CDC Workplace Safety and Health

Evaluation of Exposure to Toluene, Ethanol, and Isopropanol at an Electronics Manufacturer – Ohio

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Health Hazard Evaluation Report
HETA 2009-0070-3137
August 2011

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

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

°F	Fahrenheit
ACGIH®	American Conference of Governmental Industrial Hygienists
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CFR	Code of Federal Regulations
fpm	Feet per minute
ft^2	Square feet
GA	General area
HHE	Health hazard evaluation
LEV	Local exhaust ventilation
mg	Milligram
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL™	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation (HHE) at an electronics manufacturer in Ohio. Managers were concerned about the potential hazards from chemical odors in the electrical connecter assembly operations.

What NIOSH Did

- We evaluated the facility on February 23, 2009, and again on June 18, 2009.
- We looked at work processes, practices, and conditions at the facility. We also talked with employees about their work practices and processes.
- We took air samples for toluene and ethanol during gluing and oven curing operations.
- We took air samples for isopropanol during shell dipping operations.
- We evaluated the local exhaust ventilation in the gluing and oven curing area.
- We tested for lead on the surface of electrical shells.

What NIOSH Found

- Exposures to toluene, ethanol, and isopropanol were low. The levels we found were well below occupational exposure limits.
- Local exhaust ventilation was not always effective in controlling nuisance odors in the gluing and oven curing area.
- Lead was not detected on the electrical shells.

What Managers Can Do

- Improve the local exhaust ventilation in the gluing and oven curing area.
- Consider adding local exhaust ventilation in the shell dipping area if isopropanol nuisance odors continue to be a problem.
- Give employees who voluntarily wear respiratory protection a copy of the OSHA Respiratory Protection Standard. This document can be found in Appendix D of the standard.

What Employees Can Do

- Keep glue and isopropanol lubricant off of your skin. If you can't do this through careful handling of parts, you should wear gloves.

Summary

In January 2009, NIOSH received an HHE request from an electronics manufacturer in Ohio. The request concerned the potential for exposure to toluene and ethanol when gluing and oven curing electrical contacts to electrical shells and exposure to isopropanol when placing rubber inserts and electrical contacts into electrical shells.

NIOSH investigators made site visits to the electronics manufacturer facility on February 23, 2009, and June 18, 2009. We walked through the facility and observed work processes, practices, and conditions. We spoke with employees about health and workplace concerns and collected air samples. We used colorimetric detection tubes on February 23, 2009, to estimate air concentrations of toluene and ethanol in the gluing and oven curing area. On a return site visit on June 18, 2009, we collected full-shift and short-term air samples for toluene and ethanol in the gluing and oven curing area. We also collected task-based and short-term air samples for isopropanol in the shell dipping area. We evaluated the LEV in the gluing and oven curing area using a thermoanemometer and smoke tubes. Finally, we used colorimetric lead swabs to determine if lead was present on the electrical shells.

NIOSH investigators evaluated the potential for exposure to chemicals at an electrical connector manufacturer. We found that the air concentrations of toluene, ethanol, and isopropanol were very low, less than 6% of OELs. To reduce toluene and ethanol nuisance odors, we recommend changes to the LEV in the gluing and oven curing area. Additionally, installing LEV in the shell dipping area may reduce isopropanol nuisance odors.

We detected measurable levels of toluene, ethanol, and isopropanol; however, all samples were less than 6% of applicable OELs. Some skin contact to isopropanol was observed during the shell dipping process. Employees did not wear gloves to protect against skin exposure to these chemicals. LEV systems in the gluing and oven curing area were present but were not working optimally. Lead was not detected on the surface of the electrical shells.

Several strategies could be used to minimize exposures and improve effectiveness of the LEV systems in the gluing and oven curing area. When the LEV on either the gluing station or oven is not in use, close the damper to increase the capture efficiency. Redesign the hood types and/or place the hoods closer to contaminants for better capture efficiency. Similarly, for the shell dipping area, an LEV unit could be added to reduce nuisance odors. Gloves should be used if dermal exposure to the glue or shell dipping solution is anticipated. Employees who choose to wear respiratory protection voluntarily during work activities should be provided with Appendix D of the OSHA Respiratory Protection Standard (29 CFR 1910.134).

Keywords: NAICS 423690 (Other electronic parts and equipment merchant wholesalers), toluene, ethanol, isopropanol, lead, CAS 64-17-5, CAS 67-63-0, CAS 108-88-3, CAS 7439-92-1, local exhaust ventilation, LEV, nuisance odors, skin contact

Introduction

NIOSH received a management request for an HHE at an Ohio electronics manufacturer on January 16, 2009. The request concerned the potential for exposure to chemicals during assembly, gluing, and oven curing of electrical connectors. In response to the HHE request, NIOSH investigators visited the facility on February 23, 2009, and June 18, 2009, to evaluate employee exposures to toluene, ethanol, and isopropanol. We also evaluated engineering controls in the gluing and oven curing area.

Process Description

The electronics manufacturer built electrical connectors for the electronics and automobile industries. The facility consisted of two buildings. One building served as a warehouse and an office. The other building was used for manufacturing operations including shell dipping, assembly, gluing, and oven curing of electrical connectors. At the time of the evaluation 16 employees were at the facility, two of whom worked in the manufacturing building.

In the assembly area, one employee dipped metal electrical shells containing rubber inserts into a 50:50 ratio of isopropanol in water. This mixture acted as a lubricant so that electrical contacts could be placed into these rubber inserts. The employee was not wearing gloves, and no ventilation controls were present in this area.

In the gluing area, one employee glued electrical contacts onto the rubber inserts using a small amount (approximately 1–5 milliliters) of glue fed through a foot-controlled syringe that was mounted to the workstation. Approximately 500–800 contacts were glued per hour. After the contacts were glued in place, the electrical connectors were placed in a small oven and cured for approximately 20 minutes at 320°F. LEV systems were used in this area, which included a dampered flex-tube exhaust vent with a round inlet approximately 9 inches above the gluing station and a dampered canopy exhaust hood over the oven to capture heat and chemical vapors from the curing process. After air was collected by the LEV systems, it passed through an energy recovery unit and was exhausted to the outside on the rooftop of the building. The gluing and oven curing processes were performed intermittently; approximately 1 gallon of glue was used every 3–4 months. The gluing and oven curing employee wore an N95 filtering facepiece respirator with a carbon filter to reduce nuisance odors (Moldex® 2801N95, Culver City, California) during gluing activities.

Introduction (continued)

Manufacturer information on hazardous metal content in the electrical shells was provided by the electronics manufacturer. This information indicated that the electrical shells had low concentrations of lead and cadmium.

Assessment

Initial Evaluation

On February 23, 2009, we held an opening meeting with management and employee representatives followed by a tour of the facility. We talked with employees, observed work procedures, and used colorimetric detection tubes to evaluate air concentrations of toluene and ethanol during gluing and oven curing processes. We also evaluated the LEV in the gluing and oven curing area. This included measuring the rate of air flow across the face of the oven canopy exhaust hood and gluing station flex-tube exhaust vent. We used smoke to visualize how well the LEV captured air near the gluing and oven stations. Specifically, smoke was generated at the gluing station and oven door to determine if the LEV for each of these processes could effectively capture the smoke. Air flow measurements were made, and smoke capture was observed when the dampers were open on both LEV systems. We repeated these measurements at the oven canopy exhaust hood after closing the damper on the gluing station flex-tube exhaust vent. Similarly, measurements were repeated at the gluing station flex-tube exhaust vent after closing the damper on the oven canopy exhaust hood.

Return Evaluation

We made a return visit on June 18, 2009, to collect full-shift and short-term PBZ and GA air samples for toluene and ethanol during gluing and oven curing processes. PBZ air samples were collected on the gluing and oven curing operator over the entire work shift. Additional short-term PBZ air samples were collected for toluene and ethanol on this same employee during gluing and when loading and unloading the oven with electrical connectors. Full-shift GA air samples for toluene and ethanol were also collected near the oven.

One task-based (164 minutes) and two short-term PBZ samples (15 to 16 minutes each) were collected on another employee for isopropanol during the shell dipping operation. After the shell dipping process was completed, the operator removed the isopropanol from the work area and worked on other job tasks (without isopropanol exposure) for the remainder of the work shift. A full-shift sample was not collected because no exposure to isopropanol was anticipated after the operator finished the shell dipping process. The time that it takes to complete this process is highly variable and is dependent on work load.

We also tested the surface of the electrical shells for lead using colorimetric swabs. Details on the methods for air and surface sampling, environmental measurements, and the LEV system evaluation are presented in Appendix A. A discussion on OELs and potential health effects is presented in Appendix B.

Results and Discussion

Air Sampling

Colorimetric detection tube samples were used as a screening tool to help determine the sampling strategy used during the site visit on June 18, 2009. Our colorimetric detection tube results from February 23, 2009, indicated that toluene and ethanol were present in the air near the gluing and oven curing operator during the gluing process. Instantaneous concentrations ranged from 5–10 ppm for toluene and 500–1000 ppm for ethanol. Toluene and ethanol concentrations were below the limit of detection for samples collected near the oven door when it was opened to unload cured connectors. The colorimetric tubes have a detection limit of 5 ppm for toluene and 25 ppm for ethanol. The toluene concentrations that were measured were well below the NIOSH STEL and OSHA ceiling and peak limits (Table 1). Ethanol has no STELs; however, these results revealed that ethanol was present in the gluing process, which confirmed our decision to conduct follow-up sampling for ethanol on the second site visit.

Tables 1–3 provide the results for the PBZ and GA integrated air sampling for toluene, ethanol, and isopropanol conducted on June 18, 2009. Full-shift PBZ and GA samples for toluene and ethanol collected during gluing and oven curing operations showed detectable levels of these compounds; however, the exposures were <1% of applicable OELs (Tables 1 and 2). Similarly, short-term PBZ samples for toluene and ethanol collected on the gluing and oven curing operator when gluing were <1% of applicable OELs for these chemicals (Tables 1 and 2). The task-based isopropanol sample TWA was 9.5 ppm, which is less than 2% of existing OELs assuming no exposure for the employee during the unsampled time (Table 3). The short-term samples for isopropanol had concentrations less than 6% of existing STELs. All of the measured exposures for toluene, ethanol, and isopropanol were low compared to the most conservative OELs for these chemicals.

Table 1. PBZ and GA air sampling results for toluene during gluing and curing operations

Activity	Sample Type	Total Time (minutes)	Volume (liters)	Sample Concentration (ppm)*	TWA Concentration (ppm)*
Gluing and Oven Curing	PBZ	216	4.49	0.21	0.13
		180	3.74	0.09	
		15	2.99	0.98	—
		16	3.19	[0.06]	—
	GA	240	4.68	[0.04]	[0.04]
		209	4.11	[0.04]	

OELs (ppm)		
NIOSH REL†	OSHA PEL†	ACGIH TLV‡
100 TWA; 150 STEL	200 TWA; 300 ceiling; 500 peak	20 TWA

* Concentrations in brackets were between the minimum detectable concentration and the minimum quantifiable concentration (brackets are used to point out that there is more uncertainty associated with these values than with values above the minimum quantifiable concentration).
† [NIOSH 2005]
‡ [ACGIH 2010a]

Table 2. PBZ and GA air sampling results for ethanol during gluing and curing operations

Activity	Sample Type	Total Time (minutes)	Volume (liters)	Sample Concentration (ppm)	TWA Concentration (ppm)
Gluing and Oven Curing	PBZ	218	10.79	4.0	2.6
		180	8.91	0.8	
		16	0.795	ND*	—
	GA	245	12.59	0.5	0.5
		214	10.99	0.6	

OELs (ppm)		
NIOSH REL†	OSHA PEL†	ACGIH TLV‡
1000 TWA	1000 TWA	1000 TWA

* Ethanol was not detected above the minimum detectable concentration of 2.5 ppm.
† [NIOSH 2005]
‡ [ACGIH 2010a]

Table 3. PBZ sampling results for isopropanol during shell dipping operations

Activity	Sample Type	Total Time (minutes)	Volume (liters)	Sample Concentration (ppm)	TWA Concentration (ppm)
Shell dipping	PBZ	114	2.25	9.4	9.5
		50	0.99	9.9	
		15	2.99	22	—
		16	3.19	7.7	—

OELs (ppm)		
NIOSH REL*	OSHA PEL*	ACGIH TLV†
400 TWA; 500 STEL	400 TWA	200 TWA; 400 STEL

* [NIOSH 2005]
† [ACGIH 2010a]

The air concentrations measured for toluene and isopropanol on June 18, 2009, were above established odor thresholds for these chemicals [AIHA 1989], so it is not unexpected that nuisance odors were reported by employees in the areas where these chemicals were used.

Currently, employees do not wear gloves to protect against dermal exposure to the substances noted above. Although skin contact with the glue was not observed, some skin contact with the isopropanol-containing lubricant was noted. Employees rely on careful handling of parts while applying glue and lubricant. This practice has resulted in no dermal-related health concerns to date, but there is potential for dermal exposure. Even though employees work with small parts, commercially available high dexterity chemical protective gloves would help protect the employees' skin while performing these tasks.

Wipe Sampling

We did not detect lead on the surface of the electrical shells using colorimetric swab sampling. The colorimetric swabs are sensitive to a concentration of 1 microgram on solid surfaces.

Local Exhaust Ventilation

Table 4 summarizes the smoke tube testing and air velocity measurements on the LEV used in the gluing and oven curing area. Smoke tube testing demonstrated effective capture of smoke at the gluing station by the flex-tube exhaust vent when the damper on the canopy exhaust hood above the oven was closed. Similarly, effective capture of smoke at the oven door, by the canopy exhaust hood above the oven, was noted when the damper on the gluing station LEV was closed. When both dampers were open, both LEV systems showed some air turbulence and ineffective capture of smoke. The mean air velocities were higher for both LEV systems when the damper on the opposite LEV was closed. ASHRAE recommends that capture velocity, which is the air velocity at the point of contamination, should be 50–100 fpm when contaminants are "released with essentially no velocity into still air" [ASHRAE 2007]. The capture velocity was 26 fpm at the gluing station with both dampers open, which is less than is recommended by the ASHRAE guidelines [ASHRAE 2007]. However, meeting this ASHRAE guideline may not necessarily reduce nuisance odors from the gluing process. Capture velocities were not collected at the oven, so a comparison to the ASHRAE guidelines cannot be made using our data.

Table 4. Evaluation of the LEV used in the gluing and oven curing area

Type of LEV	Area of face (ft^2)	Face velocity (fpm) Range	Face velocity (fpm) Mean	Effective capture of smoke?
Oven canopy exhaust hood				
Damper on gluing station LEV closed	4.0	5–80	45	Yes
Damper on gluing station LEV open	4.0	2–40	23	No
Gluing station flex-tube exhaust vent				
Damper on oven LEV closed	2.6	335–400	377	Yes
Damper on oven LEV open	2.6	200–240	226	No

Nuisance odors were evident in the shell dipping and gluing and oven curing areas. Moving the flex-tube exhaust vent inlet closer to the gluing station would result in more efficient capture of odors. Alternatively, the use of a slot ventilation system or a downdraft table would also provide better capture efficiency of contaminants in both areas. Additional information on these LEV hood designs can be found in the ACGIH publication "Industrial Ventilation: A Manual of Recommended Practice for Design" [ACGIH 2010b].

Conclusions

Air sampling did not identify exposures over OELs to chemicals used in the gluing and oven curing or shell dipping areas. An evaluation of the LEV systems showed ineffective capture of contaminants when both LEV system dampers were open. Also, the potential for dermal exposure to glue components and lubricant was observed.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the electronics manufacturer to use a labor-management health and safety committee or working group to discuss the recommendations in this report 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 electronics manufacturer. Our recommendations are based on the hierarchy of controls approach (Appendix B: Occupational Exposure Limits and Health Effects). 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/or personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee.

1. Use the recommendations below to improve the existing LEV systems in the gluing and oven curing area even though measured exposures to toluene and ethanol were low. Although these engineering controls may help to reduce nuisance odors in the gluing and curing and the shell dipping areas, it may be difficult to reduce concentrations of these chemicals to below odor thresholds. For all of these chemicals, our measurements were above odor thresholds but well below OELs, and are unlikely to cause health effects at the measured concentrations.

a. Move the adjustable dampers on the flex-tube exhaust vent at the gluing station and the canopy exhaust hood over the oven to the closed position when either of the LEV systems is not in use. This increases the capture efficiency of the LEV that is in use.

b. Move the flex-tube exhaust vent inlet closer to the gluing station for better capture efficiency. Alternatively, consider a redesign of the flex-tube exhaust vent that will provide better capture efficiency of contaminants such as a slot ventilation system or downdraft table. With any LEV design or modification, we recommend consulting with a licensed engineer familiar with industrial ventilation design.

c. Consider adding LEV in the shell dipping area if nuisance odors continue to be a problem. Possible designs could include a slot ventilation system or downdraft table.

Personal Protective Equipment

PPE is the least effective means for controlling employee exposures. Proper use of PPE requires a comprehensive program, and calls for a high level of employee involvement and commitment to be effective. The use of PPE requires the choice of the appropriate equipment to reduce the hazard and the development of supporting programs such as training, change-out schedules, and medical assessment if needed. PPE should not be relied upon as the sole method for limiting employee exposures. Rather, PPE should be used until engineering and administrative controls can be demonstrated to be effective in limiting exposures to acceptable levels.

1. Prevent skin contact with toluene, ethanol, and isopropanol. When working with glue containing toluene and ethanol, glove materials such as Viton®, Barrier® (PE/PA/PE), Silver shield/4H® (PE/EVAL/PE) and Tychem® CPF3 should provide greater than 8 hours of dermal protection [Forsberg and Mansdorf 2007]. For isopropanol, all of the gloves types listed above can be used as well as some others including, butyl rubber, neoprene rubber, nitrile rubber, Viton®/butyl rubber, Tychem® F, and Tychem® Responder®. These glove materials should provide greater

Recommendations (continued)

than 8 hours of dermal protection [Forsberg and Mansdorf 2007]. The recommendation for use of neoprene and nitrile rubber gloves is not valid for gloves that are 3 millimeters or less in thickness.

2. Ensure that employees who voluntarily wear filtering facepiece respirators are provided with a copy of Appendix D of the OSHA Respiratory Protection Standard [29 CFR 1910.134] titled "Information for Employees Using Respirators When Not Required Under the Standard." Additionally, the OSHA Small Entity Compliance Guide provides guidance on voluntary respirator usage and additional information on respiratory protection at http://www.osha.gov/Publications/secgrev-current.pdf.

References

ACGIH [2010a]. 2010 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2010b]. Industrial ventilation: a manual of recommended practice for design. 27th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, pp. 6-1–6-40.

AIHA [1989]. Odor thresholds for chemicals with established occupational health standards. Fairfax, VA: American Industrial Hygiene Association, Table 5.3.

ASHRAE [2007]. Industrial local exhaust systems. In: 2007 ASHRAE Handbook - HVAC Applications. I-P Edition. Atlanta, GA: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, Inc., p. 30.2, Table 1.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Forsberg K, Mansdorf SZ [2007]. Quick selection guide to chemical protective clothing. 5th ed. Hoboken, NJ: John Wiley & Sons, Inc., pp. 132, 135, 137.

NIOSH [2005]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149. [http://www.cdc.gov/niosh/npg/]. Date accessed: June 2011.

Air Sampling for Toluene, Ethanol, and Isopropanol

During the first site visit on February 23, 2009, sampling for toluene and ethanol was conducted using Drägertube® colorimetric detection tubes attached to a handheld accuro® pump (Dräger, Lübeck, Germany). Toluene samples were collected on Toluene 5/b tubes (standard measuring range is 5–300 ppm); ethanol samples were collected on Alcohol 25/a tubes (standard measuring range is 25–2000 ppm).

During the second visit on June 18, 2009, SKC Pocket Pumps® (SKC Incorporated, Eighty Four, Pennsylvania) were used for drawing airflows of 20, 50, and 200 cubic centimeters per minute through the sampling media, depending on the type of sample collected. All pumps were precalibrated and postcalibrated with the sampling media connected. Toluene samples were collected on SKC charcoal tubes (100 mg/50 mg) (SKC 226-01, lot 2000) and analyzed using NIOSH Method 1501 modified for gas chromatography/mass spectrometry [NIOSH 2010]. Ethanol samples were collected on SKC Anasorb 747 tubes, parts A and B (SKC 226-82, Lot 5414) and analyzed using OSHA Method 100 [OSHA 2010]. Isopropanol samples were collected on SKC charcoal tubes (100 mg/50 mg) (SKC 226-01, lot 2000) and analyzed using NIOSH Method 1400 [NIOSH 2010].

Colorimetric Surface Sampling

LeadCheck® colorimetric swabs (Hybrivet Systems, Incorporated, Natick, Massachusetts) were used to determine the presence of lead on the surface of the electrical shells. The swab is activated by crushing two ampoules within the swab, which moistens a wick on the end of the swab. The moistened wick is brushed onto a surface and turns red upon the presence of lead in surface concentrations greater than 1 microgram. Swabs were brushed over the interior and exterior surfaces of the electrical shells. Swabs were also brushed onto a confirmation card that was provided with the swabs. This confirmation card contains a small amount of lead, and confirms that the colorimetric swabs are working correctly.

Ventilation Measurements

A TSI VelociCalc® Plus air velocity meter, model 8386A (TSI, Inc, Shoreview, Minnesota) was used to measure air velocity at the face of the LEV. Air velocity measurements were collected at approximately 3-inch intervals across the face of the gluing station flex-tube exhaust vent, and at approximately 8-inch intervals across the oven canopy exhaust hood. The capture efficiency of these LEV systems was also evaluated using irritant smoke tubes (Gastec Corporation, Kanagawa, Japan). To visualize the capture efficiency, smoke was generated in the work area where contaminants were to be generated.

References

NIOSH [2010]. NIOSH manual of analytical methods (NMAM®). 4th ed. Schlecht PC, O'Connor PF, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 94-113 (August, 1994); 1st Supplement Publication 96135, 2nd Supplement Publication 98-119; 3rd Supplement 2003-154. [http://www.cdc.gov/niosh/nmam/] Date accessed: June 2011.

OSHA [2010]. OSHA sampling and analytical methods. Hendricks W, ed. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration. [http://www.osha.gov/dts/sltc/methods/index.html] Date accessed: June 2011.

Appendix B: Occupational Exposure Limits and Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by federal agencies and safety and health organizations to prevent the occurrence of 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 from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or 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 employee to produce adverse health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a 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 STEL or ceiling values at which adverse health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time. The short-term exposures represent conditions to which workers can be exposed continuously for a short period of time without suffering acute effects such as (1) irritation; (2) chronic or irreversible effects; (3) dose-rate dependent toxic effects; or (4) narcotic effects that may cause accidental injury, impaired self rescue, or reduced work efficiency [ACGIH 2010].

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, while 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 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 available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2005]. NIOSH also recommends different types of 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 from these hazards.

Other OELs that are commonly used and cited in the United States include the TLVs recommended by ACGIH, a professional organization, and the WEELs 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. They are not consensus standards. ACGIH 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 2010].

WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2010].

Outside the United States, OELs have been established by various agencies and organizations and include both 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/en/gestis/limit_values/index.jsp, contains international limits for over 1,500 hazardous substances and is updated periodically.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. 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))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessments and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified 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 that focuses resources on exposure controls by describing how a risk needs to 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 the OELs, when available.

Health Effects of Organic Solvents

Organic solvents are a large class of chemicals that contain carbon and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. These chemical compounds are commonly used for tasks such as cleaning, painting, printing, degreasing, thinning, and extraction. OELs exist for some individual organic solvents, but do not exist for organic solvents as a group. Some of the organic solvents used in this facility include toluene, ethanol, and isopropanol. Toluene and ethanol are ingredients in the glue used to secure contacts to the electrical shells. Isopropanol is used to clean the rubber inserts before placing them into the electrical shells.

Inhalation and dermal exposure are important routes of exposure to organic solvents in the workplace. Absorption through the skin depends upon the degree of lipid and water solubility of the solvent [Rosenberg et al. 1997]. Almost all organic solvents cause irritation of the skin because they remove fat from the skin. Solvents are also among the leading causes of occupational skin disease [Cone 1986]. Organic solvents may cause minimal to mild irritation of the respiratory system [Blanc et al. 1991]. This irritation is usually restricted to the upper airways, mucous membranes and eyes, and it generally resolves quickly without long-term effects [Rosenberg et al. 1997].

Almost all volatile organic solvents can acutely cause nonspecific central nervous system depression. The symptoms of significant acute solvent exposure are similar to those from drinking too many alcoholic beverages, including headache, nausea and vomiting, dizziness, slurred speech, impaired balance, poor concentration, disorientation, and confusion. These symptoms go away quickly upon cessation of exposure [Gerr and Letz 1998]. Peripheral neuropathies and chronic central nervous system disorders (organic affective syndrome and mild chronic toxic encephalopathy) have been reported among workers chronically exposed to solvents [NIOSH 1987]. Organic affective syndrome is characterized by fatigue, memory impairment, irritability, difficulty in concentration, and mild mood disturbance.

References

ACGIH [2010]. 2010 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2010]. AIHA 2010 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

Blanc PD, Galbo M, Hiatt P, Olson KR [1991]. Morbidity following acute irritant inhalation in a population-based study. JAMA *266*(5):664–669.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Cone JE [1986]. Health hazards of solvents. Occup Med: State of the Art Reviews *1*(1):69–87.

Gerr F, Letz R [1998]. Organic Solvents. Chapter 78. In: Rom WN, ed. Environmental and occupational medicine, 3rd rev. ed. Philadelphia, PA: Lippincott-Raven Publishers, pp.1091–1108.

NIOSH [1987]. Current intelligence bulletin 48: organic solvent neurotoxicity. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication no. 87-104. [http://www.cdc.gov/niosh/87104_48.html]. Date accessed: June 2011.

NIOSH [2005]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149. [http://www.cdc.gov/niosh/npg/]. Date accessed: June 2011.

Rosenberg J, Cone JE, Katz EA [1997]. Solvents. In: LaDou J, ed. Occupational and environmental medicine, 2nd rev. ed. Stamford, CT: Appleton and Lange, pp. 483–513.

Acknowledgments and Availability of Report

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This report was prepared by R. Todd Niemeier of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Industrial hygiene field assistance was provided by Robert McCleery. Health communication assistance was provided by Stefanie Evans. Editorial assistance was provided by Ellen Galloway. Desktop publishing was performed by Robin Smith.

Copies of this report have been sent to employee and management representatives at the electronics manufacturer, the state health department, and the Occupational Safety and Health Administration Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed at http://www.cdc.gov/niosh/hhe/. Copies may be purchased from the National Technical Information Service at 5825 Port Royal Road, Springfield, Virginia 22161.

Below is a recommended citation for this report:
NIOSH [2011]. Health hazard evaluation report: evaluation of exposure to toluene, ethanol, and isopropanol at an electronics manufacturer – Ohio. By Niemeier RT. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA No. 2009-0070-3137.

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