Evaluation of Exposure to Metals at an Electronics Recycling Facility

George R. Grimes, MD, MPH
Catherine C. Beaucham, MPH, CIH
Jessica G. Ramsey, MS, CPE

HHE Report No. 2016-0242-3315
May 2018

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

Contents

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.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from an electronics recycling company. The managers were concerned about exposure to metals and flame retardants.

What We Did

- We evaluated the electronics recycler in February 2017 and July 2017.
- We collected surface, hand wipe, and air samples for metals including lead and cadmium.
- We collected blood samples for lead and cadmium.
- We observed employees during routine work activities.

What We Found

- We found lead and cadmium in the employees' blood, but none of the employees' blood samples were above reference levels.
- None of the air samples exceeded occupational limits.
- We found lead and cadmium on the employees' hands after they had washed them.
- We observed employees eating and drinking in the processing area and smoking as they unloaded electronics equipment.

We evaluated employee exposures to metals, including lead and cadmium, at an electronics recycling facility. Personal air concentrations of metals did not exceed any applicable occupational exposure limits. Blood lead and cadmium levels were below biological exposure indices. We found lead and cadmium on employees' hands after they washed them. We recommended that the employer provide employees with a lead-removing product to wash their hands and to include all employees in a lead exposure prevention program.

What the Employer Can Do

- Include all employees in a lead exposure prevention program.
- Provide employees with a lead-removing product to wash their hands.
- Prohibit the use of compressed air to clean electronics.
- Maintain a respiratory protection program in accordance with Washington's Department of Occupational Safety and Health's respiratory protection standard.
- Review and update the personal protective equipment hazard assessment, which is included as part of the accident prevention plan, to make sure that it includes all of the necessary personal protective equipment.
- Offer a smoking cessation program to employees.

What Employees Can Do

- Wash your hands with a lead-removing product before eating, drinking, or smoking and before leaving work.
- Do not dry sweep. Use wet cleaning methods or vacuum instead.
- Do not use compressed air to clean electronics.
- Do not eat, drink, or smoke in work areas.
- Stop smoking.

Abbreviations

μg/m³	Micrograms per cubic meter
μg/dL	Micrograms per deciliter
μg/L	Micrograms per liter
ABLES	Adult Blood Lead Epidemiology and Surveillance
ACGIH®	American Conference of Governmental Industrial Hygienists
Be	Beryllium
BLL	Blood lead levels
Cd	Cadmium
CFR	Code of Federal Regulations
Cr	Chromium
Co	Cobalt
Cu	Copper
HEPA	High-efficiency particulate air
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
Pb	Lead
PEL	Permissible exposure limit
PPE	Personal protective equipment
REL	Recommended exposure limit
STEL	Short-term exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average

This page left intentionally blank

Introduction

The Health Hazard Evaluation Program received a request from managers at an electronics recycling company. The request concerned possible employee exposures to flame retardants and metals associated with electronics. We first visited the facility in February 2017. We held an opening meeting and toured the facility to observe operations, work practices, and working conditions. We returned in July 2017 to collect air, hand wipe, and blood samples for metals. The National Institute for Occupational Safety and Health (NIOSH) Industrywide Studies Branch evaluated employees' exposure to flame retardants in July 2017 and will provide the results to the company and employee representatives in a separate report. We provided preliminary observations and recommendations to the employer and the employee representatives in February 2017 and July 2017.

Background

Electronic devices contain many hazardous components including flame retardants and heavy metals. Previous health hazard evaluations in electronics recycling facilities [NIOSH 2009, 2014] noted employee overexposures and potential take-home exposures to metals such as lead and cadmium. More detailed information about lead and other metals is available in Appendix B.

Common Elements in Electronic Scrap Recycling

Elements often found in electronic scrap waste streams vary because of the wide variety of electronic components that are recycled. Additionally, the concentration of elements may change over time, depending on the type and amount of electronics equipment being recycled. Elements commonly found in electronic scrap waste streams include the following:

- Beryllium (Be) – older printed circuit boards
- Cadmium (Cd) – nickel-cadmium batteries, printed circuit boards, pigments, plastic stabilizers, metal coatings, and coating on cathode ray tube glass
- Chromium (Cr) – data tapes, floppy disks
- Cobalt (Co) – batteries
- Copper (Cu) – wiring
- Lead (Pb) – cathode ray tube glass, batteries, solder, and older printed circuit boards

Process Description

The company opened in 2011 and has been in this location since June 2014. They lease the space and share the building with another company. The office area shares the heating, ventilation, and air-conditioning system with the other company, and the warehouse has two large bay doors that remain open throughout the day. They only do manual recycling and do not have a shredder. They do not recycle alkaline batteries, floppy disks, light bulbs, flat-panel displays, cathode ray tubes, or wood products. They accept electronics from companies as well as from the community. The company has 12 to 14 employees at this location.

Employees often rotate to different jobs, as needed, to fulfill processing demands. The facility layout is located in Appendix A.

Driving and Receiving

Driving and receiving employees picked up electronics from businesses and homes. Electronic equipment was loaded onto a truck and then transported into the warehouse manually and with a dolly. The driver and one or two employees would assist in unloading the truck. The equipment was taken directly to sorting and inventory stations.

Sorting and Inventory

Sorting and inventory employees evaluated and sorted electronics brought into the warehouse on the basis of whether the electronics were "end-of-life" or reusable. Electronics categorized as end-of-life were sent through the disassembly process. Reusable electronics were sent to the refurbishing and resale stations. Employees used a vacuum cleaner or compressed air to clean dusty electronic equipment.

Disassembly

Employees in the disassembly department received electronics from inventory stations. They used hand tools (electric drill or manual screwdriver, hammer) to disassemble the electronics. Employees removed the circuit boards and then sorted them on the basis of the value of the metals on the boards. They manually separated the plastic and metal components and placed them into bins to be shipped off site for processing.

Refurbishing

Employees tested the functionality of equipment, laptops, and batteries. If the central processing unit of the computer functioned, it was sent to the "wiping bench" where data was removed and software reloaded. Employees electronically and mechanically destroyed some hard drives. These hard drives were placed in a "degausser," where an electromagnetic pulse was applied to the hard drive, then the hard drive was mechanically split.

Resale and Shipping

Resale and shipping employees photographed the equipment, listed it on the internet for sale, and prepared it for shipping.

Office Employees

Office employees typically worked at a desk on a computer. Office employees were responsible for testing monitor screens and entered the processing area periodically to complete this task. One of the office employees was assigned to work on his computer at a workstation in the processing area. Processing employees regularly entered the office space because it was the most convenient route between the warehouse and the restroom facilities. We only collected samples on the employees who either worked in the warehouse or frequently entered the warehouse.

Methods

Our primary objective was to evaluate employee exposure to the most commonly found metals in electronic recycling streams. Our secondary objective was to determine if there was a potential for take-home contamination with metals.

Questionnaire and Consent

We obtained informed consent from all participants before beginning the evaluation. We asked all participants to fill out a questionnaire about their personal and work history (length of employment, job tasks, work history, current practices, use of personal protective equipment [PPE], and hygiene practices).

Surface and Hand Wipe Samples

We collected and analyzed surface and hand wipe samples for metals according to NIOSH Method 9102, including lithium [NIOSH 2018]. We used premoistened SKC Inc. Ghostwipe® towelettes to wipe the surfaces using a 10 by 10 centimeter square disposable template to demarcate the surface sampling area.

We collected hand wipe samples for metals from each participant at the end of shift on one day. We put on a new pair of nitrile gloves, then opened a glass vial, and asked the employee to take one Ghostwipe towelette from the vial, wipe both palms from wrist to finger tips for 30 seconds, and then place the wipe back into the same glass vial. We then asked the employee to take the second wipe and repeat the process for the back of both hands and place the wipe into the same glass vial. We sealed the vial with its lid and a parafilm wrap. We collected the postshift sample after the employees washed their hands before going home to determine the potential for take-home exposure.

Air Samples

We collected one full-shift personal air sample per participant per day on two consecutive days. We collected personal and area air samples for metals and minerals, including lithium, on 37-millimeter cassettes and analyzed them according to NIOSH Method 7303 [NIOSH 2018] with modification. The modification included using a digestible Solulcert® to collect particles on the inside of the cassette walls as recommended by NIOSH [2009].

Blood Samples for Cadmium and Lead

We collected approximately 10 milliliters of blood from each participant at the end of their shift at the end of their workweek to be analyzed for blood lead and cadmium levels. A trained technician drew blood from the vein following universal precautions for working with blood and blood products specified by the Centers for Disease Control and Prevention [Siegel et al. 2007] and the Occupational Safety and Health Administration (OSHA) [OSHA 2003].

Results and Discussion

Questionnaire

Eight of the 12 employees participated in this evaluation; one was female. The average age was 32 years (range: 19–47 years), and the median length of time in the facility was 27 months (range: 2–66 months). All participants worked 40 hours per week. Some employees listed more than one usual job duty. Duties involved disassembly (5), refurbishing (3), sorting and inventory of electronics (5), sorting of batteries (3), storage (6), shipping (1), data destruction (4), loading and unloading of trucks (5), and office work (2). Most participants (6) performed more than one task regularly. Seven participants reported wearing their work clothing home, and six reported wearing their work shoes or boots home. All eight employees reported wearing gloves at work: one all the time, five most of the time, and two some of the time. All reported reusing their gloves. Employees most commonly reported wearing cloth gloves (4), followed by cut-resistant gloves (3), and nitrile and leather gloves (1 each). The only type of glove that we observed employees using was a cut-resistant glove. Four participants reported washing their hands more than five times per day, with the remainder washing their hands less frequently. One participant reported sometimes washing hands before eating at work, with the remainder reporting that they always washed their hands before eating at work. Six participants reported always washing their hands before leaving work, while two participants reported sometimes washing their hands before leaving work. Five employees reported that they currently smoked.

Surface and Hand Wipe Sampling

Although there are no occupational exposure limits (OELs) for surface and hand wipe samples, they can provide information about the effectiveness of housekeeping practices, the potential for exposure to contaminants by other routes such as the skin or mouth (e.g., from surface contamination on a table where people eat and drink), the potential for contamination of worker clothing and subsequent transport of the contaminant outside the work place, and the potential for activities unrelated to processing, such as sweeping, to generate airborne contaminants.

Table 1 shows the surface wipe sample results for metals common in electronic scrap. The location with the highest concentration of lead, cobalt, and chromium was the refrigerator handle. The highest cadmium level was found on the women's restroom door handle. The highest copper level was on the men's restroom door handle. Although these levels were relatively low, they show migration of metal from processing areas to nonprocessing areas, most likely when employees with metal particles on their hands touch these surfaces. Similar or higher levels of metal on surfaces in nonprocessing areas suggests that these areas are not being cleaned sufficiently, and increase the risk of employees accidentally ingesting metal particles, either by direct hand-to-mouth or by ingesting a food with the contaminant on it.

Table 1. Metals detected in surface wipe samples, in micrograms per 100 square centimeters (unless otherwise noted)

Location	Be	Cd	Cr	Co	Cu	Pb
Nonprocessing areas						
Women's restroom door handle*	ND	4	0.5	0.09	8	2
Men's restroom door handle*	ND	0.1	0.5	0.06	22	2
Women's restroom floor	ND	0.1	0.3	0.2	2	5
Men's restroom floor	ND	0.1	0.4	0.2	2	5
Microwave button*	ND	0.03	0.3	ND	ND	0.4
Floor in break area	ND	0.2	0.2	0.1	1	2
Pop/soda machine	ND	0.2	0.8	ND	20	2
Refrigerator handle*	ND	1	3	0.6	18	14
Office desk	ND	ND	ND	ND	ND	0.6
Processing areas						
Door into office area	ND	0.1	0.3	0.07	5	2
Disassembly drill handle*	ND	1	0.9	0.07	10	8
Inventory scanner handle*	ND	0.05	0.3	ND	1	0.3
Testing station desk	ND	ND	0.1	ND	1	ND
Employees desk	ND	0.3	0.8	0.3	5	4
Refurbish area mouse*	ND	0.3	0.2	0.06	2	0.4
Data destruction cart	ND	0.3	0.2	ND	ND	0.5
Resale desk	ND	0.6	0.8	0.2	7	7
Rolling computer cart keyboard	ND	0.2	1	0.3	5	4
Inside delivery vehicle						
Steering wheel of delivery truck*	ND	0.03	0.3	ND	4	1
Gearshift of delivery truck*	ND	0.1	0.5	0.08	7	2
Limit of detection (micrograms per sample)	0.005	0.02	0.06	0.06	1	0.3

ND = Not detected

*Estimated 100 square centimeters

Table 2 shows the hand wipe sample results for common metals found in electronic scrap. All employees had detectable levels of cadmium, chromium, and lead on their hands. Six of the eight employees had detectable cobalt, seven of the eight employees had copper, and one of the eight employees had detectable beryllium. We collected these samples after the employees had washed their hands and immediately before the employees went home for the evening. Therefore, employees could have transferred metals from their hands to their vehicles and homes. Research has shown that washing the hands with soap and water does not efficiently remove lead and other toxic metals from the skin [Filon et al. 2006]. In contrast, the use of lead removal products to clean the hands has been shown to substantially reduce lead [Esswein et al. 2011].

Table 2. Metals detected in hand wipe samples collected immediately before the employee left the workplace, levels in micrograms per sample

Task	Be	Cd	Cr	Co	Cu	Pb
Disassembly	0.007	0.04	0.2	ND	1	0.9
Disassembly	ND	0.3	0.6	0.08	15	4
Sorting and inventory	ND	2.0	5	1	40	36
Sorting and inventory	ND	0.3	0.4	0.08	3	3
Shipping	ND	0.02	0.2	ND	ND	0.7
Office	ND	0.7	1.0	0.3	5	5
Office	ND	0.07	0.4	0.06	3	1
Driver	ND	0.1	0.8	0.1	11	3
Limit of detection (micrograms per sample)	0.005	0.02	0.03	0.06	1	0.3

Air Samples

We collected 16 personal and 4 area air samples. One employee declined wearing the personal air sampling pump; however, we collected area air samples near the employee at the workstations and consider the results to be closely representative of the employee's exposure. Personal air sample results for the most common metals found in electronic scrap are in Table 3. None of the personal exposure monitoring results exceeded applicable OELs; with the exception of chromium, they were well below the most protective OEL. The chromium concentration for one air sample was approaching half of the most protective OEL.

Table 3. Full-shift, personal air sampling results, in micrograms per cubic meter (μg/m³)

Task	Be	Cd	Cr	Co	Cu	Pb	Sample duration (minutes)
Day 1							
Disassembly	ND	ND	ND	ND	ND	[0.27]	428
Disassembly	ND	[0.05]	ND	ND	2.3	[0.59]	393
Sorting and inventory	ND	ND	ND	ND	[0.25]	[0.28]	480
Sorting and inventory	ND	ND	ND	ND	ND	ND	433
Shipping	ND	ND	ND	ND	0.49	[0.39]	401
Office	ND	ND	ND	ND	ND	[0.25]	446
Office*	ND	ND	ND	ND	ND	ND	463
Driver	ND	ND	ND	ND	ND	ND	439
Monitors testing*	ND	ND	ND	ND	ND	ND	442
Day 2							
Disassembly	ND	ND	ND	ND	[0.32]	ND	443
Disassembly	ND	[0.04]	ND	ND	0.98	[0.37]	405
Sorting and inventory	ND	ND	ND	ND	[0.27]	ND	443
Sorting and inventory	ND	ND	ND	ND	ND	ND	363
Shipping	ND	ND	ND	ND	[0.43]	[0.41]	383
Office	ND	ND	ND	ND	ND	ND	407
Office*	ND	ND	203	ND	ND	ND	422
Driver	ND	ND	ND	ND	[0.18]	ND	396
Monitors testing*	ND	ND	ND	ND	ND	ND	425
Most protective OEL	0.05	5	500	20	1000	50	—
OEL set by	ACGIH	ACGIH	ACGIH	ACGIH	ACGIH	NIOSH	—
MDC	0.01	0.04	0.08	0.06	0.12	0.24	—
MQC	0.03	0.11	0.30	0.21	0.46	0.93	—

ACGIH = American Conference of Governmental Industrial Hygienists

MDC = Minimum detectable concentration

MQC = Minimum quantifiable concentration

*Area samples close to employee workstations

Note: Values in brackets are between the MDC and MQC; more uncertainty is associated with these concentrations. The MDC and MQC were calculated using an average sample volume of 846 liters.

Blood Samples

Eight employees had blood drawn for metals. Blood lead levels (BLLs) ranged from 0.50 micrograms per deciliter (µg/dL) to 2.4 µg/dL. Blood cadmium levels were low, with six employees' levels below the laboratory limit of detection of 0.5 micrograms per liter (µg/L). Blood cadmium levels for the two employees above the limit of detection were 0.76 µg/L and 0.81 µg/L.

Blood lead and cadmium levels were well below the OSHA acceptable level of 50 µg/dL for lead and 5 µg/L for cadmium. The NIOSH Adult Blood Lead Epidemiology and Surveillance system (ABLES) uses a surveillance case definition for a lead exposed worker that is considerably lower than OSHA's acceptable level. The NIOSH ABLES considers a BLL elevated if it is 5 µg/dL or higher [CDC 2015]. No employee's level exceeded this criterion. Smoking can increase blood lead and cadmium levels [Adams and Newcomb 2014; Mannino et al. 2005]. We found that the two employees with detectable levels of cadmium in their blood smoked, but we did not see a difference in BLLs between smokers and nonsmokers. This may be because of the small number of employees we tested.

Workplace Observations and Record Review

The employer reported that they had a joint employee and employer safety committee, but it was unclear when the last committee meeting was held. We reviewed their accident prevention program, which included written documentation of a hazard assessment and the required PPE for specific job tasks. All employees were required to wear steel-toed shoes and gloves. All employees wore cut-resistant, palmar coated gloves. Employees reported that they reused gloves, but received a new pair every third day. We observed worn patches and holes in the work gloves. The company did not provide uniforms, and the employees laundered their work clothes at home. We observed steel-toed boots stored near employee food in the break area. Eye protection was required in the disassembly department, though we did not observe any employees wearing safety glasses while disassembling electronics.

Employees reported that use of N95 filtering facepiece respirators was optional. However, according to the accident prevention program and employee reports, N95 filtering facepiece respirators were required to be worn during clean-up of mercury spills or breakage of lead-containing electronics (i.e., cathode ray tube, leaded glass). In addition, the accident prevention program stated that protective eyewear, gloves, and long sleeve clothing and pants were required for these tasks. It must be noted that an N95 respirator, or other particulate respirator, would not protect against mercury vapor exposures. For protection from exposure to mercury vapor, a tight-fitting elastomeric respirator with mercury vapor cartridges would be needed.

The company did not have a respiratory protection program, which is required when respirator use is mandatory. We observed respirators in the facility, including N95 filtering facepiece respirators and an elastomeric full facepiece respirator with particulate filters. Employees using respirators voluntarily had not received a copy of Table 2 of the Washington Administrative Code 296-842-11005 or Appendix D of the OSHA respiratory protection standard, 29 Code of Federal Regulations (CFR) 1910.134, as required by OSHA. We observed that the respirators were not always properly stored or kept clean.

We reviewed records of industrial hygiene monitoring conducted in June 2015 by the Washington State Department of Labor and Industries, Division of Occupational Safety and Health. The personal air sampling showed no overexposures. Surface wipe samples for lead showed some workstations had lead levels of 120–430 micrograms per 100 square centimeters. In response, company managers wrote a "Lead Recognition and Decontamination Procedure," cleaned the surfaces with soap and water, and contracted a consultant to re-evaluate surface lead levels every 3 years. The "Lead Recognition and Decontamination Procedure" document identified more stringent PPE requirements than the accident prevention plan, noting that gloves, respirators, protective goggles, steel-toed boots, and protective clothing are required at all times in a facility with lead. The conflicting requirements between these documents could be confusing to employees.

Employees reported using compressed air to clean dusty electronic equipment outside of the warehouse. Floors and other surfaces where lead or other heavy metals accumulate should not be cleaned with compressed air [29 CFR 1910.242]. The use of compressed air can cause lead and other metal particles to become airborne, making it easier to inhale. It may also contaminate nearby surfaces. We also observed employees using pedestal fans for personal cooling and brooms to sweep up at the end of the day. Fans and dry sweeping are also known to re-aersolize dust particles that may be contaminated with lead.

The company had no shower facilities, locker rooms, or dedicated break room. Some employees ate lunch at their workstations, outside, or in their cars. Taking contaminated clothing home could potentially bring lead and other hazardous metals to employees' homes. In addition, we observed employees walking through the office area to get to the bathrooms and food storage areas instead of using the door with direct passage from the processing floor to the restrooms. This can cause hazardous materials to be tracked into nonprocessing areas. Although we did not specifically ask how frequently these areas were cleaned, we observed and collected wipe samples of dust built up on many of the horizontal surfaces in this area. Infrequent housekeeping can lead to the buildup of contaminated dusts.

Conclusions

Employees at this recycling facility are exposed to metals, including lead and cadmium; however, exposures on the days we took air samples were well below OELs. Blood measurements for lead and cadmium were also below recommended levels. We identified a potential for take-home contamination with lead and other metals as indicated by the presence of metals on surface wipe samples in production and nonproduction areas where employees eat and drink. We also found metals on employees' hands immediately before they left work at the end of the day. Take-home lead can contaminate cars and homes, and potentially expose family members.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the electronics recycling facility to use an employer-employee 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 electronics 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 PPE may be needed.

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 all employees in a lead exposure prevention program. Follow the medical surveillance program outlined in Appendix B in addition to all requirements of the OSHA lead standard. In the event that processes change, including a substantial increase or change in type of electronics recycled, more frequent BLL testing may be required. Provide employees with the results of their BLLs in writing after each blood draw.
2. Review and update the PPE hazard assessment, which is included as part of the accident prevention plan, to make sure that it includes all of the necessary PPE and types of PPE for specific job tasks. In addition, make sure that PPE recommendations included in the accident prevention and lead recognition and decontamination procedures are the same.
3. Implement a formal policy and educate employees on handwashing in the workplace, including the use of lead-removing products to wash their hands.
4. Implement a respiratory protection program if respirators are required for any task. The program at a minimum should meet the requirements of the Washington Administrative Code 296-842-11005. Ensure that employees required to wear respirators are medically cleared, fit-tested, clean-shaven, and adequately trained on respirator use and care before they use the respirators.
5. Ensure that employees whose only use of respirators is voluntary can safely wear the respirator. In addition, provide these employees with a copy of Appendix D of the OSHA respiratory protection standard (29 CFR 1910.1345) or Washington Administrative Code 296-842-11005. Ensure that respirators are stored properly so that they do not become contaminated.
6. Provide employees with a lead-removing product to wash their hands after removing gloves, and before eating, drinking, or smoking. Refer to "Information for Workers, How You Can Keep Yourself and Your Family Safe from Lead," available at http://www.cdc.gov/niosh/topics/lead/safe.html for more information about commercially available lead-removal products.

7. Clean all nonprocessing surfaces periodically to reduce the build-up of dust that contains lead, cadmium, and other metals. Consider using lead-removing wipes for this purpose. For carpeted areas or other porous surfaces, use a high-efficiency particulate air (HEPA) filtered vacuum cleaner. Prohibit dry sweeping of floors. Instead, use wet cleaning methods or a HEPA-filtered vacuum cleaner.
8. Prohibit using compressed air to blow the dust out of electronics. Instead, use a HEPA-filtered vacuum cleaner.
9. Revitalize the employer-employee health and safety committee or working group to discuss workplace concerns and develop action plans for continued improvement of worker health and safety.
10. Provide a location for food storage and consumption separate from work areas. Do not store contaminated PPE in the same location. Until a break room is provided, frequently clean the areas where employees take breaks.
11. Prohibit the consumption or storage of food and drinks at workstations.
12. Evaluate airborne exposures to metals whenever an increase in hazardous exposures is possible, such as introducing new operations, introduction of new hazards, and increased workloads. If employee exposures increase, additional protective measures may be needed.
13. Remove pedestal fans from the workbench, as they may aerosolize dust that contains heavy metals.
14. Write a formal policy for reusing or laundering cut resistant gloves. The policy should include information about the proper selection of gloves, when to use gloves, and how often gloves should be replaced.
15. Discourage workers from using the office space as a corridor to the bathroom or food preparation area. This may lead to tracking of metals into the office area. Use the door that leads directly from the processing areas into the hallway where the restrooms are located.
16. Increase the frequency of housekeeping in the nonprocessing areas to decrease the amount of lead and other hazardous materials.
17. Offer a smoking cessation program to employees.

Personal Protective Equipment

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

1. Wear steel-toed boots, safety glasses with side shields, long sleeve shirts, pants, and cut-resistant gloves while performing general warehouse work. Specific tasks, such as cleaning up cathode ray tube or fluorescent bulb breakage, may require additional PPE. If fluorescent bulbs break, wear disposable nonlatex rubber or nitrile gloves to clean up the area. Use a commercial spill kit if available, or scoop glass and powder safely into a sealable container. Use tape to pick up any remaining pieces of glass. Disposable wet wipes or damp paper towels may then be used to clean up the remaining dust. More information on avoiding mercury exposure from fluorescent bulbs can be found at https://www.osha.gov/Publications/osha3536.pdf.
2. Provide clean gloves for daily use, or use clean inner gloves when reusing dirty gloves. Instruct employees to leave dirty gloves in the work area. Encourage employees to replace dirty gloves frequently to minimize contamination of surfaces with metals.

Appendix A. Facility Layout

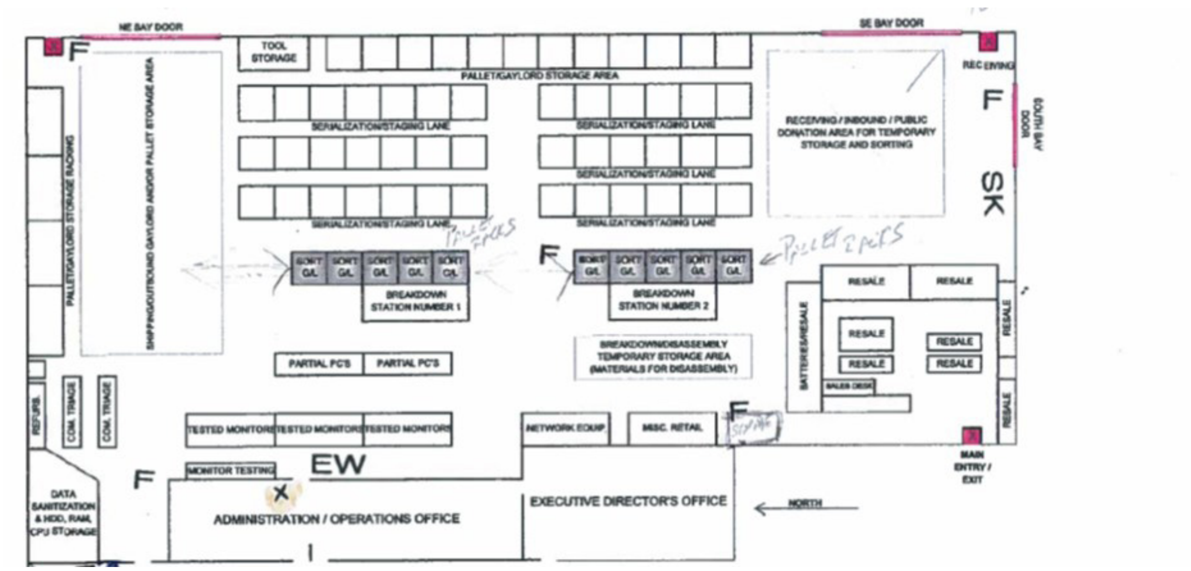

Figure A1. Floor plan for the facility. Layout provided by the company.

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 (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

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

- The U.S. Department of Labor OSHA permissible exposure limits (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 recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, PPE, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Another set of OELs commonly used and cited in the United States is the ACGIH threshold limit values (TLVs). The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They 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 2018].

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/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 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) PPE (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 has been mined and used in industry since ancient times. It 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, particularly through damaged skin [Filon et al. 2006; Stauber et al. 1994; Sun et al. 2002].

Workplace settings with exposure to lead and lead compounds include smelting and refining, scrap metal recovery, automobile radiator repair, construction and demolition (including abrasive blasting), and firing ranges. Occupational exposures also occur among workers who apply or remove lead-based paint and among welders who burn or torch-cut metal structures.

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 [CDC 2013a; Lauwerys and Hoet 2001; Moline and Landrigan 2005]. 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. The geometric mean BLL went from 1.75 µg/dL in 1999–2000 to 1.09 µg/dL in 2011–2012 [CDC 2015]. The NIOSH ABLES System uses a surveillance case definition for an elevated BLL in adults of 5 µg/dL of blood or higher [CDC 2015]. Very high BLLs are defined as BLLs $\geq$ 40 µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where exposure source was known) [CDC 2013b]. This underscores the need to increase efforts to prevent lead exposures in the workplace.

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^3 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^3 (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, which are not legally enforceable, are often followed. 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^3 averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of 50 µg/m^3 (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. ACGIH designates lead as an animal carcinogen [ACGIH 2018]. In 2013, the California Department of Public Health recommended that Cal/OSHA lower the PEL for lead to 0.5 to 2.1 µg/m^3 (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 U.S. Environmental Protection Agency and the U.S. Department of Housing and Urban Development limit lead on surfaces in public buildings 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/eating areas to ensure they are as free as practicable from lead contamination [OSHA 2003].

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 [Brown-Williams et al. 2009; Institute of Medicine 2012; Schwartz and Hu 2007; Schwartz and Stewart 2007]. 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 recently released a monograph on the health effects of low-level lead exposure [National Toxicology Program 2012]. For adults, the National Toxicology Program concluded the following about the evidence regarding health effects of lead (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	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 National Toxicology Program [National Toxicology Program 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 [IARC 2006a]. According to the American Cancer Society [ACS 2011], 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 convened by the Association of Occupational and Environmental Clinics published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. 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 were endorsed by the Council of State and Territorial Epidemiologists and the California Department of Public Health in 2009 and the American College of Occupational and Environmental Medicine in 2010 [ACOEM 2010; CDPH 2009; CSTE 2009]. The Council of State and Territorial Epidemiologists published updated guidelines in 2013 to reflect the new definition of an elevated BLL in adults of 5 µg/dL [CSTE 2015]. The California Department of Public Health recommended keeping BLLs below 5 to 10 µg/dL in 2013 [Billingsley 2013] and updated their medical management guidelines in 2014 [CDPH 2014]. In 2015, NIOSH designated 5 µg/dL of whole blood, in a venous blood sample, as the reference blood lead level for adults. An elevated BLL is defined as a BLL ≥ 5 µg/dL. In 2016, the American College of Occupational and Environmental Medicine released a position statement titled "Workplace Lead Exposure," which reinforces the guidelines and recommendations from the expert panel guidelines and those from the California Department of Public Health, The American College of Occupational and Environmental Medicine, and the Council of State and Territorial Epidemiologists. Table B2 incorporates recommendations from the expert panel guidelines and those from the California Department of Public Health and the Council of State and Territorial Epidemiologists.

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

Category of exposure	Recommendations
All lead exposed workers	• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine
BLL < 5 µg/dL	• BLL monthly for first 3 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 5–9 µg/dL	• Discuss health risks • Minimize exposure • Consider removal for pregnancy and certain medical conditions • BLL monthly for first 3 months placement or every 2 months for the first 6 months placement, or upon change in task to higher exposure, then BLL every 6 months; if BLL increases ≥ 5 µg/dL, evaluate exposure and protective measures, and increase monitoring if indicated
BLL 10–19 µg/dL	• Discuss health risks • Decrease exposure • Remove from exposure for pregnancy • Consider removal for certain medical conditions or BLL ≥ 10 µg/dL for extended period • BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal. • Revert to BLL every 6 months after 3 BLLs < 10 µg/dL
BLL 20–29 µg/dL	• Remove from exposure for pregnancy • Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL • Annual lead medical exam recommended • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 30–49 µg/dL	• Remove from exposure • Prompt medical evaluation • Monthly BLL testing • Consider return to work after 2 BLLs < 15 µg/dL a month apart, then monitor as above
BLL 50–79 µg/dL	• Remove from exposure • Prompt medical evaluation • Consider chelation with significant symptoms
BLL ≥ 80 µg/dL	• Remove from exposure • Urgent medical evaluation • Chelation may be indicated

Adapted from Kosnett et al. 2007, CSTE 2013, 2015, and CDPH 2014

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, 2012].

The Centers for Disease Control and Prevention 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 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.

Beryllium, Cadmium, Chromium, Cobalt, and Copper

Below is a table summarizing the OELs for the other common metals found in electronic scrap recycling, as well as a discussion of the potential health effects from exposure to these elements.

Table B3. Chemical health effects

Chemicals	Health effects	IARC	OEL (µg/m^3)
Beryllium	● Beryllium exposure may cause dermatitis, lung inflammation, and chronic beryllium disease in humans [Proctor et al. 1991]. ● Exposure to beryllium can lead to sensitization. ● Exposure also slightly increases the risk for lung cancer [Schubauer-Berigan et al. 2010].	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 0.2 NIOSH REL: 0.5 ACGIH TLV: 0.05
Cadmium	● Long-term occupational exposure to cadmium is associated with increased occurrence of lung cancer, kidney damage, and chronic obstructive lung disease [WHO 1992].	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 5.0 NIOSH REL: Cancer ACGIH TLV: 10 (2 respirable fraction)
Chromium	● The toxic effects of chromium exposure, including lung and nasal cancer, are primarily related to hexavalent chromium. ● Skin exposure to chromium dust can cause skin irritation and skin ulceration, and allergic contact dermatitis.	Group 1: carcinogenic to humans [IARC 2012]	OSHA PEL: 1000 NIOSH REL: 500 ACGIH TLV: 500
Cobalt	● Exposure to elevated levels of cobalt can cause gastrointestinal irritation, nausea, and vomiting. ● Inhaled cobalt can lead to lung damage. ● Skin exposure can cause irritant and allergic contact dermatitis [Vincoli 1997].	Group 2B: possibly carcinogenic to humans [IARC 2006b]	OSHA PEL: 100 NIOSH REL: 50 ACGIH TLV: 20
Copper	● Inhalation of copper fumes can produce toxic effects on the respiratory tract and may cause metal fume fever. ● Copper salts may be absorbed through the skin causing systemic toxicity [IPCS 2017].	No evidence of carcinogenicity	OSHA PEL: 1,000 NIOSH REL: 1,000 ACGIH TLV: 1,000

IARC = International Agency for Research on Cancer

References

ACGIH [2018]. 2018 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACOEM [2010]. ACOEM provides input to OSHA on key issues facing agency in 2010. Letter to David Michaels. Elk Grove Village, IL: American College of Occupational and Environmental Medicine, http://www.acoem.org/Page2Column.aspx?PageID=7392&id=6676.

ACS [2011]. Lead. Atlanta, GA: American Cancer Society, http://www.cancer.org/cancer/cancercauses/othercarcinogens/athome/lead.

Adams SV, Newcomb PA [2014]. Cadmium blood and urine concentrations as measures of exposure: NHANES 1999-2010. J Expo Sci Environ Epidemiol *24*(2):163–170, http://dx.doi.org/10.1038/jes.2013.55.

ATSDR [2007]. Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services.

Billingsley KJ [2013]. Letter of September 30, 2013, from K. J. Billingsley, California Department of Public Health, to Juliann Sum, Division of Occupational Safety and Health (Cal/OSHA), California Department of Industrial Relations.

Brown-Williams H, Lichterman J, Kosnett M [2009]. Indecent exposure: lead puts workers and families at risk. Health Research in Action, University of California, Berkeley. Perspectives *4*(1):1–9.

CDC (Centers for Disease Control and Prevention) [2009]. Childhood lead poisoning associated with lead dust contamination of family vehicles and child safety seats --- Maine, 2008. MMWR *58*(32):890–893.

CDC (Centers for Disease Control and Prevention) [2012]. Adult blood lead epidemiology and surveillance (ABLES), http://www.cdc.gov/niosh/topics/ABLES/description.html.

CDC (Centers for Disease Control and Prevention) [2013a]. Blood lead levels in children aged 1–5 years — United States, 1999–2010. MMWR *62*(13):245–248.

CDC (Centers for Disease Control and Prevention) [2013b]. Very high blood lead levels among adults — United States, 2002–2011. MMWR *62*(47):967–971.

CDC (Centers for Disease Control and Prevention) [2015]. Adult blood lead epidemiology and surveillance (ABLES), http://www.cdc.gov/niosh/topics/ables/description.html.

CDPH [2009]. Medical guidelines for the lead-exposed worker. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, http://www.cdph.ca.gov/programs/olppp/Documents/medgdln.pdf.

CDPH [2014]. Management guidelines for blood lead levels in adults. Sacramento, CA: California Department of Public Health, Occupational Lead Poisoning Prevention Program, http://www.cdph.ca.gov/programs/olppp/documents/adultmgtguide.pdf.

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

CSTE [2009]. Proposal to adopt new or amended surveillance definitions for four environmental conditions. CSTE position statement 09-OH-02. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/PS/09-OH-02.pdf.

CSTE [2013]. Management guidelines for blood lead levels in adults. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/OccupationalHealth/ManagementGuidelinesforAdult.pdf.

CSTE [2015]. Public health reporting and national notification for elevated blood lead levels. CSTE position statement 15-EH-01. Atlanta, GA: Council of State and Territorial Epidemiologists, http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/2015PS/2015PSFinal/15-EH-01.pdf.

EPA [1998]. Risk analysis to support standards for lead in paint, dust, and soil. EPA Publication EPA-747-R097-006. Washington, D.C., http://www2.epa.gov/lead/risk-analysis-support-standards-lead-paint-dust-and-soil-volume-i-chapters-1-7-and-appendix-epa.

Esswein EJ, Boeniger MF, Ashley K [2011]. Handwipe method for removing lead from skin. J ASTM International. *8*(5):1–10, http://dx.doi.org/10.1520/STP49744S.

Filon FL, Boeniger M, Maina G, Adami G, Spinelli P, Damian A [2006]. Skin absorption of inorganic lead (PbO) and the effect of skin cleansers. J Occup Environ Med *48*(7):692–699, http://www.joem.org/pt/re/joem/abstract.00043764-200607000-00012.htm.

HUD [2012]. Guidelines for the evaluation and control of lead-based paint hazards in housing, http://portal.hud.gov/hudportal/HUD?src=/program_offices/healthy_homes/lbp/hudguidelines.

IARC [2006a]. IARC monographs on the evaluation of carcinogenic risks to humans: inorganic and organic lead compounds. Volume 87. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://monographs.iarc.fr/ENG/Monographs/vol87/.

IARC [2006b]. IARC monographs on the evaluation of carcinogenic risks to humans: cobalt in hard metals and cobalt sulfate, gallium arsenide, indium phosphide and vanadium pentoxide. Volume 86. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://monographs.iarc.fr/ENG/Monographs/vol86/mono86.pdf.

IARC [2012]. IARC monographs on the evaluation of carcinogenic risks to humans: arsenic, metals, fibres and dusts. Volume 100C. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C.pdf.

Institute of Medicine [2012]. Potential health risks from recurrent lead exposure of DOD firing range personnel. Washington, D.C.: National Academies Press.

International Programme on Chemical Safety (IPCS) [2017]. InChem: chemical safety information from intergovernmental organizations, http://www.inchem.org/.

Kosnett MJ, Wedeen RP, Rothenberg SJ, Hipkins KL, Materna BL, Schwartz BS, Hu H, Woolf A [2007]. Recommendations for medical management of adult blood lead exposure. Environ Health Perspect *115*(3):463–471, http://dx.doi.org/10.1289/ehp.9784.

Lauwerys RR, Hoet P [2001]. Industrial chemical exposure: guidelines for biological monitoring. 3rd ed. Boca Raton, FL: CRC Press, LLC, pp. 21–180.

Mannino DM, Homa DM, Matte T, Hernandez-Avila M [2005]. Active and passive smoking and blood lead levels in U.S. adults: data from the Third National Health and Nutrition Examination Survey. Nicotine Tob Res *7*(4):557–564, http://dx.doi.org/10.1080/14622200500185264.

Moline JM, Landrigan PJ [2005]. Lead. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. Philadelphia, PA: Elsevier Saunders, pp. 967–979.

National Toxicology Program [2011]. Report on carcinogens. 12th ed. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/Lead.pdf.

National Toxicology Program [2012]. Monograph on the health effects of low-level lead. Research Triangle Park, NC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program.

NIOSH [1995]. Report to Congress on the workers' home contamination study conducted under the Workers' Family Protection Act 29 U.S.C. 671a. 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. 95-123, http://www.cdc.gov/niosh/docs/95-123/.

NIOSH [2009]. Exposure to hazardous metals during electronics recycling at four UNICOR facilities. By Page E, Sylvain D. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2008-0055-3098, https://www.cdc.gov/niosh/hhe/reports/pdfs/2008-0055-3098.pdf.

NIOSH [2010]. 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. 2010-168c, http://www.cdc.gov/niosh/npg/.

NIOSH [2014]. Evaluation of occupational exposures at an electronic scrap recycling facility. By Ceballos D, Chen L, Page E, Echt A, Oza A, Ramsey J. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Health Hazard Evaluation Report 2012-0100-3217, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0100-3217.pdf.

NIOSH [2018]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, 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 No. 2014-151, http://www.cdc.gov/niosh/nmam.

OSHA [2003]. Standard interpretation letter – lead standard 29 CFR 1926.62 (i)(2)(ii), http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=25617.

Proctor NH, Hughes JP, Fischmann ML [1991]. Chemical hazards of the workplace, 3rd ed. New York: Van Nostrand Reinhold.

Schubauer-Berigan MK, Deddens JA, Couch JR, Petersen MR [2010]. Risk of lung cancer associated with quantitative beryllium exposure metrics within an occupational cohort. Occup Environ Med *68*(5):354–360, http://dx.doi.org/10.1136/oem.2010.056515.

Schwartz BS, Hu H [2007]. Adult lead exposure: time for change. Environ Health Perspect *115*(3):451–454, https://dx.doi.org/10.1289%2Fehp.9782.

Schwartz BS, Stewart WF [2007]. Lead and cognitive function in adults: a question and answers approach to a review of the evidence for cause, treatment, and prevention. Int Rev Psychiatry *19*(6):671–692, http://dx.doi.org/10.1080/09540260701797936.

Siegel JD, Rhinehart E, Jackson M, Chiarello L, Healthcare Infection Control Practices Advisory Committee [2007]. Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings, http://www.cdc.gov/hicpac/pdf/isolation/Isolation2007.pdf.

Stauber JL, Florence TM, Gulson B, Dale L [1994]. Percutaneous absorption of inorganic lead compounds. Sci Total Environ *145*(1–2):55–70, https://doi.org/10.1016/0048-9697(94)90297-6.

Sun CC, Wong TT, Hwang YH, Chao KY, Jee SH, Wang JD [2002]. Percutaneous absorption of inorganic lead compounds. Am Ind Hyg Assoc J *63*(5):641–646. https://doi.org/10.1080/15428110208984751.

Vincoli JW [1997]. Risk management for hazardous chemicals. Boca Raton, FL: CRC Press.

WHO [1992]. Environmental Health Criteria 134. Cadmium. Geneva, Switzerland: World Health Organization, http://www.inchem.org/documents/ehc/ehc/ehc134.htm.

Keywords: North American Industry Classification System (NAICS) 423930 (Recyclable Material Merchant Wholesalers), Washington, Electronics Recycling, E-Scrap, E-Waste, Lead, Cadmium

This page left intentionally blank

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

Disclaimer

The recommendations in this report are made on the basis of the findings at the workplace evaluated and may not be applicable to other workplaces.

Mention of any company or product in this report does not constitute endorsement by NIOSH.

Citations to Web sites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. NIOSH is not responsible for the content of these Web sites. All Web addresses referenced in this document were accessible as of the publication date.

Acknowledgments

Analytical Support: Maxxam Laboratories, Washington State Public Health Laboratory
Desktop Publisher: Shawna Watts
Editor: Ellen Galloway
Industrial Hygiene Field Assistance: Jonathan Slone
Logistics: Donnie Booher, Kevin Moore
Medical Field Assistance: Deborah Sammons, Shirley Robertson

Availability of Report

Copies of this report have been sent to the employer and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

Recommended citation for this report:
NIOSH [2018]. Evaluation of exposure to metals at an electronics recycling facility. By Grimes GR, Beaucham CC, Ramsey JG. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2016-0242-3315, https://www.cdc.gov/niosh/hhe/reports/pdfs/2016-0242-3315.pdf.

Delivering on the Nation's promise:
Promoting productive workplaces through safety and health research

To receive NIOSH documents or more information about occupational safety and health topics, please contact NIOSH:

Telephone: 1–800–CDC–INFO (1–800–232–4636)

TTY: 1–888–232–6348

CDC INFO: www.cdc.gov/info

or visit the NIOSH Web site at www.cdc.gov/niosh

For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting www.cdc.gov/niosh/eNews.

SAFER • HEALTHIER • PEOPLE™