, one sample, collected inside the East paint shop spray booth, exceeded the TRIG Ceiling Limit of 70 µg/m^3.

The PBZ air sampling results for VOCs are presented in Table 3. Simultaneous general area air sampling using the TD tubes identified 14 abundant VOCs that were quantified using charcoal tubes (Table 4). Eleven PBZ samples were collected, with no sample exceeding any occupational exposure limit. General area air samples yielded similar results.

Of the 11 PBZ samples collected for total particulates during prep/sanding, sweeping, and painting (Table 5), three workers' levels exceeded the ACGIH TLV of 10 mg/m^3. Levels for two of these three workers also met or exceeded the OSHA PEL of 15 mg/m^3 for total particulates. The six general area air samples collected within both paint shops were lower than the PBZ samples collected on the same day (Table 6). For example, on December 15, 2004, the highest PBZ dust samples (11 mg/m^3 and 19 mg/m^3) were collected in the same area as the highest general area air sample (1.3 mg/m^3). All of the particulate air samples were analyzed for silica (Quartz and Cristobalite); no silica was detected.

Ventilation

Two filtered, overhead ceiling supply ducts introduced air into the East paint shop paint booth. Exhaust from the booth was achieved via four outlets (two on each side of the booth), each measuring 3'6" by 18'. The paint booth within the West paint shop consisted of two outlets on

one side of the building which were covered with a paint-arresting filter. Supply ducts on the wall opposite the outlets introduced air into the West paint shop. Ten measurements per exhaust outlet were made within each spray booth (East and West). Average face velocities in the East paint shop booth ranged from 50 feet per minute (fpm) to 63 fpm, while the average face velocities for the two exhaust outlets in the West paint shop were 416 fpm and 132 fpm.

Medical Evaluation

Interviews

All but one of the paint shop employees (11 men and 2 women) were interviewed. Their average age was 40 years (range: 22 to 55 years). The average length of time worked at the facility was 5 years (range: 1 to 26 years). Four were sanding/prep workers and nine were painters/touch-up/ladder finishers. There were eight current smokers, two former smokers and three non-smokers.

The painters indicated that they were required to wear supplied air respirators while painting in the booth. Sanding/prep employees have NIOSH-certified N-95 filtering-face piece respirators available for voluntary use. Both groups also indicated that a variety of protective gloves (nitrile, latex, rubber, leather, and cotton) as well as disposable Tyvek® suits is made available to them. Glove selection was based on personal preference and not by the particular work tasks or materials. Although some wore disposable Tyvek® suits over their street clothes, most workers wore only their street clothes. None of the workers had separate work clothing. Workers reported they did not change clothing at work because there was no changing room on site.

There were no complaints of chronic or recurrent skin conditions by the workers. Two complained of skin blistering and one of skin burns from contact with MEK and a type of metal cleaner (aluminum brightener). One employee complained of late onset, episodic shortness of breath, with coughing and wheezing that he said improved on days away from work. The NIOSH medical officer recommended this employee seek appropriate management and care from a health care provider. Another employee reported exertional shortness of breath that he believed was related to smoking. No one reported current upper respiratory or mucous membrane irritation. One employee reported childhood-onset asthma with no apparent worsening of symptoms since starting work at the facility. One employee was experiencing respiratory symptoms similar to those consistent with isocyanate exposure. However, no definitive medical determination could be made. Spirometry identified mild obstructive findings in an asymptomatic employee.

Eight workers reported using MEK to remove paint from their skin and to wash their hands; three workers denied ever using this product, while the remaining two recently stopped using MEK.

OSHA 200/300 logs

The NIOSH medical officer reviewed the OSHA logs from January 2002 through December 2004. A paint shop worker reported vapor inhalation in April 2004, and another worker reported an episode of irritation of both eyes from an unknown cause in June 2004. Most entries were for strains, contusions, lacerations, and hearing loss.

Respiratory protection program/records

Kewaunee Fabrications, LLC has a respiratory protection program that complies with OSHA 29 CFR 1910.134. The program involves all painters, touch-up, and sanding/prep personnel in the paint department. The respiratory protection equipment in use is manufactured by the 3M company (Half-mask Facepiece 7500 series and Full Face 6800).

Paint shop workers may use supplied air or filtering face piece respirators (depending on their exposures). Paint-arresting pre-filters and organic vapor cartridges are changed daily. All face pieces are cleaned and stored according to manufacturer recommendations and OSHA requirements. Kewaunee Fabrications, LLC has

an occupational health physician who works with the on-site occupational health nurse to coordinate the annual respiratory protection program medical evaluation, and the annual pulmonary function test. Additionally, two management staff (the safety coordinator and the paint shop supervisor) have been trained in respirator fit testing.

The results of the most recent respirator clearance tests revealed normal spirometry for all tested employees except one individual with a mild obstructive tracing. There was no follow-up testing on this employee.

DISCUSSION/CONCLUSIONS

Because there are no appropriate occupational exposure limits for N-C-O monomer and oligomer, the UK-HSE TRIG exposure criterion (8-hour TWA and Ceiling Limits) was used for comparison purposes. This limit is not legally enforceable in the United States. The full-shift PBZ results from this survey indicate that some sample results exceeded both UK-HSE TRIG criteria, but not the NIOSH REL or the ACGIH TLV for the HDI monomer species. However, personal protective equipment used when spraying (supplied air respirator, disposable Tyvek suit, and boot covers), cannot be relied upon to control exposure to HDI monomer and oligomer species. Ventilation inside the East paint shop needs to be improved (increase exhaust air velocity) to reduce isocyanate concentrations. Latex gloves do not adequately protect employees who spray paints containing HDI or use MEK to clean paint equipment. Neoprene, nitrile, or butyl rubber gloves provide better protection against HDI and MEK.

The results from the general area air samples confirm that HDI monomer and oligomers were present during paint spraying activities, especially the sample collected inside the East paint shop spraying booth. The impinger sampling method used in this survey (NIOSH Method 5525) is suitable for collecting both the fast-curing HDI monomer and the slower reacting HDI oligomer. This method is more versatile than methods using treated filters as the collection medium, because the latter does not effectively capture the HDI monomer, potentially underestimating total HDI levels in the environment. The disadvantages of NIOSH Method 5525 as a personal sampling method are that the impingers are bulkier to wear than the filters, and they may spill or overflow if the employees twist, turn, or lie on their backs.

Results from the PBZ and general area air samples for VOCs indicated that no airborne occupational exposure limits were exceeded during the NIOSH survey. However, a common practice employed by workers involved washing their skin with MEK to remove paint buildup. Because MEK can be absorbed through the skin and result in unnecessary exposure, this practice should cease. Additionally, workers should use nitrile gloves for protection against MEK.

Results from the PBZ samples for particulates indicate that one sample exceeded the OSHA PEL (Table 5), while other samples exceeded the ACGIH TLV and the OSHA PEL. However, the general area air samples did not exceed any occupational exposure limits. This is most likely due to the close proximity of the PBZ samples relative to the source of exposure (sanding/prep activities) whereas general area air samples were collected near the work area but 5–10 feet away from the sanding/prep activity. Some workers did not routinely use respiratory protection while performing sanding/prep work. Silica (Quartz or Cristobalite) was not present in any dust sample.

The ventilation systems used in the East and West paint shops were quite different in their design and their ability to control HDI paint spray. The spray booth located in the East paint shop had inadequate air velocity at all four exhaust outlets. In contrast, the West paint shop had higher air velocities and appeared to remove paint spray mist adequately. The average air velocity measured at the exhaust outlet inside the West paint shop booth was approximately 2.5 to 7 times higher than the average air velocity measured inside the East paint shop booth. Both paint shops changed the paint-arresting filters just prior to air velocity measurements. This difference in ventilation may explain the higher TRIG values for workers spraying in the East paint shop versus those

spraying in the West paint shop. The low average air velocity present in the East paint shop (50 fpm to 63 fpm) fails to meet the minimum air velocity criteria of 100 fpm established by the ACGIH for paint booth operation.[41] However, the average air velocities measured at the two spray booths in the West paint shop (132 fpm to 416 fpm) is above the minimum air velocity criteria.

The medical interviews revealed one employee who was experiencing respiratory symptoms consistent with isocyanate exposure but a definitive determination could not be made. Spirometry conducted on an asymptomatic employee identified a mild obstruction. These individuals were referred to their personal physician. In general, if workers are sensitized to isocyanates, they should be removed from tasks requiring them to handle such compounds.

RECOMMENDATIONS

Based on the environmental data, medical interviews, and the observations during this survey, the following recommendations are made to improve the health and safety of the employees:

1. Management should select and enforce the use of appropriate NIOSH-certified N-95 filtering-face piece respirators during sanding/prep work and train employees on the proper use of respirators. Employees should wear respirators until the sanding/prep work is complete and they are ready to leave the sanding/prep work area. Respirator use should be mandatory until engineering or administrative controls are implemented to control dust generated from sanding/prep activities.

2. Stop using latex gloves while spraying and cleaning spray equipment. Instead, use gloves made of a suitable material such as nitrile or butyl rubber that provides protection from isocyanates and MEK.

3. Stop using solvents, particularly MEK, to remove paint from skin. Exposure to MEK may result in irritation of the eyes, nose and the upper airway; headaches; nausea; vomiting; fatigue; dizziness; and even loss of consciousness. Chronic exposure may also be associated with brain damage and skin problems.[6]

4. Increase the ventilation in the East paint shop spray booth to an average face velocity of at least 100 fpm.[41] Since there is no air flow monitoring device installed in either paint shop, the facility should consider installing a manometer or other flow monitoring device to make sure the ventilation system is operating properly. Also, check air velocities in all paint shop exhausts monthly.

5. Require all workers engaged in sanding/prep work to wear Tyvek® suits to keep particulate off their street clothes and prevent them from bringing any contamination into their homes.

6. Remove an employee from further exposure to isocyanates if a medical evaluation reveals that he/she may have isocyanate-related disease, because low levels may exacerbate disease in sensitized individuals.

7. Encourage workers to quit smoking. Many adverse health effects have been associated with tobacco use including, but not limited to, various forms of cancer and respiratory diseases. Smoking may also act synergistically with some of the hazards present at work places. Additional information on smoking cessation programs available in the state can be obtained by calling 1-800-QUIT NOW (1-800-784-8669) or from:

Wisconsin Tobacco Control Program
Division of Public Health
Box 2659
Madison, WI 53701-2659
Phone: (608) 266-8526
Fax: (608) 266-8925

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Table 1
Personal breathing zone (PBZ) sampling results for Hexamethylene diisocyanate (HDI) (µg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Job Title	Paint Location	Sampling Time (min)	HDI Monomer	NCO Monomer	NCO Oligomer	TRIG
12-13-2004	PM	Touch up	East	255	1.3	0.7	0.8	0.7
12-13-2004	PM	Painter	East	275	2.1	1.1	295	148 [1,2]
12-13-2004	PM	Touch up	West	365	1.1	0.5	3.0	1.8
12-14-2004	AM	Painter	East	446	0.6	0.3	36	18
12-14-2004	AM	Painter	East	298	1.6	0.8	1.7	1.3
12-14-2004	AM	Touch up	East	270	2.2	1.1	4.5	2.8
12-14-2004	AM	Touch up	East	283	1.2	0.6	0.3	0.4
12-14-2004	AM	Painter	East	163	3.3	1.7	298	150 [1,2]
12-14-2004	AM	Painter	West	411	1.9	1.0	89	45 [1]
12-14-2004	AM	Painter	West	514	2.6	1.3	121	61 [1]
12-15-2004	AM	Touch up	East	378	1.4	0.7	1.9	1.3
12-15-2004	AM	Touch up	East	305	1.6	0.8	0.9	0.8
12-15-2004	AM	Painter	East	438	3.6	1.8	205	104 [1,2]
12-15-2004	AM	Painter	East	325	3.8	1.9	160	81 [1,2]
12-15-2004	AM	Painter	West	443	0.7	0.3	25	13

ACGIH 8-hr TLV 34 **UK-HSE - TRIG Ceiling Limit 70**
OSHA 8-hr PEL N/A **UK-HSE - TRIG 8-hr TWA 20**
NIOSH REL 35

NCO = functional isocyanate group

[1] Value exceeds the UK-HSE TRIG 8 hour TWA, assuming work continues for an 8-hour shift.
[1,2] Value exceeds the UK-HSE TRIG Ceiling limit

Table 2
General area air sampling results for HDI (µg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Paint Location	Sampling Time (mins)	HDI Monomer	NCO Monomer	NCO Oligomer	TRIG	Comments
12-13-2004	PM	East	388	1.8	0.9	0.4	0.6	Next to spray booth entry door
12-13-2004	PM	East	254	3.4	1.7	372.7	187.2*	Inside spray booth
12-13-2004	PM	West	375	1.5	0.8	1.3	1.1	Next to side draft booth nearest oven
12-14-2004	AM	East	470	2.4	1.2	12.7	7.0	Next to entry door leading to spray booth
12-14-2004	AM	West	523	0.8	0.4	0.7	0.6	In front of second spray booth
12-14-2004	AM	West (STEL)	10	1.4	1.4	17.0	9.2	STEL Sample-spraying Barko Brown paint
12-14-2004	AM	West (STEL)	10	1.4	1.4	24.1	12.7	STEL Sample-spraying Barko Brown paint
12-15-2004	AM	East	440	1.6	0.8	0.4	0.6	Next to entry door leading to spray booth
12-15-2004	AM	West	415	1.1	0.6	5.4	3.0	Next to second spray booth

NCO = functional isocyanate group
STEL = Short Term Exposure Limit
* Indicates value exceeded the UK-HSE TRIG Ceiling limit of 20 µg/m^3

Table 3
Personal breathing zone air sampling results for Volatile Organic Compounds (mg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13-15, 2004
HETA 2004-0349-2970

Date	AM/PM	Job title	Paint location	Sampling time (min)	Methyl ethyl ketone	Methyl propyl ketone	Methyl isobutyl ketone	Methyl amyl ketone	Methyl isoamyl ketone
12-13-2004	PM	Prep	East	286	5.59	0.38	0.04	1.13	0.06
12-13-2004	PM	Painter	West	427	42.19	0.01	0.06	9.49	0.09
12-14-2004	AM	Touch up	East	272	13.84	0.06	0.07	1.71	0.04
12-14-2004	AM	Painter	East	280	69.56	0.98	0.11	1.69	0.04
12-14-2004	AM	Painter	East	296	43.70	0.13	0.05	2.35	0.02
12-14-2004	AM	Touch up	East	284	20.51	0.08	0.02	0.77	0.02
12-14-2004	AM	Painter	East	176	33.92	2.63	0.42	19.79	0.03
12-15-2004	AM	Painter	East	328	6.65	0.14	0.02	7.41	0.02
12-15-2004	AM	Touch up	East	407	23.19	0.32	0.04	1.34	0.02
12-15-2004	AM	Painter	East	438	11.11	1.23	0.10	12.35	0.15
12-15-2004	AM	Painter	West	445	6.27	0.01	0.57	1.57	0.04
				ACGIH TLV	**590**	**705**	**205**	**233**	**233**
				OSHA PEL	**250**	**480**	**100**	**465**	**475**
				NIOSH REL	**590**	**530**	**205**	**465**	**240**

Table 3 (continued)
Personal breathing zone air sampling results for Volatile Organic Compounds (mg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Job title	Paint location	Sampling time (mins)	1-methoxy-2-propanol	Toluene	Butyl Acetate	PGMEA	Ethyl benzene	Xylenes	Trimethyl benzenes	Butanol	Butyl benzoate
12-13-2004	PM	Prep	East	286	0.35	0.16	1.55	0.11	0.08	0.35	0.06	0.02	0.01
12-13-2004	PM	Painter	West	427	3.05	0.01	0.87	0.23	0.12	0.57	0.02	0.32	0.02
12-14-2004	AM	Touch up	East	272	0.36	0.12	0.98	0.04	0.07	0.25	0.04	0.02	0.04
12-14-2004	AM	Painter	East	280	1.78	0.17	1.39	0.10	0.18	0.68	0.06	1.05	0.02
12-14-2004	AM	Painter	East	296	0.34	0.04	2.19	0.10	0.15	0.61	0.11	0.14	0.02
12-14-2004	AM	Touch up	East	284	0.34	0.02	0.72	0.03	0.07	0.27	0.09	0.09	0.01
12-14-2004	AM	Painter	East	176	2.83	0.04	19.79	0.45	0.42	1.89	1.02	2.06	0.03
12-15-2004	AM	Painter	East	328	0.30	0.03	8.62	0.17	0.18	0.71	0.36	0.18	0.03
12-15-2004	AM	Touch up	East	407	0.24	0.03	1.59	0.16	0.06	0.27	0.04	0.17	0.01
12-15-2004	AM	Painter	East	438	1.35	0.31	12.35	0.40	0.31	1.35	0.58	0.95	0.01
12-15-2004	AM	Painter	West	445	0.83	0.01	1.57	0.26	0.08	0.38	0.05	0.60	0.03
				ACGIH TLV	**360**	**188**	**713**	**N/A**	**435**	**435**	**122**	**60**	**N/A**
				OSHA PEL	**N/A**	**750**	**710**	**N/A**	**435**	**435**	**N/A**	**N/A**	**N/A**
				NIOSH REL	**360**	**375**	**710**	**N/A**	**435**	**435**	**125**	**N/A**	**N/A**

PGMEA = Propylene glycol monomethyl ether acetate
N/A = Not available

Table 4
General area air sampling results for Volatile Organic Compounds (mg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Paint location	Sampling time (mins)	Methyl ethyl Ketone	Methyl propyl ketone	Methyl isobutyl ketone	Methyl amyl ketone	Methyl isoamyl ketone	Comments
12-13-2004	PM	East	391	11.09	1.39	0.10	1.07	0.01	Next to entry door of paint booth
12-14-2004	AM	West	249	3.35	0.13	0.07	0.20	0.59	Center of spray area outside paint booth
12-15-2004	AM	West	408	3.02	0.01	0.10	0.31	0.02	Next to 2nd spray booth

Date	AM/PM	Paint location	Sampling time (mins)	1-methoxy-2-propanol	Toluene	Butyl Acetate	PGMEA	Ethyl benzene	Xylenes	Trimethyl benzenes	Butanol	Butyl benzoate	Comments
12-13-2004	PM	East	391	0.25	0.03	0.89	0.05	0.10	0.37	0.04	0.15	0.03	Next to entry door of paint booth
12-14-2004	AM	West	249	ND	ND	0.06	ND	ND	ND	ND	0.19	0.06	Center of spray area outside paint booth
12-15-2004	AM	West	408	ND	0.00	0.18	0.04	0.01	0.07	ND	0.11	0.01	Next to second spray booth

PGMEA = Propylene glycol monomethyl ether acetate
ND – None detected

Table 5
Personal Breathing Zone (PBZ) air sampling results for Particulates (mg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Job title	Paint location	Sampling time (minutes)	Particulate Concentration	Comments
12-13-2004	PM	Floor Sweeper	East	361	1.8	Dry sweeping floor
12-13-2004	PM	Painter	West	427	2.9	Spraying jet black, then tan military paint
12-14-2004	AM	Prep/sanding	East	262	8.2	Prep/sand ladders prior to painting
12-14-2004	AM	Prep/sanding	East	254	6.2	Prep/sand ladders prior to painting
12-14-2004	AM	Prep/sanding	East	267	**15****	Prep/sand ladders prior to painting
12-14-2004	AM	Prep/sanding	East	125	5.8	Prep/sand ladders prior to painting
12-14-2004	AM	Prep/sanding	East	147	4.1	Prep/sand ladders prior to painting
12-14-2004	AM	Prep/sanding	East	131	2.6	Prep/sand ladders prior to painting
12-15-2004	AM	Prep/sanding	East	339	**19***	Prep/sand ladders prior to painting
12-15-2004	AM	Prep/sanding	East	446	**11****	Prep/sand ladders prior to painting
12-15-2004	AM	Prep/sanding	East	125	2.6	Prep/sand ladders prior to painting
				OSHA PEL	15	
				ACGIH TLV	10	

* indicates value would exceed the OSHA PEL if exposure continues over an 8-hour shift.
** indicates value would exceed the ACGIH TLV if exposure continues over an 8-hour shift.

Table 6
General area air sampling results for Particulates (mg/m^3)
Kewaunee Fabrications, LLC
Kewaunee, Wisconsin
December 13–15, 2004
HETA 2004-0349-2970

Date	AM/PM	Paint location	Run time (minutes)	Particulate Concentration	Comments
12-13-2004	PM	East	356	0.28	Next to paint booth, near entry door
12-13-2004	PM	West	375	0.08	Next to side draft booth nearest oven-lower face velocity
12-14-2004	AM	East	474	0.83	On shelf next to sanding area
12-14-2004	AM	East	466	0.30	Next to entrance to spray booth
12-14-2004	AM	West	262	0.13	In front of 2nd spray booth
12-15-2004	AM	East	562	1.31	On shelf next to sanding area

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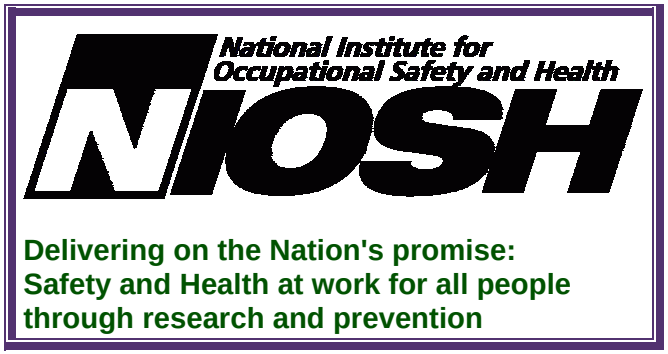

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