

# Metal Exposures in an Electronic Scrap Recycling Facility

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**HE** Health Hazard  
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The employer is required to post a copy of this report for 30 days at or near the workplace(s) of affected employees. The employer must take steps to ensure that the posted report is not altered, defaced, or covered by other material.

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.

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## Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a manager at an electronic scrap recycling facility. The employer was concerned about exposure to metals, including lead and cadmium, from recycling electronic scrap.

### What We Did

- We evaluated the electronic scrap recycling facility in April and June 2013.
- We interviewed employees about their work practices, symptoms, and health concerns related to work.
- We tested work surfaces, skin, and clothing for metals such as lead, cadmium, chromium, nickel, and mercury.
- We tested employees' urine for cadmium and mercury and their blood for lead and cadmium.

### What We Found

- The employees we interviewed reported no work-related health complaints.
- The employees we interviewed knew about potential hazards in the facility and about required personal protective equipment.
- Two employees had elevated blood lead levels. A blood lead level of 10 micrograms per deciliter or higher is considered elevated.
- Blood and urine cadmium levels were not elevated.
- No mercury was detected in employees' urine.
- We found lead and other metals on the skin of employees at lunch and before going home. We also found metals on nonproduction work surfaces. These metals could be transferred to employee vehicles and homes, and ultimately to family members.
- Lockers stored personal items and food along with work clothing and personal protective equipment.
- Showers and laundered uniforms were only offered to the glass shredding employees.
- Workers unjammed scrap from equipment that was powered on and running.

We evaluated exposure to metals, including lead, at an electronic scrap recycling facility. Some employees had blood lead levels above 10 micrograms per deciliter, a level considered elevated. We provided recommendations to prevent exposure to lead and other metals to employees and to prevent unintentionally exposing family members.

### What the Employer Can Do

- Include all employees exposed to lead in a lead prevention program. Follow the OSHA lead standard and the guidelines for medical monitoring referenced in Appendix B of this report.
- Install a clean locker room area for employees to store personal items and food.

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- Provide scrubs, uniforms, shoe covers, and a contract laundering service for all employees exposed to lead.
  - Require all employees exposed to lead to shower and change clothing before leaving work.
  - Increase the number of sinks for hand washing.
  - Follow lockout/tagout procedures to de-energize machinery before conducting any troubleshooting, repairs, or maintenance.

## **What Employees Can Do**

- Take a shower at the end of the shift. Do not wear or take work clothing or shoes home.
- Wash your hands before eating or smoking.
- Tell your doctor that you work with lead and other metals. Give your doctor a copy of this report.
- See your doctor about blood tests for lead for your children and other family members.

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## Abbreviations

µg	Micrograms
µg/dL	Micrograms per deciliter
µg/g/Cr	Micrograms per gram creatinine
µg/L	Micrograms per liter
µg/m <sup>3</sup>	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
CRT	Cathode ray tube
CFR	Code of Federal Regulations
dBa	decibels A-weighted
LOD	Limit of detection
LOQ	Limit of quantitation
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PPE	Personal protective equipment
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average

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## Introduction

The Health Hazard Evaluation Program received a request from a manager at an electronic scrap (e-scrap) recycling company. The request concerned potential exposure to metals, including lead and cadmium. We visited the facility in April 2013 to observe work processes, learn about the health concerns of employees, take surface wipe samples for metals, and measure area noise levels. We sent a letter summarizing our results and recommendations from this visit to the company and employee representatives in April 2013. We visited the facility again in June 2013 to collect air and surface wipe samples for metals, test employees' blood and urine for metals, and conduct more noise monitoring. We sent letters to the company and employee representatives summarizing our results and recommendations from this visit in July 2013 and February 2014.

## Process Description

The company employed about 80 individuals who processed and recycled computers, monitors, hard drives, televisions, printers, light bulbs, and other e-scrap. All work was done on one shift, five days per week. The production warehouse had three rooms. In the first room, e-scrap was received, stored, inventoried, tested, refurbished (when possible), and sorted. In the second room, called the consumer room, employees did teardown (disassembly) of e-scrap (referred to as teardown in this report). The third room was the shred room where shredding occurred.

Teardown employees disassembled cathode ray tubes (CRTs) from computer monitors and televisions along two parallel consumer teardown conveyors. Employees worked on one side of the conveyor, and dumpsters and large cardboard boxes lined the other side of the conveyor. Forklifts brought loaded pallets of CRTs to the front of the conveyor. Employees manually unloaded the CRTs from the pallets (Figure 1) and placed them onto a conveyor belt where employees used pneumatic pistol grip tools to dismantle them (Figure 2). Plastic cases were removed and thrown into a dumpster. Wiring and circuitry were removed next (Figure 3). Employees removed the yoke and electron gun on the CRT by manually breaking them off, an activity that also released the CRT vacuum. Finally, metal banding and adhesives were removed before the CRT glass was pushed into a large cardboard box at the end of each conveyor. The filled cardboard boxes were weighed and then moved to the shred room with a forklift. The warehouse had no local exhaust ventilation or general ventilation. Pedestal fans circulated room air on warmer days.



Figure 1. Employees unloading televisions from pallets. Photo by NIOSH.



Figure 2. Employees dismantling televisions and computer monitors. Photo by NIOSH.



Figure 3. Employee removing wires and other circuitry before breaking of the electric gun. Photo by NIOSH.

Teardown employees processed large televisions on a conveyor near the consumer teardown lines. The conveyor was fitted with a sheet metal trough that ran the length of the line to keep disassembled parts from spilling onto the floor. Single televisions or pallets of large televisions were delivered by forklift and placed on the floor (Figure 4). Manual teardown was similar to the consumer lines, with plastic components, wiring, and circuitry placed on a roller conveyor for manual sorting into cardboard boxes or dumpsters. A fourth line dismantled CRTs as well as printers, children's toys, and computers.

Teardown employees were required hearing protection, safety glasses, and steel-toed safety boots. Items available for voluntary use included N95 filtering facepiece respirators, and cut-resistant gloves and sleeves.

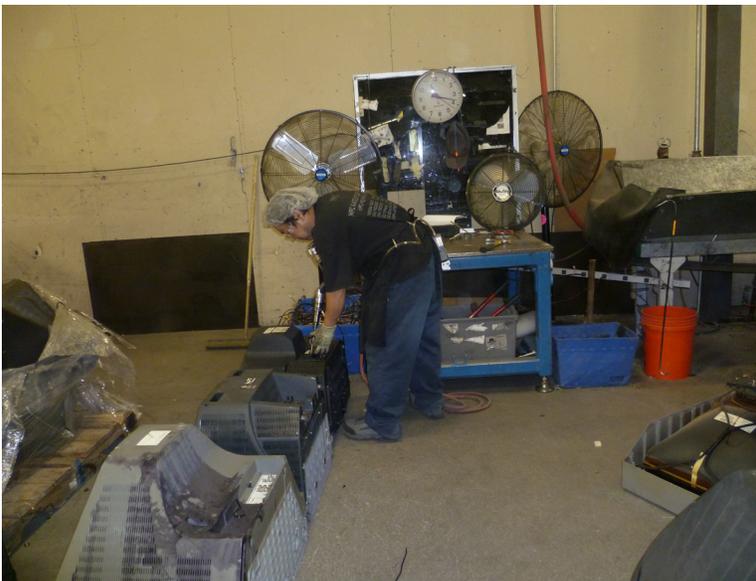


Figure 4. Employee removing CRT plastic casing with pneumatic tool. Photo by NIOSH.

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The shred room had two shredding lines, one for CRT glass and another for electronic components. We observed only CRT glass being shredded. Lead is found in CRT frit, the solder used to join the two types of glass [Florida Department of Environmental Protection 2014], and in the CRT rear funnel glass. An average 19-inch CRT contains around 2.5 pounds of lead [EIA 2014]. We considered shred room employees to have the greatest potential for lead exposure because of the amount of lead in CRTs.

Large cardboard boxes containing CRTs from the consumer room were delivered to the shred room by forklift, then placed onto one of two tilting stations on the loading platform. Two employees on the loading platform used a pulley to tilt the box and dump the contents onto the platform. Employees then used shovels and hooks to load the CRTs and fragments onto the conveyor for shredding. Following shredding, ferrous and nonferrous metals were sorted by magnets and shaker tables, then processed by a machine that separated leaded and nonleaded glass. Each of two baghouse dust collectors had a 55-gallon drum to contain dust removed from the conveyor.

The employees in the shred room were required to wear company-provided long-sleeve uniforms, safety glasses, half-mask respirators with P100 cartridges, hearing protection, bump caps, steel-toed safety boots, and cut-resistant gloves and sleeves. They also wore optional shin guards.

## Methods

The objectives of this evaluation were to determine the extent and routes of exposure to metals in the facility and to make recommendations to minimize exposure. In addition, after receiving support from facility managers, we asked employees who were having their blood collected for lead and cadmium to allow us to perform a finger stick to measure lead with a portable blood-lead testing device so that we could examine its utility. Results of the finger stick testing are in Appendix A.

Prior to the visit we reviewed company health and safety records. These records included industrial hygiene reports that evaluated noise and airborne lead exposures, employee blood lead level (BLL) records, and the company's respiratory protection, hearing conservation, and hazard communication programs.

### April 2013 Site Visit

We observed workplace conditions and work processes and practices. We held confidential medical interviews with employees who worked in different areas of the plant. These employees were selected to represent different jobs titles and for their ability to speak English. Almost half of employees spoke Hmong and we did not have a Hmong interpreter available during this visit. We asked about work-related health issues, job duties, and personal protective equipment (PPE) use. We obtained a complete medical history to look for unrecognized occupational illnesses. We collected surface wipe samples for lead, cadmium, chromium, nickel, and mercury and measured noise levels throughout the facility.

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## June 2013 Site Visit

We took air samples and surface/skin wipe samples for elements and measured noise levels throughout the facility. We took blood samples for lead and cadmium and urine samples for cadmium and mercury from shred room, teardown, battery sorting, maintenance, and forklift employees. These employees were selected because of potential for exposure to metals. All potential study participants read and signed a consent form in their native language (English or Hmong) before having their blood and urine samples collected. A Hmong interpreter was onsite during all testing to assist with the consent procedure and answer questions. We followed universal (standard) precautions for working with blood and blood products [Siegel et al. 2007; 29 CFR 1910.1030]. Blood and urine samples were analyzed by a contract laboratory. Mercury and cadmium results were standardized to grams of creatinine to account for differences in urine concentration. We compared results of urine and blood testing to several occupational exposure limits (OELs). The health effects and OELs for lead and cadmium are provided in Appendix B. We individually notified study participants in writing of their blood and urine test results and explained what these results meant in their native language.

We measured personal exposure to respirable particulate in the air during two shifts following National Institute for Occupational Safety and Health (NIOSH) Method 0600 [NIOSH 2014]. We sampled work tasks in the shred room and tear down areas for respirable dust during two workshifts. We analyzed the respirable particulate for elements, including indium and mercury, following NIOSH Method 7301. However, for this report we present detailed data only for the most toxicologically relevant metals such as lead, cadmium, chromium, and nickel. We were unable to schedule a follow up visit to evaluate employee exposures to metals in total dust.

We also measured personal exposure to mercury vapor and mercury particulate in the air during one shift following NIOSH Method 6009 [NIOSH 2014a]. We sampled mercury side-by-side to the other metals on one employee in the shred room and another employee in the teardown area. A third employee in the shred room handling batteries and other electronics suspected to contain mercury was sampled exclusively for mercury.

We collected surface wipe samples for lead, cadmium, chromium, nickel, and mercury in production areas and nonproduction areas such as break rooms, locker rooms, and offices. We took wipe samples from the skin of employees (e.g., hands, neck, or forearm) immediately prior to leaving work noting if they washed up or not. We also took a wipe sample from the clothing of a shred room employee after that employee showered and changed into street clothes at the end of the shift before going home.

Wipe samples were taken using premoistened Ghost Wipe towelettes following wiping instructions and analysis from NIOSH Method 9102 [NIOSH 2014a]. We analyzed for elements including indium; but present data only for the most toxicologically relevant metals such as lead, cadmium, chromium, and nickel. Wipe samples for mercury were taken using a Whatman LabSales Inc. No. 41 filter and analyzed following the Occupational Safety and Health Administration (OSHA) Method ID-145 [OSHA 2014]. For all wipe samples, we used clean nitrile gloves to avoid cross contamination and measured the area sampled with

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a 10-square centimeter, disposable cardboard template when possible. For uneven or irregular surfaces, we estimated the sample area. For hand wipes, we asked employees to wipe both hands (i.e., wrist down to fingers including palm and back of the palm) for at least 30 seconds. Hand wipes at the end of the shift after washing from shred room employees were compared to those from teardown employees by a two-way t-test of the logarithm of the means.

We used a Larson-Davis model 2800 sound level meter to measure sound levels in production areas during our April 2013 visit. During our June 2013 visit, we used a Larson-Davis model 824 octave band analyzer to measure noise levels in production areas. We had planned to analyze the June 2013 electronically recorded data to recommend potential noise controls and decide if additional employee hearing protection was needed in the glass shredding room. However, we were unable to retrieve the recorded data from the instrument.

## Results and Discussion

### Document Review

The company had written hazard communication, hearing conservation, and respiratory protection programs that were comprehensive and well-organized. We reviewed BLLs from shred room and maintenance employees from 2008–2012; most BLLs were below 10 micrograms per deciliter of blood ( $\mu\text{g}/\text{dL}$ ). Seventeen of 107 employees for whom BLLs were reviewed had at least one BLL above 10  $\mu\text{g}/\text{dL}$ ; the highest BLL was 18  $\mu\text{g}/\text{dL}$ . Although this is below the level allowed by OSHA, an expert panel recommends keeping BLLs below 10  $\mu\text{g}/\text{dL}$  [Kosnett et al. 2007]. NIOSH defines an elevated BLL in adults as 10  $\mu\text{g}/\text{dL}$  or higher. Most of the employees that had elevated BLLs also had BLLs that were not elevated, i.e., they did not remain elevated. For detailed information about the health effects of lead and recommended BLL levels see Appendix B.

We reviewed six industrial hygiene reports from consultants the company hired to evaluate lead exposures. The evaluations occurred between June 2011 and October 2012. The reports identified that some employees' lead exposure in the shred room had either exceeded the OSHA action level of 30 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) or permissible exposure limit (PEL) of 50  $\mu\text{g}/\text{m}^3$ . Employees in other production rooms were not evaluated for lead exposure. The facility managers continued to improve engineering controls (i.e., ventilation), administrative controls (i.e., showers), and required PPE (i.e., respirators) based upon findings from the consultants. The managers performed air monitoring after every ventilation intervention, as stipulated by OSHA, and was continuing their efforts during our evaluation. Employees were in a blood lead monitoring program as required by OSHA.

We also reviewed industrial hygiene consultant reports dated November 2011 to May 2012 that evaluated noise exposures. These reports identified that some exposures for employees working in the shred room, consumer teardown, and dumpster area were above the OSHA action level and NIOSH recommended exposure limit (REL) of 85 decibels A-weighted (dBA). The facility began to require use of hearing protection in these areas and continued to monitor employees' exposure and do baseline and annual audiometric testing.

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## Observations

We saw good compliance with the use of required PPE throughout the facility. PPE was widely available and signs showing the type of PPE needed were posted in each area. However, respirators used voluntarily by the teardown employees were sometimes used improperly (i.e., only one strap or over facial hair) which would reduce the protection afforded by the respirator.

The employees who processed large televisions had to bend over and lift heavy components manually to disassemble and expose the CRT. The process of dismantling large televisions could be changed to reduce ergonomic strain on employees performing this task.

We saw two recycling tasks that could be changed to reduce airborne dust. The first task occurred at the end of the teardown line where employees pushed CRTs into cardboard boxes. The CRTs broke when they fell into the boxes, releasing dust. The other dust-producing task occurred when these cardboard boxes were emptied onto the loading platform at the glass shredding conveyor.

We noticed several work practices that could result in unnecessary lead exposure and potentially increase employees' BLLs.

1. Shred room employees removed their company provided uniforms immediately outside the shred room when leaving the work area, but told us they put this same uniform back on when they returned. This practice could contaminate their hands and personal clothes.
2. Teardown employees were not required to wear uniforms and were not required to shower at the end of their workday. We also observed that employees without uniforms did not always change into clean clothes before going home, and that work clothes were laundered at home.
3. Maintenance employees did not remove their uniform or gloves when they left the shred room.
4. We observed employees dry sweeping, including in the shred room. We saw visible plumes of dust when employees swept and shoveled debris in the shred room.
5. We saw teardown employees using compressed air to clean work areas and their clothing and skin at the end of the shift, although this practice was prohibited by the company. Using compressed air can increase employees' exposure to metals and other workplace contaminants and may cause skin or eye injuries.
6. The company required cut-resistant sleeves were widely available, and most employees wore them. However, there was no written policy on reuse or laundering of sleeves. Reusing dirty sleeves can be a source of exposure.
7. We saw employees using pedestal fans in the teardown lines for cooling. However, the fans faced employees who were breaking CRTs, potentially increasing exposures among employees working downwind.

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We found several ways that dust containing lead and other metals could be tracked from the shred room to nonproduction areas and to employees' homes.

1. Employees stored their personal clothes and items with their PPE in lockers.
2. Employees from all areas could enter the shred room and track lead back to their work areas.
3. Shred room employees wore their work boots to the locker room for storage when not in use.
4. Forklifts travelled from the shred room to other areas of the facility, potentially carrying dust with lead and other metals.
5. Most employees washed their hands before lunch, but many did not remove all PPE. Many employees did not wash their hands or change clothes before going home. This practice could result in employees transporting workplace contaminants to their cars and homes, placing their families at risk of exposure to dust containing lead and other metals.

We observed the conveyor belt immediately beyond the shredder frequently jamming with CRT fragments. When this occurred, the shredder rebooted. When the shredder failed to unjam, we saw employees climbing on the scrap metal in the dumpster and manually dislodging the fragments in the shredder while the conveyor was operating. In addition to possible falls, these employees were at risk of severe injury or death by not implementing lockout/tagout of the shredder.

## Employee Interviews

We interviewed 24 English speaking employees with a variety of job titles including teardown (6), shred room (5), sorting, weighing, and data entry (4), diagnostic technician (2), janitor (1), battery sorter (1), maintenance (2), finished goods (1), bailer (1), logistics (1). Employees had no health complaints related to exposures on the job. Employees were knowledgeable about potential hazards in the plant and about required PPE. Most employees who had BLL testing did not know what their BLL was, but they knew how to get the information.

## Blood and Urine Testing

Of 40 employees, 24 in the targeted areas participated in the blood and urine testing: 13 from teardown, seven from the shred room, two fork truck drivers, one from battery and bulb processing (which took place in the consumer room), and one who reported working in both the shred room and teardown. Results are presented in Table 1. Two employees had elevated BLLs (i.e., 10 µg/dL or higher); neither worked in the shred room. All employees had urine mercury levels below the limit of detection of 5 micrograms per liter (µg/L). Urine and blood cadmium levels were below OSHA limits.

The OSHA standard, established in 1976, requires immediate removal of employees from lead exposure at work if they have a BLL of 60 µg/dL, or if the average level of the last three tests is 50 µg/dL or higher. Most experts now believe that BLLs in workers should be kept at much lower levels than OSHA requires. These experts believe that BLLs should be kept below 10 µg/dL (Appendix B). For cadmium levels, OSHA requires blood cadmium levels

to be below 5 µg/L and urine cadmium levels to be below 3 micrograms per gram creatinine (µg/g/Cr). OSHA does not have a legal requirement for a level of mercury in the urine, but the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that the level of urine mercury be kept below 20 µg/g/Cr.

Table 1. Lead and cadmium biomonitoring results, June 2013

Location/ activities	Number of employees	Blood lead levels (µg/dL)	Blood cadmium (µg/L)	Urine cadmium (µg/g/Cr)
Shred room	7	ND*–4.6	ND†–1.7	0.1–0.9
Teardown	13	ND*–13.4	ND†–0.9	ND‡–1.1§
Forklift drivers and battery and bulb employees	3	6.6–9.4	ND†–1.5	ND‡–0.9

ND = not detected

\*Not detected, blood lead below the limit of detection of 3.0 µg/dL.

†Not detected, blood cadmium below the limit of detection of 0.5 µg/dL.

‡Not detected, urine cadmium below the limit of detection of 0.1 µg/g/Cr.

§Two employees did not have their urine cadmium levels checked because they had not worked at this facility long enough for cadmium to build up in their kidneys.

## Air Sampling

Results of personal air sampling for metals (not including mercury) are shown in Table 2. We compared our air sampling results for respirable cadmium to the ACGIH threshold limit value (TLV) of 2 µg/m<sup>3</sup>. There are no OELs for respirable lead, nickel, and chromium. We found the highest respirable cadmium concentrations on samples collected on glass operators who handled broken CRTs at the shred room platform. Respirable lead concentrations were higher in the shred room than in the teardown area, as would be expected on the basis of the work performed in these areas.

Table 2. Personal air sampling results for respirable elements over two work shifts, June 2013

Respirable elements*	Job title	Number of samples	Results ( $\mu\text{g}/\text{m}^3$ )	OEL ( $\mu\text{g}/\text{m}^3$ )
Lead	Teardown	25	ND† to 1.8	None
	Shred room	15	1.9 to 6.8	None
Cadmium	Teardown	25	ND† to 0.18	2 (ACGIH)
	Shred room	15	ND† to 0.24	2 (ACGIH)
Chromium	Teardown	25	ND** to (0.58)‡	None
	Shred room	15	(0.35) to (0.82)‡	None
Nickel	Teardown	25	ND†	None
	Shred room	15	ND†	None

\*Elements that were not detected (minimum detectable concentration [MDC] of  $1.1 \mu\text{g}/\text{m}^3$  or less): cobalt, indium, lanthanum, lithium, nickel, phosphorus, selenium, tellurium, thallium, and vanadium.

Elements that were detected but below the minimum quantifiable concentration (MQC) of  $1.0 \mu\text{g}/\text{m}^3$ : copper, molybdenum, potassium, and silver. Elements that were above the MQC: aluminum (up to  $2.7 \mu\text{g}/\text{m}^3$ ), zinc (up to  $3.5 \mu\text{g}/\text{m}^3$ ), barium (up to  $2.1 \mu\text{g}/\text{m}^3$ ), beryllium (up to  $0.02 \mu\text{g}/\text{m}^3$ ), calcium (up to  $30 \mu\text{g}/\text{m}^3$ ), iron (up to  $22 \mu\text{g}/\text{m}^3$ ), magnesium (up to  $2.4 \mu\text{g}/\text{m}^3$ ), manganese (up to  $0.32 \mu\text{g}/\text{m}^3$ ), strontium (up to  $1.5 \mu\text{g}/\text{m}^3$ ), tin (up to  $0.49 \mu\text{g}/\text{m}^3$ ), titanium (up to  $0.14 \mu\text{g}/\text{m}^3$ ), yttrium (up to  $0.81 \mu\text{g}/\text{m}^3$ ), and zirconium (up to  $0.05 \mu\text{g}/\text{m}^3$ ).

†For these samples the MDC was  $0.16 \mu\text{g}/\text{m}^3$  for respirable lead,  $0.11 \mu\text{g}/\text{m}^3$  for respirable nickel, and  $0.027 \mu\text{g}/\text{m}^3$  for respirable cadmium.

‡The chromium concentrations in parenthesis are between the MDC of  $0.32 \mu\text{g}/\text{m}^3$  to the MQC of  $1.0 \mu\text{g}/\text{m}^3$ . This means there is more uncertainty associated with these values.

We did not detect mercury particulate or mercury vapor in the three personal air samples measured. This means that the measured exposures were well below the ACGIH TLV of  $25 \mu\text{g}/\text{m}^3$ , NIOSH REL of  $50 \mu\text{g}/\text{m}^3$ , and OSHA PEL of  $100 \mu\text{g}/\text{m}^3$ . The minimum detectable concentration was  $0.0099 \mu\text{g}/\text{m}^3$  for mercury particulate and  $0.0023 \mu\text{g}/\text{m}^3$  for mercury vapor.

## Wipe Sampling

Personal wipe sample results for selected elements are shown in Table 3. Overall, lead was found more frequently than the other metals, although all metals were found on some employees in both rooms.

We found lead on the skin of all 12 shred room employees tested, nickel on the skin of three employees, chromium on the skin of eight employees, and cadmium on the skin of eight employees. We did not find mercury on the skin of the four shred room employees we tested (not in table). We found mercury on the street clothes of the one shred room employee tested (not in table).

Lead was found on the skin of all 19 teardown employees we tested. We found nickel on the hands of ten employees, chromium on the hands of 15 employees, and cadmium on the hands of 17 employees. We took skin wipe samples for mercury from five teardown employees, and found mercury on one (not in table).

Table 3. Wipe sample results for selected elements taken at the end of the shift, unless otherwise specified

Surface	Was the surface washed	Work area	Number of samples	Loading geometric mean [range], shown in µg			
				Lead	Cadmium	Chromium	Nickel
Hands	Yes	Teardown	12	26 [4.4–150]	0.36 [0.09–1.6]	0.94 [0.26–21]	2.5 [ND–14]
	Yes	Shred room	10	7.9 [1.5–39]	0.011 [ND–0.45]	0.076 [ND–0.99]	0.0048 [ND–3.7]
Right forearm*	Unsure	Teardown	1	84	0.58	1.2	4.0
Right forearm*	No	Teardown	1	53	4.0	0.5	2.6
Right forearm or neck*†	Unsure	Teardown	5	10 [2.9–29]	0.19 [ND–0.44]	0.18 [ND–0.40]	0.000014 [ND–0.59]
Forearm or neck*	Yes	Shred room	2	[2.4–3.2]	[0.090]	[ND–0.070]	[ND]
Personal clothing	Yes	Shred room	1	0.96	0.050	ND	ND
LOD				0.3	0.02	0.05	0.5
LOQ				0.84	0.054	0.17	1.6

LOD = Limit of detection

LOQ = Limit of quantitation

\*Approximated 100 cm<sup>2</sup> surface area.

†These samples were taken during the lunch break.

‡Result is below the LOD.

§Washing “yes” meant that the employee said he washed his hands. At the end of the shift all shred room employees were required to shower and change clothes while teardown employees may have washed hands and/or change clothes only on a volunteer basis.

We found that after washing their hands, teardown employees had more metal contamination remaining on their hands than shred room employees. For example, teardown employees had 3 times more lead ( $P = 0.01$ ), 33 times more cadmium ( $P = 0.03$ ), 12 times more chromium ( $P = 0.06$ ), and 520 times more nickel ( $P = 0.01$ ). It is likely that the differences in administrative controls for shred room and teardown employees played a role in these results. Shred room employees showered and changed clothes before leaving work, while teardown employees did not.

Beryllium was present on one surface sample in the personal protective equipment storage room (0.06 µg/sample). Beryllium was not detected on any other skin, clothing, production or non-production surfaces (LOD of 0.009 µg/sample in first visit and LOD of 0.02 µg/sample in second visit).

Indium was not detected on production or non-production surfaces during the first visit (LOD of 1 µg/sample). We detected indium below LOQ (1.5 µg/sample) on two shred room employee’s hands and one shred room employee’s clothing during the second visit. Indium was not detected on any other skin or non-production surfaces during the second visit. However, we detected indium on production surfaces during the second visit (up to 5.5 µg/sample).

There are no OELs for metals on surfaces or employees' skin or clothing. However, the metals found on employees' skin or clothing can add exposure through ingestion or skin absorption. Employees can also transfer metals to their car or home, resulting in potential exposures to family members.

As expected, metals were present on production surfaces (Tables 4 and 5). However, we found one or more of the following metals on nonproduction surfaces during both visits: mercury, lead, nickel, chromium, and cadmium (Tables 4 and 5). Most surfaces had low levels; the highest levels we found were from a location close to the PPE room. This is not surprising as the PPE room had teardown employee lockers and stored both clean and dirty PPE and clothing.

Table 4. Surface wipe sample results on work surfaces for selected metals, April 2013

Location	Lead ( $\mu\text{g}/100\text{ cm}^2$ )	Cadmium ( $\mu\text{g}/100\text{ cm}^2$ )	Chromium ( $\mu\text{g}/100\text{ cm}^2$ )	Nickel ( $\mu\text{g}/100\text{ cm}^2$ )	Mercury ( $\mu\text{g}/100\text{ cm}^2$ )
<b>Production areas</b>					
Floor in entrance to wear house	32	0.20	0.80	ND	ND
PPE dispenser	4.2	ND	ND	ND	ND
<b>Nonproduction areas</b>					
Locker PPE room	56	0.82	0.87	2.4	ND
PPE room table where shoes were stored	24	0.35	0.46	ND	ND
Microwave	9.9	ND	ND	ND	ND
Water fountain by lockers	2.4	ND	ND	ND	ND
Table in conference room	ND	ND	ND	ND	ND
Lunch table near PPE room	ND	ND	ND	ND	ND
Shower locker	ND	ND	ND	ND	ND
Lunch room table by window	ND	ND	ND	ND	ND
Desk in office	ND	ND	ND	ND	ND
LOD	0.60	0.05	0.08	0.50	0.02
LOQ	1.8	0.18	0.26	1.7	0.0055

Table 5. Surface wipe sample results on work surfaces for selected metals, June 2013

Location	Lead ( $\mu\text{g}/100\text{ cm}^2$ )	Cadmium ( $\mu\text{g}/100\text{ cm}^2$ )	Chromium ( $\mu\text{g}/100\text{ cm}^2$ )	Nickel ( $\mu\text{g}/100\text{ cm}^2$ )	Mercury ( $\mu\text{g}/100\text{ cm}^2$ )
<b>Production areas</b>					
Shredding room scaffolding	6400	100	38	210	ND
Forklift foreface	1400	15	10	43	0.0058
Computer station glass break	130	1.4	1.2	3.1	0.014
Table near bailer in tear down area	150	2.0	4.7	7.2	0.19
<b>Nonproduction</b>					
Locker PPE room	18	0.39	0.48	(0.96)	0.0057
Lunch table near PPE room	5.3	0.53	(0.080)	ND	0.0049
Microwave	4.0	0.14	0.12	ND	0.0053
Lunch table near window	3.4	3.8	0.25	(0.84)	0.0038
Bench locker room	9.0	0.16	(0.090)	ND	0.0057
Desk office 1	1.8	(0.050)	ND	ND	0.0047
Desk office 2	3.2	(0.050)	ND	ND	0.0067
Table in conference room	2.5	0.15	(0.07)	ND	0.0069
Lobby coffee table	2.6	0.14	ND	ND	ND
Receptionist's desk	(0.58)	(0.04)	ND	ND	ND
LOD	0.3	0.02	0.05	0.5	0.0007
LOQ	0.84	0.054	0.17	1.6	0.0022

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

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There are no OELs for metals on surfaces. OSHA housekeeping provisions state that surfaces in nonproduction areas such as change rooms, storage facilities, and lunchroom/eating areas should be kept “as free as practicable” of toxic metals such as lead and cadmium. The metals found on nonproduction areas suggest that a reorganization of the locker/PPE room is needed to avoid bringing contaminated dust from the production area. The company had a janitorial service that cleaned nonproduction areas several times a day. Further, when employees bring PPE into the lunch room or do not wash their hands or change clothes before lunch, they can transfer contaminants from the production area into nonproduction areas.

## Noise Measurements

During our first visit we measured noise levels that exceeded 85 dBA in the shred room and near the baler when it was operating (Table 6). These results, which are consistent with the industrial hygiene consultant reports, suggest that employees working in these areas for a full shift may be overexposed to noise. The facility posted that hearing protection was required in these areas, and we saw employees wearing foam insert-type ear plugs. It is important that the company continues the hearing conservation program as lead exposures in conjunction with noise exposures can increase the potential for hearing loss [Sliwinska-Kowalska et al. 2004; Morata 2007; Hwang et al. 2009].

Table 6. Short-term area noise levels, April 2013

Warehouse area	Noise levels (dBA)
Shred room	85.0–97.0
CRT teardown line	80.1–84.0
Large TV teardown line	77.0–82.0
Baler (on)	86.0–88.0
Baler (off)	80.1–80.8
Consumer teardown line	82.1
Receiving area	66.4–71.8
Forklift charging area	76.0
Battery sort and storage	76.0–83.0

## Limitations

We were planning to go back to the facility to measure total particulate in air and repeat our octave band measurements, but were unable to do so. The results for respirable metals indicate that some portion of the metal dust may be able to go deep into the lungs. In the absence of total particulate results, however, we cannot draw conclusions about how exposure levels compare to OELs. Company air sampling results indicated overexposure to lead in the shred room area.

Because we did not have a Hmong interpreter during our first visit, it is unclear if the results from the English speaking employees can be extrapolated to the Hmong employees. However, the distribution of Hmong and English speaking employees by job title does not suggest that exposures differed by language. For example, 3/8 shred room employees and 16/25 teardown employees spoke only Hmong. All maintenance and janitorial employees spoke English. Training was done in the employees preferred language.

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## Conclusions

Exposure to lead was well controlled in the shred room as indicated by the BLLs of shred room employees. This outcome likely resulted from a combination of engineering controls, administrative controls, and PPE. In contrast, exposure to metals was not adequately controlled in teardown areas, where exposure to lead had not been recognized by the facility. Some dismantlers in the teardown area had elevated BLLs. Lead and other metals were being tracked outside of the shred room, presumably by forklifts and employees. We found lead and other metals on surfaces in nonproduction areas. We found lead and other metals on the skin of employees from the shred room and teardown, and on the clothing of one employee from the shred room as they left work. This can contaminate cars and homes, and expose family members to these metals.

## Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the e-scrap recycling facility 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 electronic scrap recycling facility.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). 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.

## 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. Install a lid with an adjustable opening that can close as the CRT drops to the bottom of the container pallet at the end of the teardown line. Another option is to extend the glass shredding conveyor to the end of the teardown line. This will transport CRTs directly to the shredder without breaking them.
2. Discontinue use of pedestal fans and consider adding supplemental ventilation for cooling in the warehouse.
3. Follow lockout/tagout procedures to de-energize machinery before conducting any troubleshooting, repairs, or maintenance.
4. Provide employees working in the large television teardown lines with an elevated work surface to reduce the need to bend over, which can cause ergonomic strain and back injury.

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## 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. Include teardown employees, including forklift drivers and battery and bulb employees, in the lead prevention program. Follow the medical surveillance program outlined in Appendix B in addition to all requirements of the OSHA lead standard. Provide employees with the results of their individual BLLs in writing after each blood draw.
2. Perform industrial hygiene personal air monitoring for cadmium and mercury for employees in production areas.
3. Provide all production employees with scrubs to wear under their work uniforms. Employees would change into the scrubs when they arrive at work and store their personal clothing and shoes in a clean locker. They would wear their work uniform on top of the scrubs and remove their uniforms before breaks and lunch. Before leaving work, they would remove uniforms and scrubs, and put on their clean personal clothes. Scrubs and work uniforms would be laundered by your contractor.
4. Write a formal procedure for reuse or laundering of cut resistant sleeves and gloves.
5. Require employees to wear disposable shoe covers or change shoes when leaving the shred room to prevent dust from being tracked outside the area.
6. Require that all production employees shower before leaving work. Redesign the locker room and shower area so that traffic only flows one way. That is, once employees shower, they cannot re-enter the potentially contaminated locker area. Clean items should be stored in separate locker rooms from work items.
7. Require all employees to wash their hands before donning and after removing gloves; when leaving the production areas; and before eating, drinking, or smoking. Lead removal soap is more effective than soap and water.
8. Stop employees from taking potentially contaminated PPE from the production areas to nonproduction areas, including the lunchroom. Maintenance employees should keep a pair of gloves and a uniform stored in the shred room for use only in the shred room.
9. Stop dry sweeping. Debris should be wetted before it is swept or shoveled to reduce dust. Once the large debris is removed, use a vacuum equipped with a high efficiency particulate air filter to remove the remaining smaller debris or use wet methods.
10. Never use compressed air to clean.
11. Use one forklift in the shred room, and do not allow it to be used in other areas of the facility.
12. Continue to train employees in the correct use of respirators and other PPE in their native language.

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## Appendix A: Portable Blood Lead Testing Device

The gold standard for BLL measurement is collection of a venous sample, which is analyzed in a laboratory. This method can be costly and does not provide an instantaneous result. Measuring lead in the workplace has been suggested but interference from skin contamination with lead in the workplace has been a concern [Taylor et al. 2001]. NIOSH researchers have assessed the effectiveness of cleansing methods. In one study, the traditional soap and water method for hand washing did not efficiently remove lead from skin [Filon et al. 2006]. In another, hand washing with a wipe that contains a pH balanced wetting agent and chelating agent was greater than 99% effective in removing lead from skin [Esswein et al. 2011]. This technology is available commercially as Hygenall® wipes.

We evaluated the LeadCare II® Test Kit, which measures lead in fresh whole blood from either a skin puncture or a venipuncture. We asked employees who were having their blood collected for lead and cadmium to allow us to collect a capillary blood sample from one finger on each hand. Lead was measured onsite by NIOSH. Prior to sample collection, one hand was cleaned with a PDI® castile soap towelette and rinsed with water, and the other was cleaned with a Hygenall (a lead removal soap) hand wipe and rinsed with water.

Each participant's capillary blood sample results were compared to the results of their venous BLL testing reported by our contract laboratory. For statistical analysis we used the student's paired *t*-test and Pearson's correlation coefficient (SAS version 9.3). Results with *P* values  $\leq 0.05$  were considered statistically significant.

Twenty-two employees participated. For the hand cleaned with the castile soap towelette and the hand cleaned with the lead removal soap, the mean BLL was higher ( $P < 0.05$ ) than the mean BLL from the venous sample, although the differences were small. For the hand cleaned with the castile soap towelette, the mean capillary BLL was 2.2  $\mu\text{g/dL}$  higher than the mean venous BLL ( $P < 0.01$ ). For the hand cleaned with the lead removal soap wipe, the mean capillary BLL was 3.2  $\mu\text{g/dL}$  higher than the mean venous BLL ( $P < 0.01$ ). Both capillary BLLs were highly significantly correlated with the venous BLLs ( $r = 0.96$ ,  $P < 0.01$  for the hand cleaned with the lead removal soap wipe, and  $r = 0.97$ ,  $P < 0.01$  for the hand cleaned with the castile soap towelette).

These findings support use of the LeadCare II kit in the field. They are consistent with prior results showing that venous blood tested with the LeadCare II kit and venous blood tested in the laboratory had a mean difference of 1.2  $\mu\text{g/dL}$ , which is clinically insignificant [Stanton and Fritsch 2007]. Capillary earlobe and venous blood testing were compared with the LeadCare II kit and found to have mean differences of 38.8  $\mu\text{g/dL}$ . The higher levels in earlobe samples were presumed to be because of skin contamination. The differences we found were much smaller; it is possible that the level of skin contamination was low, the cleaning methods were effective, or a combination of both. Further research in other settings is needed to more definitively determine the utility of the LeadCare II device in the workplace.

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## Appendix B: 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 a 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 or ceiling values. Unless otherwise noted, the short term exposure limit 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 2014c]. 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, which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and workplace environmental exposure levels 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

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by industrial hygienists and others trained in this discipline “to assist in the control of health hazards” [ACGIH 2014]. Workplace environmental exposure levels have been established for some chemicals “when no other legal or authoritative limits exist” [AIHA 2014].

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.

## **Lead**

Inorganic lead is a naturally occurring, soft metal that comes in many forms (e.g., lead acetate, lead chloride, lead chromate, lead nitrate, lead oxide, lead phosphate, and lead sulfate). Lead is considered toxic to all organ systems and serves no useful purpose in the body.

Occupational exposure to inorganic lead occurs via inhalation of lead-containing dust and fume and ingestion of lead particles from contact with lead-contaminated surfaces. Exposure may also occur through transfer of lead to the mouth from contaminated hands or cigarettes when careful attention to hygiene, particularly hand washing, is not practiced. In addition to the inhalation and ingestion routes of exposure, lead can be absorbed through the skin,

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particularly through damaged skin [Stauber et al. 1994; Sun et al. 2002; Filon et al. 2006].

## **Blood Lead Levels**

In most cases, an individual's BLL is a good indication of recent exposure to lead because the half-life of lead (the time interval it takes for the quantity in the body to be reduced by half its initial value) is 1–2 months [Lauwerys and Hoet 2001; Moline and Landrigan 2005; CDC 2013a]. Most lead in the body is stored in the bones, with a half-life of years to decades. Measuring bone lead, however, is primarily done only for research. Elevated zinc protoporphyrin levels have also been used as an indicator of chronic lead intoxication; however, other factors, such as iron deficiency, can cause an elevated zinc protoporphyrin level, so monitoring the BLL over time is more specific for evaluating chronic occupational lead exposure.

BLLs in adults in the United States have declined consistently over time. In the last 10 years alone, the geometric mean BLL went from 1.75 µg/dL to 1.23 µg/dL [CDC 2013b]. The NIOSH Adult Blood Lead Epidemiology and Surveillance System uses a surveillance case definition for an elevated BLL in adults of 10 µg/dL of blood or higher [CDC 2012a]. Very high BLLs are defined as  $\geq 40$  µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where exposure source was known) [CDC 2014]. Greater effort to prevent lead exposures in the workplace should be made.

## **Occupational Exposure Limits**

In the United States, employers in general industry are required by law to follow the OSHA lead standard [29 CFR 1910.1025]. This standard was established in 1978 and has not yet been updated to reflect the current scientific knowledge regarding the health effects of lead exposure.

Under this standard, the PEL for airborne exposure to lead is 50 µg/m<sup>3</sup> of air for an 8-hour TWA. The standard requires lowering the PEL for shifts that exceed 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m<sup>3</sup> (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL.

In the United States, other guidelines for lead exposure that are not legally enforceable also exist. Similar to the OSHA lead standard, these guidelines were set years ago and have not yet been updated to reflect current scientific knowledge. NIOSH has an REL for lead of 50 µg/m<sup>3</sup> averaged over an 8-hour work shift [NIOSH 2014b]. ACGIH has a TLV for lead of 50 µg/m<sup>3</sup> (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. The ACGIH designates lead as an animal carcinogen [ACGIH 2014]. In 2013, the California Department of Public Health recommended that California OSHA lower its PEL for lead to 0.5 to 2.1 µg/m<sup>3</sup> (8-hour TWA) to keep BLLs below the range of 5 to 10 µg/dL [Billingsley 2013].

Neither NIOSH nor OSHA has established surface contamination limits for lead in the workplace. The United States Environmental Protection Agency and the United States Department of Housing and Urban Development limit lead on surfaces in public buildings

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and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace exposures to lead must implement regular and effective cleaning of surfaces in areas such as change areas, storage facilities, and lunchroom or eating areas to ensure they are as free as practicable from lead contamination.

## **Health Effects**

The PEL, REL, and TLV may prevent overt symptoms of lead poisoning, but do not protect workers from lead's contributions to conditions such as hypertension, renal dysfunction, reproductive, and cognitive effects [Schwartz and Hu 2007; Schwartz and Stewart 2007; Brown-Williams et al. 2009; IOM 2012]. Generally, acute lead poisoning with symptoms has been documented in persons having BLLs above 70 µg/dL. These BLLs are rare today in the United States, largely as a result of workplace controls put in place to comply with current OELs. When present, acute lead poisoning can cause myriad adverse health effects including abdominal pain, hemolytic anemia, and neuropathy. Lead poisoning has, in very rare cases, progressed to encephalopathy and coma [Moline and Landrigan 2005].

People with chronic lead poisoning, which is more likely at current occupational exposure levels, may not have symptoms or they may have nonspecific symptoms that may not be recognized as being associated with lead exposure. These symptoms include headache, joint and muscle aches, weakness, fatigue, irritability, depression, constipation, anorexia, and abdominal discomfort [Moline and Landrigan 2005].

The National Toxicology Program (NTP) recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, the NTP concluded the following about the evidence regarding health effects of lead (Appendix B, Table B1).

Table B1. Evidence regarding health effects of lead in adults

Health area	NTP conclusion	Principal health effects	Blood lead evidence
Neurological	Sufficient	Increased incidence of essential tremor	Yes, < 10 µg/dL
	Limited	Psychiatric effects, decreased hearing, decreased cognitive function, increased incidence of amyotrophic lateral sclerosis	Yes, < 10 µg/dL
	Limited	Increased incidence of essential tremor	Yes, < 5 µg/dL
Immune	Inadequate		Unclear
Cardiovascular	Sufficient	Increased blood pressure and increased risk of hypertension	Yes, < 10 µg/dL
	Limited	Increased cardiovascular-related mortality and electrocardiography abnormalities	Yes, < 10 µg/dL
Renal	Sufficient	Decreased glomerular filtration rate	Yes, < 5 µg/dL
Reproductive	Sufficient	Women: reduced fetal growth	Yes, < 5 µg/dL
	Sufficient	Men: adverse changes in sperm parameters and increased time to pregnancy	Yes, ≥ 15–20 µg/dL
	Limited	Women: increase in spontaneous abortion and preterm birth	Yes, < 10 µg/dL
	Limited	Men: decreased fertility	Yes, ≥ 10 µg/dL
	Limited	Men: spontaneous abortion in partner	Yes, ≥ 31 µg/dL
	Inadequate	Women and men: stillbirth, endocrine effects, birth defects	Unclear

Various organizations have assessed the relationship between lead exposure and cancer. According to the Agency for Toxic Substances and Disease Registry [ATSDR 2007] and the NTP [NTP 2011], inorganic lead compounds are reasonably anticipated to cause cancer in humans. The International Agency for Research on Cancer classifies inorganic lead as probably carcinogenic to humans [WHO 2006]. According to the American Cancer Society [ACS 2014], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed.

## Medical Management

To prevent acute and chronic health effects, a panel of experts published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The complete guidelines are available at <http://www.cdph.ca.gov/programs/olppp/Documents/medmanagement.pdf>. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. The panel's recommendations are outlined in Appendix B, Table B2. These recommendations do not apply to pregnant women, who should avoid BLLs > 5 µg/dL. Removal from lead exposure should be considered if control measures over an extended period do not decrease BLLs to < 10 µg/dL or an employee has a medical condition that would increase the risk of adverse health effects from lead exposure. These

guidelines are endorsed by the Council of State and Territorial Epidemiologists [CSTE 2014] and the American College of Occupational and Environmental Medicine [ACOEM 2010]. The California Department of Public Health recommended keeping BLLs below 5 to 10 µg/dL in 2013 [Billingsley 2013].

Table B2. Health-based medical surveillance recommendations for lead-exposed employees

Exposure category	Recommendations
All lead exposed workers	<ul style="list-style-type: none"> <li>• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine.</li> </ul>
BLL < 10 µg/dL	<ul style="list-style-type: none"> <li>• Monitor BLL monthly for first 3 months after placement, or upon change in task to higher exposure, then monitor BLL every 6 months.</li> </ul>
BLL 10–19 µg/dL	<ul style="list-style-type: none"> <li>• If BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated.</li> <li>• As above for BLL &lt; 10 µg/dL, plus: monitor BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal.</li> </ul>
BLL ≥ 20 µg/dL	<ul style="list-style-type: none"> <li>• Revert to BLL every 6 months after three BLLs &lt; 10 µg/dL.</li> <li>• Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL, or if first BLL is ≥ 30 µg/dL.</li> <li>• Monthly BLL testing</li> <li>• Consider return to work after two BLLs &lt; 15 µg/dL a month apart, then monitor as above.</li> </ul>

Adapted from Kosnett et al. 2007

## Take-home Contamination

Occupational exposures to lead can result in exposures to household members, including children, from take-home contamination. Take-home contamination occurs when lead dust is transferred from the workplace on employees' skin, clothing, shoes, and other personal items to their vehicle and home [CDC 2009, 2012b].

The CDC considers a BLL in children of 5 µg/dL or higher as a reference level above which public health actions should be initiated, and states that no safe BLL in children has been identified [CDC 2013a].

The U.S. Congress passed the Workers' Family Protection Act in 1992 (29 U.S.C. 671a). The Act required NIOSH to study take-home contamination from workplace chemicals and substances, including lead. NIOSH found that take-home exposure is a widespread problem [NIOSH 1995]. Workplace measures effective in preventing take-home exposures were (1) reducing exposure in the workplace, (2) changing clothes before going home and leaving soiled clothing at work for laundering, (3) storing street clothes in areas separate from work clothes, (4) showering before leaving work, and (5) prohibiting removal of toxic substances or contaminated items from the workplace. NIOSH noted that preventing take-home

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exposure is critical because decontaminating homes and vehicles is not always effective. Normal house cleaning and laundry methods are inadequate, and decontamination can expose the people doing the cleaning and laundry.

## Cadmium

Cadmium metal is used in batteries, pigments, plastic stabilizers, metal coatings, and television phosphors [ACGIH 2001]. Employees may inhale cadmium dust when sanding, grinding, or scraping cadmium-metal alloys or cadmium-containing paints [ACGIH 2001]. In addition to inhalation, cadmium may be absorbed via ingestion. Non-occupational sources of cadmium exposure include cigarette smoke and dietary intake [ACGIH 2001]. Early symptoms of cadmium exposure may include mild irritation of the upper respiratory tract, a sensation of constriction of the throat, a metallic taste and/or cough. Short-term exposure effects of cadmium inhalation include cough, chest pain, sweating, chills, shortness of breath, and weakness [Thun et al. 1991]. Short-term exposure effects of ingestion may include nausea, vomiting, diarrhea, and abdominal cramps [Thun et al. 1991]. Long-term exposure effects may include loss of the sense of smell, ulceration of the nose, emphysema, kidney damage, mild anemia, and an increased risk of cancer of the lung, and possibly of the prostate [ATSDR 1999]. Blood cadmium levels measure recent exposure in the past few months [Lauwerys and Hoet 2001; Franzblau 2005], while urinary cadmium levels can measure longer-term exposure (several years) [Lauwerys and Hoet 2001].

The OSHA PEL for cadmium is  $5 \mu\text{g}/\text{m}^3$  as an 8-hour TWA [29 CFR 1910.1027]. The ACGIH has a TLV for total cadmium of  $10 \mu\text{g}/\text{m}^3$  (8-hour TWA), with employee blood levels to be controlled at or below  $5 \mu\text{g}/\text{L}$  and urine levels to be below  $5 \mu\text{g}/\text{g}/\text{Cr}$ , and designation of cadmium as a suspected human carcinogen [ACGIH 2014]. NIOSH recommends treating cadmium as a potential occupational carcinogen and reducing exposures to the lowest feasible concentration [NIOSH 1984].

OSHA requires a preplacement examination and medical surveillance on any employee who is or may be exposed to an airborne concentration of cadmium at or above the action level of  $2.5 \mu\text{g}/\text{m}^3$  as an 8-hour TWA, for more than 30 days per year [29 CFR 1910.1027]. OSHA defines acceptable blood cadmium levels as  $< 5 \mu\text{g}/\text{L}$ , urine cadmium levels as  $< 3 \mu\text{g}/\text{g}/\text{Cr}$ , and beta-2-microglobulin levels as  $< 300 \mu\text{g}/\text{g}/\text{Cr}$ . None of the employees we tested had blood or urine cadmium levels that approached these OELs. The geometric mean blood cadmium was  $0.3 \mu\text{g}/\text{L}$  among U.S. men in 2009–2010 [CDC 2013b]. Smokers can have blood cadmium levels much higher than nonsmokers, with levels up to  $6.1 \mu\text{g}/\text{L}$  [Martin et al. 2009]. The geometric mean urine cadmium for men in 2009–2010 was  $0.2 \mu\text{g}/\text{g}/\text{Cr}$  [CDC 2013b]. For employees who meet the OSHA cadmium exposure criteria, periodic surveillance is also required 1 year after the initial exam and at least biennially after that [29 CFR 1910.1027]. Periodic surveillance shall include the biological monitoring; history and physical examination; a chest x-ray (frequency to be determined by the physician after the initial x-ray); pulmonary function tests; blood tests for blood urea nitrogen, complete blood count, and creatinine; urinalysis; and a prostate examination for men over 40. The frequency of periodic surveillance is determined by the results of biological monitoring and medical examinations. Biological monitoring is required annually, either as part of the

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periodic surveillance or on its own. We recommend that the preplacement examination be identical to the periodic examinations so that baseline health status may be obtained prior to exposure. Termination of employment examinations that are identical to the periodic examinations are also required. The employer is required to provide the employee with a copy of the physician's written opinion from these exams and a copy of biological monitoring results within 2 weeks of receipt.

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