Evaluation of Dermatitis Among Sanders in a Furniture Manufacturing Plant

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a chair manufacturing facility. The employer was concerned about skin rashes among sanders in the clean-up (or "sanding") department.

What We Did

- We evaluated the sanding department in November 2011.
- We asked employees about their health concerns.
- We observed employees' work practices.
- We sampled the air for volatile organic compounds from the epoxy resins, glues, and chemicals used to clean the wood.
- We took samples from the work surfaces to look for bisphenol A, diglycidyl ether of bisphenol A, and elements (metals and minerals).
- We evaluated the ventilation in the work area.
- We looked at employees' personal protective equipment use.
- We reviewed employee medical records.

We found that work activities in the sanding department exposed the sanders to epoxy resins. Employees reported more rashes after epoxy resin use increased because of a change in chair frame assembly. To reduce exposures we recommend the use of local exhaust ventilation on hand sanders and wearing protective gloves when working with epoxy resins.

What We Found

- Employees who worked in the sanding department reported recent skin rash.
- Employees were exposed to epoxy resin through skin contact and from breathing the dust.
- Airborne exposures to volatile organic compounds were below occupational exposure limits.
- Low levels of metals and diglycidyl ether of bisphenol A were found in the wipe samples. Bisphenol A was not detected.
- The downdraft tables were not effective in controlling dust when employees sanded large frames.

What the Employer Can Do

- Install local exhaust ventilation to use with the hand sanders.
- Use a vacuum system instead of compressed air to remove dust from the chairs.
- Use a dispensing gun for applying epoxy resin to the chairs.
- Provide education on epoxy resins and how to reduce exposures.

What the Employer Can Do (continued)

- Provide employees with protective gloves (polyvinylalcohol or multiple layered gloves) when handling epoxy resin.
- Provide employees with safety glasses or goggles when working with epoxy resin.
- Encourage employees to report possible work-related skin rash early.
- Refer employees with persistent rash to a dermatologist knowledgeable in occupational medicine.

What the Employees Can Do

- Learn about the risks of using epoxy resins and getting sensitized to them.
- Avoid getting epoxy resin on your skin.
- Always wear polyvinylalcohol or multiple layered gloves and eye protection when handling epoxy resin.
- Wash skin as soon as possible with soap and water if epoxy resin gets on it.
- Clean up and maintain all equipment regularly so that it has no residual epoxy resin on it.
- Talk to your supervisor about any workplace health concerns.

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Abbreviations

µg	Microgram
ACGIH®	American Conference of Governmental Industrial Hygienists
BEI®	Biological exposure index
cm^2	Square centimeter
CFR	Code of Federal Regulations
DGEBA	Diglycidyl ether of bisphenol A
LOD	Limit of detection
LOQ	Limit of quantitation
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppm	Parts per million
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound
WEEL™	Workplace environmental exposure level

Introduction

The Health Hazard Evaluation Program received a request from a furniture manufacturer in North Carolina. The employer was concerned about skin rashes among sanders in the clean-up (or "sanding") department. Two sanders had severe skin reactions at work and were unable to continue work in the area; they were permanently reassigned to another department. In November 2011, we visited the facility to evaluate exposures, work conditions, and employees' health concerns. We sent a letter with preliminary findings to employer and employee representatives in November 2011.

Figure 1. Cleaning department with 10 sanders' workstations. Photo by NIOSH.

Figure 2. Screw holes in chair frames that were to be filled with epoxy resin. Photo by NIOSH.

The furniture manufacturing company had been in business for more than 40 years and employed 200 employees at this plant. There was no union or employee bargaining unit. Employees worked 9 hours per day, Monday through Friday, and a half day on Saturday. The company trucked in assembled, imported wooden chair frames from another facility and unloaded them onto the manufacturing floor. The clean-up department was on one side of a large open room that also housed the inspectors (Figure 1). Eighteen employees, including ten sanders, worked in the clean-up department. The remaining clean-up employees performed repairs, distressed wood, pushed frames to various work spaces, and inspected the frames. The 10 sanders plugged the screw holes in the frames with epoxy resin and used hand-held orbital sanders to sand rough areas on chair and other furniture frames. Each frame was individually checked for imperfections, which were then repaired. The sanders worked on downdraft benches, raised platforms, or the floor depending on the size of the frame. The sanders worked on a piece-rate pay scale.

In the past, the screw holes were plugged with wooden plugs, and epoxy resins were used for repairs. About 18 months before our site visit, the company started using larger screws with angled holes to strengthen the wood frames (Figure 2). They also began using epoxy resins instead of wood to plug the screw holes and mixed the epoxy resins by hand to match wood colors. This change led to an increased use of epoxy resins, which had previously only been used to repair imperfections in the wood. Epoxy resins of different colors came in plastic tubes. Employees squeezed out different colors of epoxy resins onto their fingers, kneaded them together to approximate the color of the wood, and filled the screw holes of the wooden frames with the epoxy resin mixture. Each chair had six or more screw holes and each screw hole was filled with a grape-sized amount of epoxy resin. A few months before our site visit, the company instituted a mandatory glove-use policy for sanders. The company provided three styles of gloves made of either nitrile (two types) or vinyl. Acetone was used to remove excess epoxy resin from each chair. The chairs were then inspected, distressed if indicated, and stained. After drying, the chairs were moved to an upholstery department where cushions and fabrics were applied, finishing the chair or sofa.

Managers reported that the first employee developed a red, itchy, rash on the hands and wrists 9 to 10 months before our visit. Over the next 4 months, two additional employees developed similar rashes on their arms and face. All three employees were sanders. Managers stated that the employees had not reported rashes in the past. The company initially worked with the Occupational Safety and Health Administration (OSHA); OSHA suggested the company contact the Health Hazard Evaluation Program.

Methods

Our main objectives were to assess the dust and chemical exposures of sanding employees from epoxy resins, glues, acetone, and other chemicals, to evaluate whether employee reports of skin symptoms could be related to work exposures, and to determine appropriate methods to reduce employees' exposures, if needed.

We toured the facility and observed work processes to see what tasks had the potential for hazardous exposures. We used a smoke tube to observe air flow patterns which informed us about ventilation in the work area. We reviewed the material safety data sheets provided by the employer for the epoxy resins, glues, and acetone used by the sanders. We interviewed employees confidentially to discuss their work practices, medical history, and workplace health concerns or symptoms. We reviewed medical records of employees who had seen a medical provider because of a rash. We reviewed the OSHA Form 300 Logs of Work-Related Injuries and Illnesses for years 2009, 2010, and January through November 2011.

We collected short-term breathing zone air samples on thermal desorption tubes for volatile organic compounds (VOCs). The thermal desorption tubes were analyzed according to National Institute for Occupational Safety and Health (NIOSH) Method 2549 [NIOSH 2013]. We also collected full-shift breathing zone air samples using charcoal tubes on the same employees. On the basis of the results of the VOC screening samples and considering the compounds listed in the material safety data sheets, we analyzed the charcoal tube samples for acetone, n-butyl acetate, isobutyl acetate, 2-propoxyethanol, 2-butoxyethanol, and toluene according to NIOSH Method 1501 [NIOSH 2013].

We collected surface wipe samples for bisphenol A and diglycidyl ether of bisphenol A (DGEBA) (epoxy resin components) with 3 inch by 3 inch cotton gauze pads moistened with 2 milliliters of isopropyl alcohol. A 10 centimeter by 10 centimeter template was placed on the employees' work surface where they placed their tools and supplies. The area was wiped twice with the gauze pad in a concentric square pattern. The gauze pads were placed in a polypropylene tube, and 20 milliliters of acetonitrile was added after collection. The samples were shipped cold and analyzed by high performance liquid chromatography according to a draft NIOSH method.

We also collected surface samples for elements (metals and minerals) using Ghostwipes with a 5 centimeter by 5 centimeter template on the sanders' work bench surfaces. We collected these samples to look for trace metals that have been associated with skin sensitization and dermatitis. The wipe samples were digested and analyzed for 26 metals and minerals according to NIOSH Method 7303 [NIOSH 2013].

Results

Confidential Employee Interviews

We held confidential medical interviews with 18 employees, including all 16 employees working in the clean-up department at the time of our site visit (including 10 sanders) and 2 former sanders now working in the cloth and upholstery departments. Five of the employees were male. The average age was 43 (range: 22 to 62 years of age); the average length of employment was 11.4 years (range: 7 months to 40 years). All of the sanders wore wrist-length gloves when using epoxy resins; some reported that they began this practice 2 weeks to 2 months before our visit. We asked how many times they washed their hands during work hours; the average number of times was 5 (range: 3 to 12 times). Hand washing facilities were located between the clean-up and upholstery departments.

Of the 18 employees, eight reported current or recent skin rash that began within 2 years of our site visit and that they associated with work. Of the eight employees reporting current or recent skin rash, seven were current or prior sanders at the time of our site visit. None of the eight employees had a history of skin disorders. Of the 18 employees, three reported sinus problems, and one reported recent onset of asthma symptoms (shortness of breath and wheezing) that they believed were related to their work. One employee reported a respiratory disorder that was unrelated to work, but was aggravated by work dust.

Upon skin examination, five employees had visible skin rash with dryness, redness, swelling, small bumps, and/or fluid-filled bumps on their hands and/or arms at the time of our site visit. Three reported that they had seen the physician contracted by the company, and one had an upcoming appointment with the contracted physician. Two reported seeing a private medical provider. Three reported they had also seen a dermatologist; one of the three reported having skin patch testing that revealed a skin allergy to bisphenol A, a component of the epoxy resin.

Of the eight employees reporting a current or recent rash, four had been transferred to a different department because of their rash. Two of the four (the two former sanders) had been permanently transferred to a department away from sanding and without epoxy resin exposure after the employees' attempts to work in the clean-up area resulted in recurrence of their skin rash. One employee reported having a skin reaction to the gloves provided for epoxy resin work and was provided a different type of glove.

The interviewed employees reported that they used a much larger amount of epoxy resin at the time of our visit than they did 2 years prior (8–12 tubes of epoxy resin per day compared to 2–4 tubes per week). Employees reported using their hands and fingers to mix the epoxy resins because of their thick consistency. In the month prior to our visit, the company started a policy of wearing gloves while working with epoxy resins, and all employees stated that they now wore gloves during this task.

OSHA Log Review

The 2009 log had eight entries, and the 2010 log had six entries; neither had entries for skin-related disorders. The 2011 log had thirteen entries including five entries for skin disorders. One of these five entries documented a job transfer or job restriction.

Medical Record Review

We reviewed the medical records of four employees who had seen a doctor. One of the four employees saw a dermatologist and had skin patch testing showing an allergic skin reaction to bisphenol A. This employee was diagnosed with work-related allergic contact dermatitis. The three other employees were seen by either a primary care or occupational physician and did not have skin patch testing. These three employees were diagnosed with contact dermatitis. Their records documented work exposures as a possible cause or contributor to the condition, on the basis of presentation and history. Two of the three were given instructions to avoid work exposures or contact with epoxy resins. None of the four employee medical records mentioned respiratory symptoms.

Sampling Results

The most prevalent chemicals on the thermal desorption tubes were toluene, isobutyl acetate, decamethylcyclopentasiloxane, and C7 hydrocarbons including heptane and methyl hexanes. Other compounds identified include acetone, ethanol, butyl acetate, xylene isomers, and methyl amyl ketone. Of these, acetone, n-butyl acetate, isobutyl acetate, 2-propoxyethanol, 2-butoxyethanol, and toluene were analyzed quantitatively from the charcoal tube samples. The results for the breathing zone air samples are given in Table 1. The minimum detectable concentrations (MDCs) and minimum quantifiable concentrations (MQCs) are also provided in Table 1. The MDCs and MQCs were calculated by dividing the analytical limits of detection and quantitation (mass units) by the minimum volume of air sampled. The MDCs and MQCs represent the smallest air concentrations that could have been detected (MDC) or quantified (MQC) for the volume of air sampled. All of the chemicals were present above MQCs, but exposure levels were well below their occupational exposure limits (OELs). The lowest NIOSH recommended exposure limit (REL) for any of these VOCs is 5 parts per million (ppm) for 2-butoxyethanol. However, the OEL for 2-butoxyethanol has a skin notation indicating the potential for significant contribution to overall exposure by the cutaneous route, including direct skin contact. Additional information on VOCs can be found in Appendix A.

Table 1. Breathing zone air sampling for volatile organic compounds on November 3, 2011

Job Title	Sample time	Concentration (ppm)					
		Acetone	n-Butyl acetate	Isobutyl acetate	2-Propoxy-ethanol	2-Butoxy-ethanol	Toluene
Sander	7:39–15:15	1.1	0.055	0.31	0.083	0.0054	0.19
Sander	7:32–11:15*	0.94	0.42	0.37	0.11	(0.006)†	0.36
Sander	7:35–15:15	1.1	0.060	0.43	0.098	0.0068	0.20
Sander	7:26–15:15	1.1	0.072	0.38	0.091	0.006	0.28
NIOSH REL		250	150	150	NA	5 (skin)	100
OSHA PEL		1000	150	150	NA	50 (skin)	200
ACGIH TLV		500	150	150	NA	20	20

ACGIH = American Conference of Governmental Industrial Hygienists

PEL = Permissible exposure limit

TLV = Threshold limit value

*Collected on morning shift only due to battery failure after lunch

†Concentration was between the MDC of 0.002 ppm and MQC of 0.0007 ppm indicating there is more uncertainty associated with this concentration.

The results for the bisphenol A and DGEBA on wipe samples are shown in Table 2. Bisphenol A was not detected in any of the wipe samples at a limit of detection (LOD) of 0.6 micrograms (µg) per sample. The levels of DGEBA ranged from 5.0 µg/100 square centimeters (cm^2) to 56 µg/100 cm^2. Additional information about epoxy resins can be found in Appendix A. Few standards define "acceptable" levels of workplace surface contamination. Wipe samples provide information about (1) the effectiveness of cleaning practices; (2) exposure by other routes such as dermal or ingestion; (3) contamination of clothing and possible take-home exposures; and (4) settled dust levels from activities such as sweeping or using compressed air to generate airborne contaminants.

Table 2. Results of wipe samples for DGEBA on November 3, 2011

Workstation number/location	Level ($\mu g/100\ cm^2$)
1 – right side of table on slats	41
2 – right side of table on board	56
3 – right side of table on slats	12
4 – right side of table on slats	7.9
5 – right side of table on slats	5.0
6 – right side of table on slats	7.8
7 – right side of table on board	33
8 – empty workstation on board	18
9 – left side of table on board	38
10 – right side on work table	28

The levels of metals and minerals in surface wipes samples were low (Table 3). From the table, the highest levels detected were for calcium and iron. Barium and lithium are not included in Table 3. Barium levels ranged from 0.25 $\mu g/25\ cm^2$ to 1.2 $\mu g/25\ cm^2$. Lithium levels ranged from 0.01 $\mu g/25\ cm^2$ to 0.26 $\mu g/25\ cm^2$. No antimony, arsenic, beryllium, cadmium, lanthanum, molybdenum, silver, tellurium, or thallium was detected above the LOD in any samples. No quantifiable concentrations of cobalt, potassium (except in one sample), tin, titanium, vanadium, or yttrium were found in any of the samples.

Table 3. Wipe sample levels for metals and minerals on November 3, 2011

Workstation	Levels ($\mu g/25\ cm^2$)							
	Al	Ca	Cr	Cu	Fe	Pb	Mn	Ni	Sr
Sander 1	6.1	550	(0.10)*	(1.1)	7.6	(0.22)	0.51	ND	0.3
Sander 2	5.7	520	(0.075)	ND	12	(0.44)	0.67	ND	0.30
Sander 3	8.1	830	(0.095)	(2.0)	11	ND	0.73	0.65	0.29
Sander 4	(3.1)	580	(0.10)	ND	7.5	(0.29)	0.55	ND	(0.17)
Sander 5	28	930	0.69	3.8	120	(0.28)	6.4	2.0	0.68
Sander 6	(3.7)	610	(0.088)	ND	9.8	ND	1.3	ND	0.24
Sander 7	7.2	450	(0.21)	ND	22	ND	1.3	(0.26)	0.62
Sander 8	6.4	900	(0.18)	ND	45	(0.23)	1.7	(0.51)	1.7
Sander 9	31	1400	0.53	(2.5)	110	(0.22)	2.9	5.7	2.8
Sander 10	21	580	0.75	(1.3)	61	ND	2.9	2.0	1.0
LOD	2	4	0.07	1	0.6	0.2	0.1	0.2	0.05
LOQ	5.5	12	0.23	3.7	1.9	0.82	0.49	0.60	0.18

Al = Aluminum, Ca = Calcium, Cr = Chromium, Cu = Copper, Fe = Iron, Pb = Lead,

Mn = Manganese, Ni = Nickel, Sr = Strontium

LOQ = limit of quantitation

ND = not detected

*Values in parentheses indicate concentrations above the LOD but below LOQ. Parentheses are used to indicate there is more uncertainty associated with these values.

Observations

The downdraft tables did not capture dust generated when sanding about 1 foot above the workbench surface. Several of the furniture frames were about 3 feet tall, and some of the pieces were being sanded on the floor because they were too big to place on the downdraft tables. The downdraft ventilation make-up air was drawn from other parts of the building. Compressed air was used to clean off the chairs, which increased the airborne dust levels in the clean-up department. There was no general ventilation system for the building. The smoke tube traces showed little air movement in the general area of the sanders except near the downdraft tables. The facility had a hot water heating system for the cooler months with natural gas heating units at the building entrances for supplemental heating. Personal cooling fans were used throughout the work area for comfort.

Discussion

Eight employees working in the sanding department, or who had worked in sanding previously, reported having a recent or current rash. Our wipe samples of work surfaces in the sanding department found low levels of DGEBA, indicating that employees had potential for skin contact with this epoxy resin component. We also found low levels of metals and minerals in surface wipe samples and low concentrations of airborne VOCs. The most likely cause for the recent rashes among sanders was the increased use of epoxy resin compounds in the past few years, the method of hand-mixing of epoxy resin systems, and lack of protective glove use until the month before our site visit. The gloves that were used provided some protection but were not the best material for the type of chemicals in use.

Employees who have contact with epoxy resin may become sensitized and experience an allergic skin and/or respiratory reaction. The most frequent type of skin disorder that results from epoxy resin system exposures is allergic contact dermatitis. Concurrent use of irritant chemicals, such as solvents and amine hardeners, increase the risk of skin sensitization [Bjorkner 1999]. Exposure to paints, surface coatings, and adhesives has been reported to be the most common cause of occupational skin disorders induced by epoxy resin systems. About 90% of allergic contact dermatitis caused by epoxy resin systems is due to epoxy resin made from DGEBA [Bjorkner 1999]. Medical record review found that one employee underwent dermatologic skin patch testing and was diagnosed with skin allergy to bisphenol A, a component of DGEBA which is the compound contained in the epoxy mix the sanders used. Irritant contact dermatitis may also develop from DGEBA exposure but is less common. Contact urticaria (hives) and occupational asthma have also been reported following DGEBA epoxy resin exposure [Cao et al. 2009]. One employee who developed asthma symptoms after being hired felt the symptoms were related to work.

The risk of allergic skin rash increases in employees who handle uncured epoxy resins. The hands and forearms are most commonly affected by dermatitis, but the neck and face may also be involved because of indirect contact with the hands or airborne exposure. The hardeners and reactive diluents in the epoxy resin systems are typically more volatile than the epoxy resins so, if an employee becomes sensitized to one of these ingredients, dermatitis of the face, eyelids, and neck is more likely to occur. Skin patch testing is necessary to determine which allergen(s) the employee is sensitized. If testing the employee with standardized concentrations of allergens does not detect sensitization, additional testing with workplace concentrations of components may be needed [Cao et al. 2009].

Studies on the prognosis of occupational contact dermatitis stress the importance of primary prevention. One study found that 25% of 540 surveyed patients had persistently severe or aggravated symptoms 1 year after initial diagnosis of occupational hand dermatitis. Poor prognosis was associated with the presence of atopic dermatitis and being 25 years of age or older. Prognosis was not affected by whether the dermatitis was irritant or allergic [Cvetkovski et al. 2006]. Widespread hand dermatitis on initial examination was found to be the greatest factor for a poor long-term prognosis in another study [Meding et al. 2005]. In addition, many skin disorders, including contact dermatitis, have been shown to have a significant impact on quality of life [Kadyk et al. 2003; Cvetkovski et al. 2005; Fowler et al. 2006; Lan et al. 2008].

Conclusions

Sanding employees had skin exposure to uncured epoxy resin during work tasks such as mixing and applying epoxy resins to chair frames. The wipe samples showed that one of the epoxy components (DGEBA) was present in the dust at the sanders' work stations. We found little dust control when employees sanded large chair frames. Of the 18 employees we interviewed, 8 reported history and symptoms and/or signs of work-related rash. Skin contact with epoxy resin may cause allergic contact dermatitis and occupational asthma. The increased use of epoxy resin 18 months before our site visit, insufficient dust control during sanding, and lack of skin protection likely played a major role in the development of dermatitis among sanders.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the furniture company to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the furniture company.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix A). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Consider using premixed colored epoxy resins so employees do not need to mix epoxy resins to match chair colors.
2. Investigate options for a substitute for epoxy resins that has fewer potential health effects.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Use a dispensing gun to apply the epoxy resins.
2. Use a vacuum system with high efficiency particulate air (HEPA) filtration instead of compressed air to clean furniture frames.
3. Add local exhaust ventilation to the hand-held sanders to control dust because the downdraft tables are too small for the larger furniture pieces. Refer to the ACGIH publication, Industrial Ventilation: A Manual of Recommended Practice for Design for further guidance [ACGIH 2010].

Administrative Controls

The term "administrative controls" refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Educate employees to recognize the hazards of epoxy resin exposure and to use work practices that prevent skin exposure to epoxy resin components. Instruct employees how to wear gloves and, if epoxy resins touches the skin, to wash it off with soap and water as soon as possible. Review skin protection techniques and spill clean-up procedures with employees.
2. Encourage employees to report all potential work-related skin and respiratory problems to their supervisors. These problems should be investigated individually by the company or consulting healthcare providers. Because the work-relatedness of skin and respiratory diseases may be difficult to prove, each person with possible work-related skin or respiratory problems should be fully evaluated by a physician with expertise in occupational medicine. A complete evaluation would include a full medical and occupational history, a medical exam, a review of exposures, and

complete follow-up to note the progress of the affected worker. Employees with persistent work-related dermatitis need to be referred to a dermatologist for possible diagnostic tests such as skin patch tests to detect causes of allergic contact dermatitis. Employees with persistent work-related respiratory problems need to be referred to a pulmonologist familiar with workplace respiratory disorders.

3. Protect individuals with definite or possible occupational skin or respiratory diseases from exposures to substances that cause or exacerbate the disease. In some cases of allergic asthma and allergic contact dermatitis, employees may need to be reassigned with retention of pay and employment status to areas where exposure is minimal or nonexistent.
4. Monitor reported health problems systematically to identify particular job duties, work materials (such as epoxy resins), machines, or areas of the plant that may be associated with certain health effects.
5. Consider developing a skin and respiratory surveillance program to identify skin and respiratory conditions that could lead to an occupational disease.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Provide employees with adequately protective gloves when they work with epoxy resins. Gloves recommended for use when handling DGEBA epoxy resins include polyvinyl alcohol and Barrier®, Silver Shield/4H®, and Tychem® [Forsberg and Mansdorf 2007]. Natural rubber, neoprene rubber, polyethylene, and polyvinyl chloride gloves are not protective for epoxy resins.
2. Provide employees with safety glasses or goggles to protect eyes from epoxy resins.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limit (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by ACGIH, a professional organization, and the workplace environmental exposure levels (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs

are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2013]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2013].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause 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))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Below we provide the OELs and surface contamination limits for the compounds we measured, as well as a discussion of the potential health effects from exposure to these compounds.

Volatile Organic Compounds

VOCs are a large class of low molecular weight chemicals that are organic (i.e., containing carbon) and have a sufficiently high vapor pressure to allow some of the compounds to exist in the gaseous state at room temperature. The health effects associated with VOCs depend on the toxicity of the specific VOC, the level of exposure, and the duration of the exposure [EPA

2013]. Symptoms experienced from exposure to VOCs may include eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment [NIOSH 2010]. The most common route of exposure to VOCs is through inhalation, but some solvents may contribute to systemic health effects through skin absorption [LaDou 2004; Klaassen 2008]. The rate of systemic elimination of solvents depends on how volatile and lipophilic the chemicals are. Some subpopulations may be more susceptible to health effects from solvents based on age, sex, and genetics [Klaassen 2008]. VOCs are emitted in varying concentrations from numerous indoor sources including, but not limited to, carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources. Heating, burning, or chemical reactions may cause materials to emit VOCs. The most common work practice leading to solvent-related dermatitis is washing the hands with a solvent. Because solvents tend to combine with lipids, they can dry out the skin. NIOSH and ACGIH have recommended occupational exposure limits for many VOCs [NIOSH 2010; ACGIH 2013]. OSHA also has standards and/or PELs for many VOCs [29 CFR 1910.1000].

Epoxy resins

Epoxy resin systems are used in protective surface coatings and adhesives and consist of uncured epoxy monomers plus additives, e.g., hardeners, metallic compounds, plasticizers, solvents, flame retardants. Of these systems, 75% to 90% are based on DGEBA. About 1 million tons of epoxy resins are produced annually worldwide. Other synthetic plastic resin systems include methacrylic, polyurethane, and phenol-formaldehyde, but epoxy resin systems are responsible for the largest share of dermatologic disorders [Cao et al. 2009].

Epoxy resin systems with DGEBA vary as to the amounts of low and high molecular weight resins. Sensitization appears to decrease as the average molecular weight increases. High-molecular weight epoxy resins in solvents for paint and in powder form for electrostatic coating of metals rarely cause sensitization. As much as 25% of epoxy resin has been found to remain unhardened after it is thought to be "cured." When cured at room temperature, a small percentage of the resin may remain uncured for several days or more. Tiny amounts of unhardened epoxy resin have been found in twist off caps, furniture, textile labels, nasal cannulas, polyvinyl chloride plastic, among other products, which may produce an allergic skin reaction in persons already sensitized [Bjorkner 1999].

The most frequent type of skin disorder that results from epoxy resin system exposures is allergic contact dermatitis, most of which arises from workplace exposures. Finnish studies have found that epoxy resin system compounds are responsible for 7%–12% of current occupational allergic contact dermatitis cases. Depending on the study, they are the second or third most common cause of work-related allergic contact dermatitis. Exposure to paints, surface coatings, and adhesives has been reported to be the most common cause of occupational dermatoses induced by epoxy resin systems. About 60%–80% of patients with allergic contact dermatitis to epoxy resins are sensitized to DGEBA. About 90% of contact dermatitis caused by epoxy resin systems is due to epoxy resin made from DGEBA [Bjorkner 1999]. Irritant contact dermatitis is a less common form of occupational contact dermatitis related to DGEBA epoxy resin exposure; contact urticaria and occupational asthma have also been reported [Cao et al. 2009].

Sensitization is usually seen in employees who handle uncured epoxy resins. The hands and forearms are most commonly affected by dermatitis, but the neck and face may also be involved because of indirect contact with the hands or airborne exposure. The hardeners and reactive diluents in the epoxy resin systems are typically more volatile than the epoxy resins so, if an employee becomes sensitized to one of these ingredients, dermatitis of the face, eyelids, and neck is more likely to occur. Skin patch testing is necessary to determine which allergen(s) the employee is sensitized to. If testing the employee with standardized concentrations of allergens does not detect sensitization, additional testing with workplace concentrations of components may be needed [Cao et al. 2009].

Employees who handle epoxy compounds should be informed of the risk of skin sensitization and be advised to avoid skin contact. Concurrent use of irritant chemicals, such as solvents and amine hardeners, increase the risk of sensitization. Epoxy resins penetrate plastic and rubber gloves, so only polyvinylalcohol gloves provide adequate protection. Multilayered gloves, such as Barrier®, Silver Shield/4H®, and Tychem®, give even better protection [Forsberg and Mansdorf 2007]. Cleaning and maintenance of all contaminated equipment is also necessary. The use of epoxy resin systems with the least amount of low-molecular weight epoxy resin and high-molecular weight reactive diluents will reduce their sensitizing potential [Bjorkner 1999].

Employees sensitized to components of epoxy resin systems should avoid exposure. If employees continue to have skin symptoms, they may need to transfer to a different job without exposure. Immediate job change after sensitization has been found to prevent aggravation of dermatitis symptoms and also may prevent the employee from developing further sensitization to other epoxy resin system components [Cao et al. 2009].

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The Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 (29 U.S.C. 669(a)(6)) or the Federal Mine Safety and Health Act of 1977 (30 U.S.C. 951(a)(11)). The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational illness. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations (42 CFR 85).

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Copies of this report have been sent to the employer, employees, and union at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy.

This report is available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2011-0180-3193.pdf.

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