Evaluation of Occupational Exposures at an Electronic Scrap Recycling Facility

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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 a health and safety manager at an electronic scrap recycling facility. The employer was concerned about workplace exposures, including lead and cadmium, from recycling electronic scrap.

What We Did

- We evaluated the electronic scrap recycling facility in March, July, and November 2012 and January and February 2013.
- We interviewed employees about their work practices, symptoms, and health concerns related to work.
- We measured employees' exposures to noise, dust, silica, and metals.
- We tested work surfaces, skin, and clothing for metals, including lead, cadmium, chromium, and nickel.
- We tested employees' urine for cadmium and mercury and blood for lead and cadmium.
- We looked at possible ergonomic hazards and ventilation controls.

We evaluated air, surfaces, blood, and urine for metals at an electronic scrap recycling facility. We also evaluated noise exposures. We found overexposures to lead, cadmium, and noise. Some employees had blood lead levels above 10 ug/dl. We provided recommendations to prevent these exposures to employees, and to prevent unintentionally taking metals home to family members.

What We Found

- Blood lead levels ranged up to 13.7 micrograms per deciliter of blood. A level of 10 or higher is considered high. Two employees had blood lead levels above 10.
- Blood and urine cadmium levels were below current occupational exposure limits.
- No mercury was detected in employees' urine.
- One employee was overexposed to lead in air. Two employees were overexposed to cadmium in air. Silica concentrations in air were well below occupational exposure limits.
- We found lead on the clothing and skin of employees and on work surfaces.
- Employees were overexposed to noise.
- Employees worked in awkward positions, used forceful exertions, and performed repetitive motions. These activities can lead to musculoskeletal disorders.
- Potentially contaminated air was recirculated back into production areas.

What the Employer Can Do

- At a minimum, follow the Occupational Safety and Health Administration's lead standard [29 CFR 1910.1025] and cadmium standard [29 CFR 1910.1027]. Exposure to lead should be controlled so that employees' blood lead levels remain below 10 micrograms per deciliter of blood.
- Start a medical monitoring program for all employees exposed to lead. Follow the guidelines referenced in Appendix A of this report.
- Start a hearing conservation program. Require hearing protection in areas with noise levels at or above 85 decibels.
- Require respirator use in cathode ray tube buffing and grinding and shredder operations.
- Do not dry sweep. Use wet methods or a vacuum with a high efficiency air filter.
- Provide uniforms and a contract laundering service for all employees exposed to lead.
- Install a clean locker room area for employees to store personal items and food.
- Design work tasks and workstations to reduce bending, lifting, and other postures that do not allow employees to work efficiently and comfortably.

What Employees Can Do

- Tell your doctor you work with lead and other metals. Give your doctor a copy of this report.
- Learn about the hazards of lead and other metals you work with. Attend training.
- Wear required personal protective equipment.
- Take a shower at the end of the shift. Do not wear work clothing or shoes home. Do not take work clothing or shoes home for laundering.
- See your doctor about blood tests for lead for your children and other family members.

Abbreviations

μg/dL	Micrograms per deciliter
μg/L	Micrograms per liter
μg/g/Cr	Micrograms per gram creatinine
μg/m³	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
cfm	Cubic feet per minute
CFR	Code of Federal Regulations
CRT	Cathode ray tube
dBA	Decibels, A-scale
HEPA	High-efficiency particulate air
LEV	Local exhaust ventilation
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
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 an electronic scrap (e-scrap, also known as e-waste) recycling facility. We made five visits between 2012 and 2013 to evaluate employee exposures to workplace contaminants. We collected air samples for metals, dust, and crystalline silica; surface wipe samples for metals; and blood and urine samples for metals. We also did employee medical interviews; reviewed the facility's health and safety monitoring plans; and evaluated noise, engineering controls, and ergonomics in the work areas. We provided managers and employee representatives a summary of our activities and recommendations in March 2012, August 2012, January 2013, and March 2013. We notified participants of their own sampling results in August 2012.

Process Description

Computers, monitors, hard drives, televisions, printers, light bulbs, and other e-scrap were recycled and processed at this facility. The e-scrap components were tested, fixed, and resold when possible. The main recycling operation occurred in three leased warehouses. Warehouse 1 housed the cathode ray tube (CRT) processing, which included demanufacturing and glass breaking operations. Demanufacturing is the disassembly of an electronic item to gain the maximum amount of recyclable materials. Warehouse 2 housed the electronic sorting, demanufacturing, shredding, and bailing operations for all other electronics. Warehouse 3 was used for storage.

Cathode Ray Tube Processing

Employees used handheld tools to demanufacture televisions and computer monitors with CRTs. The CRT neck containing the electron gun or "yoke" was broken off the CRT by tapping it with a hammer. Employees placed the electron gun in a large cardboard box for shipment to another facility for further recycling. A conveyor transferred the CRT to a workstation where employees removed the metal support band covering the seam between the front panel and the funnel glass using an electric angle grinder. Employees removed unwanted labels and adhesives on the CRT with a cutting knife or the flat surface of an electric angle grinder. The tasks were done on the conveyor or occasionally on a Grizzly Industrial, Inc., model G0631 downdraft table, as shown in Figure 1. Prior to our first visit, the employer enclosed the downdraft table with an exhaust hood connected to a small industrial vacuum cleaner. On our first visit, we found that this setup recirculated the air back into the production area. The employer stopped using the downdraft table after our second visit.

Figure 1. Operator buffing the sides of a CRT on a downdraft table. The strap of the respirator should be under the hat. Photo by NIOSH.

The buffed CRT was conveyed to a three bay automated crushing machine called a CRT Angel (Figure 2). At the first bay an operator lowered a protective glass shield, and the CRT Angel automatically cut the unleaded panel glass from the leaded funnel glass using diamond saw blades. The CRT pieces were carried to the second bay of the CRT Angel where an employee manually separated the leaded and unleaded glass. At the third bay an employee used a mounted ultraviolet light with a high-efficiency particulate air (HEPA) filtered vacuum to identify and clean the phosphor dust from the panel glass.

Figure 2. Operator at CRT Angel bay #1 being monitored for airborne metal exposure. Photo by NIOSH.

A mix of broken leaded and unleaded glass recovered from the CRT Angel machine was temporarily stored in metal boxes inside the CRT Angel. The metal boxes were manually emptied at the end of the day into a larger enclosed metal receptacle (Figure 3) called the mixed glass station. Any remaining glass debris inside the CRT Angel was cleaned daily using brushes and HEPA filtered vacuums. The mixed glass station was kept under negative pressure relative to its surroundings by using a Minuteman International LeadVac, model 829117 industrial vacuum cleaner attached to the side. This vacuum exhausted the filtered air into the production area.

Figure 3. Employee emptying a metal box with broken glass into the mixed glass station. Photo by NIOSH.

Other Electronic Equipment Processing

Computer printers, circuit boards, central processing units, and other electronics were manually demanufactured or shredded. In the shredder area, an employee emptied a large box of electronics onto a conveyor using a forklift. An employee arranged the electronics on the conveyor to ensure a steady feed into a shredder. After the initial shredding two employees removed undesirable items such as batteries and ink cartridges before the material was shredded again (Figure 4). Aluminum and plastic components were separated from ferrous (iron containing) metal. The plastic pieces were compacted and shipped to an offsite recycler.

Figure 4. Sorters removing undesirable materials, such as batteries and ink cartridges, at the shredding machine. Photo by NIOSH.

Methods

The objectives for this evaluation were the following:

1. Identify potential work-related employee health concerns
2. Measure employee exposures to metals, dust, and silica
3. Measure metal contamination on work surfaces, skin, and clothing
4. Measure employee noise exposures
5. Evaluate workplace ergonomics
6. Recommend controls to reduce or eliminate workplace hazards

Interviews

During our evaluation, the e-scrap recycler had about 80 employees at this location. Employees spoke English, Spanish, or French. We interviewed all employees in the CRT processing area, maintenance, and bulb and battery sorting who spoke English or Spanish. We did not have a French interpreter on the first site visit so we did not interview French speaking employees. We included employees from these work areas because we thought they had highest potential for metal exposure. We also serially selected English and Spanish speaking employees from other areas for interviews to assess potential problems in other areas. All interviews were in the employee's native language. We asked about work-related health issues, job duties, and personal protective equipment (PPE) use. We obtained a complete medical history to determine if any medical issues employees had that they did not relate to their work could be unrecognized occupational illnesses.

Biological Monitoring

We tested blood for lead and cadmium, and we tested urine for mercury and cadmium from employees working in the CRT processing, maintenance, bulb and battery sorting, and shredding areas. All potential study participants read and signed a consent form in their native language (i.e., English, Spanish, or French) prior to having their blood and urine samples collected. We individually notified study participants in writing of their blood test results and explained what these results meant in their native language.

We followed the universal (standard) precautions for working with blood and blood products [Siegel et al. 2007; 29 CFR 1910.1030]. Urine samples were collected in metal-free cups then transferred in the field to 30-milliliter acid-washed centrifuge tubes. 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, cadmium, and mercury are provided in Appendix A.

Air Sampling

We took personal and area air samples (Table 1). Personal air samples were collected on most production employees but mercury vapor samples were only collected on employees working with bulb and battery sorting.

Table 1. Air sampling methods

Substance	Reason for sampling	Sampling method*
Metals and minerals	Used in the manufacturing of electronic components	NIOSH Method 7303†
Respirable dust	Dust generated from handling and shredding electronics	NIOSH Method 0600
Respirable crystalline silica	Component in some wiring and electronic components	NIOSH Method 7602
Mercury	Found in some bulbs, batteries, gauges, switches, and medical and telecommunication equipment	NIOSH Method 6009

NIOSH = National Institute for Occupational Safety and Health
*Following NIOSH Manual of Analytical Methods [NIOSH 2014a].
†Each filter sample cassette was wiped with a wet smear tab to collect particles remaining on the inside wall of the cassette. The smear tab was then analyzed along with the sample filter as recommended by NIOSH [2014b].

Personal air sample results for lead and cadmium were compared to OELs and analyzed using American Industrial Hygiene Association IHstats V229 to determine the distribution, range, central tendencies (geometric mean and estimated arithmetic mean), and geometric standard deviation. For sample results that were reported as "not detected" we used the minimum detectable concentration (MDC) divided by two as the concentration estimate [Hornung and Reed 1990]. For sample results above the MDC but below the minimum quantifiable concentration (MQC), we used the estimated concentration reported by the laboratory.

Surface Wipe Sampling

We collected surface wipe samples for metals and minerals in production areas and non-production areas such as break rooms, locker rooms, and offices. We used premoistened Ghost wipe® towelettes and quantitatively analyzed the wipes using NIOSH Method 9102 [NIOSH 2014a]. We used a 10-square centimeter disposable cardboard template when possible to outline the surface that we sampled. For uneven or irregular surfaces, we estimated the sample area.

We collected qualitative wipe samples for identification of lead on employees' skin and work shirts using color-changing SKC Inc. Full Disclosure wipes. The estimated visual identification limit was 17–20 micrograms of lead per wipe sample. We used a 10-square centimeter disposable cardboard template when possible to outline the surface that we sampled. For uneven or irregular surfaces, we estimated the sample area. We asked employees to wash and dry their hands and then wipe their hands with the Full Disclosure wipe for at least 30 seconds at the end of their work shift. We also took a wipe sample from the front shoulder area of the employee's uniform.

Noise Sampling

Using integrating noise dosimeters, we took full-shift noise exposure measurements over 3 days on employees working with the shredder, baler, and forklifts and on employees in the CRT demanufacturing area. The dosimeters simultaneously collected data using three different settings to compare noise measurements with the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL), the OSHA action level, and NIOSH recommended exposure limit (REL).

Ergonomic Assessment

We observed workplace conditions and work processes and practices related to ergonomics. We measured workstation heights and reach distances and noted the availability of antifatigue mats. A full description of the criteria we used to determine risk factors for work-related musculoskeletal disorders is provided in Appendix A.

Engineering Controls Assessment

We evaluated the engineering controls in the CRT buffing and grinding and shredding areas where we measured overexposures to metals. We also evaluated the CRT Angel and mixed glass station because the facility had documented overexposures and they were near the CRT buffing and grinding area. At the time of our evaluation the CRT buffing and grinding downdraft table was only used to store CRTs. Therefore, our evaluation included reviewing design specifications from the manufacturer and observing employees buffing and grinding CRTs on the roller conveyor. Our evaluation of the unventilated shredder included observing employees and reviewing information on the shredder.

We evaluated the CRT Angel by measuring the openings in the front of the first two bays (those with no ultraviolet light), using theatrical smoke to visualize air flow patterns, and obtaining the make and model of the air handlers and air filters. We did not measure air duct velocity because the employer did not want us to drill into the ducts.

We evaluated the mixed glass station by observing its use, measuring dimensions, and obtaining performance specifications from the manufacturer.

Document Review

We reviewed company results of past biomonitoring for lead on maintenance employees and employees who processed CRTs. We reviewed company reports of noise and airborne lead exposure monitoring. We also reviewed the written hazard communication, respiratory protection, and lead compliance programs, and written health and safety plans and procedures.

Observations

We toured the facility and observed work processes and practices, and PPE use.

Results and Discussion

Interviews

Twenty-six employees (17 English speaking and 9 Spanish speaking) participated in confidential medical interviews. Employee job titles included shipping and receiving, shredding, weighing, inventory, printer and computer demanufacturing, CRT demanufacturing, maintenance, forklift driver, CRT Angel operator, configuration (testing and refurbishing of computers), bulb and battery sorting, truck driving, and office work. All employees were male and aged 22–62 years. Eight employees smoked cigarettes, and four smoked cigars. Fifteen employees had worked at the facility for less than 1 year, and 3 years was the longest reported employment time. All but three employees reported having received safety or hazard communication training, and all knew the required PPE for their job. Most employees reported receiving training for handling batteries and fluorescent bulbs and for job safety issues, but few reported training on hazards of lead. Some interviewed CRT Angel operators and maintenance employees reported having no training on lead hazards. A CRT Angel operator had not yet had baseline blood lead level (BLL) testing or been medically cleared or fit-tested for his company-required respirator. Given that the company had previously documented airborne lead overexposures among the CRT Angel operators and required these employees to wear respirators, baseline BLL testing and participation in a respirator program should have been performed before the CRT Angel operator started work duties in the CRT processing area.

Nineteen employees reported no health concerns about their jobs. One employee reported eye irritation; one reported lightheadedness when circuit boards were shredded; and one reported sore throat, cough, and chest pain related to dust. Four reported concern about exposure on the job, but did not report health problems.

Biological Monitoring

We tested 13 employees' blood for lead and cadmium, and 14 employees' urine for mercury and cadmium. One employee declined blood testing.

Nine employees who worked in maintenance or in the CRT processing area had BLLs ranging from 5.3–14 micrograms per deciliter of whole blood (µg/dL); two were above 10 µg/dL. An elevated BLL is 10 µg/dL or higher. Their blood cadmium levels ranged from below the limit of detection (0.5 micrograms per liter [µg/L]) to 1.0 µg/L. OSHA requires specific actions if blood cadmium levels exceed 5 µg/L. Urine cadmium levels ranged from 0.1–0.8 micrograms per gram creatinine (µg/g/Cr). OSHA requires specific actions if urine cadmium levels exceed 3 µg/g/Cr. All urine mercury levels were below the limit of detection (5 µg/L).

The remaining five employees worked on the baler, shredder, or in bulb and battery sorting and had BLLs ranging from below the limit of detection (3.0 µg/dL) to 8.8 µg/dL. Their blood cadmium levels ranged from below the limit of detection to 1.2 µg/L. Urine cadmium levels ranged from 0.3–1.0 µg/g/Cr. All urine mercury levels were below the limit of detection.

Blood cadmium levels can be affected by smoking. This may explain why the highest blood cadmium level was found in an employee who was a heavy smoker, but did not work in the CRT area. The average blood cadmium level among the seven employees who smoked was 0.82 µg/L, compared to an average of 0.44 µg/L for the six nonsmokers.

Air Sampling

Employees' airborne exposures to lead and cadmium are shown in Appendix B, Tables B1 and B2. One employee's exposure (a shredder sorter) exceeded the NIOSH, OSHA, and American Conference of Governmental Industrial Hygienists (ACGIH) OEL for lead of 50 micrograms per cubic meter (µg/m^3), expressed as a time-weighted average (TWA) over the work shift. Shredding only occurred on the first day of our evaluation because of a lack of material on the second day. Cadmium exposures for two employees who were buffing and grinding CRTs exceeded the OSHA PEL of 5 µg/m^3. Although we measured lead or cadmium overexposures on only three employees, these results should be interpreted cautiously because employees' exposures vary depending on the variety and quantity of materials being recycled.

Cadmium is present in the powder coating inside the CRT. Employees may be exposed when this coating becomes airborne when the electron gun (or yoke) is manually broken and the CRT vacuum is released [Peters-Michaud et al. 2003]. Cadmium exposures may also result from CRT buffing and grinding.

When grouped by job tasks, CRT Angel operation and CRT buffing and grinding had the highest exposures (Tables 2 and 3). Shredder sorting was the task with the next highest lead concentrations. Cadmium levels had a higher geometric standard deviation compared to lead levels, indicating more variability among the cadmium exposures. On the basis of these results, engineering controls should be prioritized for the CRT buffing and grinding, CRT Angel, and shredder sorting.

Table 2. Summary of full-shift personal air sample results for lead, organized by job task

Job Task	No. of samples	Range of concentrations (μg/m³)	Geometric mean	Estimated arithmetic mean	Geometric standard deviation
CRT buffing and grinding*	5	9.8 to 27	16.4	17.6	1.52
CRT Angel operation	6	6.1 to 16	9.40	10.0	1.49
Shredder sorting	9	(1.6)† to 67	4.08	8.58	3.82
Forklift driving and baling	2	2.8 to 3.9	3.30	3.35	1.26
CRT demanufacturing	8	2.1 to 5.3	3.1	3.39	1.33
Maintenance	5	(1.4)† to 4.1	2.04	2.46	2.00
Bulb and battery sorting	3	ND to (1.5)†	—‡	—	—

ND = Not detected; result is below the MDC of 0.60 μg/m³.
*CRT buffer and grinding included employees performing CRT buffing only or CRT buffing and grinding.
†Sample result(s) were between the MDC of 0.60 μg/m³ and the MQC of 2.0 μg/m³. There is more uncertainty associated with these values.
‡Summary statistics were not computed when all or most of the values were below the MQC.

Table 3. Summary of full-shift personal air sample results for cadmium, by job task

Job Task	No. of samples	Range of concentrations (μg/m³)	Geometric mean	Estimated arithmetic mean	Geometric standard deviation
CRT buffing and grinding	5	0.18 to 10	1.60	4.18	5.31
CRT Angel operation	6	(0.090)† to 0.34	0.14	0.17	1.97
CRT demanufacturing	9	†	—‡	—	—
Bulb and battery sorting	3	ND	—	—	—
Forklift driving and baling	2	†	—	—	—
Maintenance	5	ND to 0.10	—	—	—
Shredder sorting	9	ND to 0.84	—	—	—

ND = Not detected; result is below the MDC of 0.020 μg/m³.
*CRT buffer and grinding included employees performing CRT buffing only or CRT buffing and grinding.
†Sample result(s) were between the MDC of 0.020 μg/m³ and the MQC of 0.090 μg/m³. There is more uncertainty associated with these values.
‡Summary statistics were not computed when all or most of the values were below the MQC.

Area air sampling results for lead and cadmium are shown in Appendix B, Table B3. The air concentrations decreased from production to non-production areas with highest concentrations near the CRT glass breaking area and lowest concentrations in the break rooms. Airborne lead and cadmium were present throughout the facility because the glass breaking and demanufacturing areas (the areas with the highest air concentrations of these metals) were not isolated from the remainder of the facility.

The shredder sorter's personal airborne exposure to nickel was 13 µg/m³, near the NIOSH REL of 15 µg/m³. Elements analyzed in personal air samples and found at levels well below OELs included aluminum, antimony, calcium, chromium, lithium, magnesium, manganese, molybdenum, phosphorous, strontium, thallium, tin, vanadium, yttrium, zinc, and zirconium. Elements detected but with no OELs included lanthanum and titanium. Arsenic, beryllium, cobalt, potassium, selenium, silver, and tellurium were not detected.

Personal air sampling results for mercury are shown in Appendix B, Table B4. Mercury exposures were less than 1 µg/m³, well below the NIOSH REL of 50 µg/m³. Area air sample results for mercury are shown in Appendix A, Table A5. Area concentrations of mercury were also low, ranging up to 1.3 µg/m³.

Personal air sample results for respirable dust and respirable crystalline silica are shown in Appendix B, Tables B6 and B7. Crystalline silica concentrations ranged up to 10 µg/m³ in personal air samples, below the most protective OEL of 25 µg/m³. Area air sample results for respirable dust and crystalline silica are shown in Appendix B, Table B8. Only the area air sample taken near CRT demanufacturing had a quantifiable concentration of respirable dust. Crystalline silica was detected throughout the production areas but at levels below the MQC of 10 µg/m³.

Surface Sampling

We found lead, cadmium, chromium, and nickel on all wipe samples collected on work surfaces in production and non-production areas (Appendix B, Table B9). We found lead on a supply diffuser in the office area, even though this ventilation system was independent of the production area. No OELs are available for surface contamination; however, OSHA has established housekeeping provisions that state that surfaces in non-production areas such as change rooms, storage facilities, and lunchroom/eating areas should be kept "as free as practicable" of lead. At the time of our evaluations the company did not have a janitor. After sharing our surface sampling results the company reinstated the janitor and the housekeeping program.

We found lead on the hands and work shirts of employees at the end of their shift when leaving the facility. Eight of the 12 pairs of employee hands tested positive for lead even after washing with soap and water. Twelve of the 13 work shirts or uniforms tested positive for lead. The finding of lead contamination on hands suggests that hand soap and water did not adequately remove metals off the hands of the employees. The finding of lead contamination on employees' work shirts was not surprising to us, given that production employees were working with lead-containing materials, and did not shower or change their clothes before leaving the worksite. As a result, metals could be carried out of the facility on clothing and skin, possibly contaminating personal vehicles, employees' homes, and other places where employees visit after leaving the facility. The local children's hospital informed us that two children of a former employee at this facility were found to have take-home lead poisoning in 2010. No lead-based paint or other lead containing items had been found in their home.

Noise Assessment

Employee noise exposures are provided in Appendix B, Table B10. Seven of 13 employees' 8-hour TWA personal noise measurements exceeded the NIOSH REL, and three exceeded the OSHA action level. The job tasks that exceeded the NIOSH REL for noise included CRT buffing and grinding, shredder sorting (when the shredder was operating), forklift driving, and baling. Hearing protection was available but not worn. Noise is important to control in an e-scrap recycling facility because it is known that lead exposures in the presence of noise, can further impair hearing or increase the potential for hearing loss [Sliwinska-Kowalska et al. 2004; Morata 2007; Hwang et al. 2009].

Ergonomic Assessment

Televisions and monitors, some weighing over 50 pounds, arrived at the facility stacked on pallets. The varying heights of these stacks required employees to sometimes reach overhead and bend at the waist to lift them from the pallets to the disassembly workstations. The company required employees to use two-person lifting techniques; however, this policy was not always enforced.

The heights of the disassembly workstations were not adjustable, and some disassembly occurred on the floor. This lack of workstation adjustability resulted in some hand working heights outside the recommended hand working range of 38″–49″. Employees used tools at the disassembly workstations including pistol-grip cordless tools. Using tools with pistol grips on a horizontal surface can place the wrist in an awkward position. In these situations, inline tools are preferred (Figure 5).

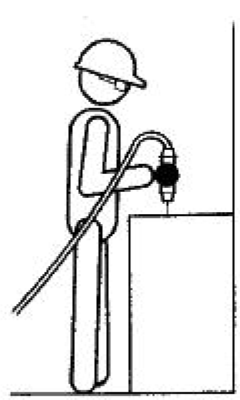

Figure 5. Drawing of an employee using an inline tool in a perpendicular position. Source: http://www.ccohs.ca/oshanswers/safety_haz/power_tools/ergo.html. Date accessed: July, 2014.

We saw employees reaching over the television and monitor cases during disassembly. Ideally, the cases should be rotated to shorten the reach. After the case was removed, the CRTs were manually placed on conveyors. For one commonly handled CRT we measured a hand working height for the CRT buffing and grinding employee of 36″, below the recommended hand working range of 38″–49″. However, some employees turned the CRTs on their side, bringing the hand working height into the proper range.

We saw employees at a disassembly workstation using wire cutters to remove ends from cables. We did not measure the force used to cut the cable, but it seemed to require a lot of force. Using wire cutters with longer handles or stabilizing one side of the wire cutter by attaching it to the table would increase leverage and reduce the force needed to perform the task. Not all workstations had antifatigue mats for standing employees. Mats should be ≥ 0.5″ thick, have an optimal compressibility of 3%–4%, have beveled edges to minimize trip hazards, and be placed at least 8″ under a workstation to prevent uneven standing surfaces. Mats should cover the entire area that the employee moves in while performing the work task. They should be replaced when worn out or damaged.

Two employees were required to lift heavy metal boxes at or above shoulder height to empty glass into the mixed glass station. Additionally, the handle at the mixed glass station to dump the glass was at or above shoulder height for most employees. While a step had been added to reduce the reach, it was still above the recommended height. A ramp or scissor table could be used instead of the step to reach the desired height. Redesigned metal boxes using lighter materials and adding handles on the sides would aid lifting and dumping. Regardless, two employees would still need to lift the boxes because of the size of the box and weight of the glass.

We saw employees on the shredding machine reaching to straighten items that were caught on the conveyor. Employees could use a hook to pull items closer to eliminate the extended reach. The conveyor that fed electronics to the shredder was 38″ high, within the recommended hand working height range. The conveyor that fed the shredder sorting workstation was 36″ high, just below the recommended range. The employees performing the sorting job placed the undesirable items into bins and cardboard boxes. The location of these bins and boxes required employees to twist their backs. Employees also had to pick some bins off the floor. Placing the smaller bins on stacks of empty pallets would elevate them to a better height.

Engineering Controls Assessment

A simple and safe engineering control approach to reducing metal dust in the workplace is to use local exhaust ventilation (LEV) for specific processes and to direct the exhaust ventilation to the outdoors. Another engineering control approach is to recirculate the air into the workplace using appropriate filters and do continuous monitoring to ensure airborne concentrations of hazardous substances are kept below specific levels. The recirculation of air containing highly hazardous substances (as defined by the OSHA hazard communication standard) requires an effective cleaning device (filtration) and a continuous monitoring device. The monitoring device should be capable of detecting a concentration as low as 10% of the acceptable level in the discharge duct [ANSI/AIHA 2007]. The American National

Standard for Recirculation of Air from Industrial Process Exhaust Systems states that continuous monitoring of the static pressure drop across serial filters (e.g., a HEPA filter following a minimum efficiency reporting value-13 filter) is an acceptable alternative to a continuous monitoring device. However, the exhaust ventilation system should also have the ability to by-pass the recirculation of the exhaust air if the static pressure monitor failed. The use of a continuous static pressure monitoring system while also ensuring and documenting airborne concentrations below the PEL would be an acceptable method to comply with the intent of the OSHA cadmium and lead standards [OSHA 2013].

The lead and cadmium standards include requirements to monitor the performance (e.g., capture velocity, duct velocity, or static pressure) of industrial ventilation systems used to control exposures [29 CFR 1910.1025, 29 CFR 1910.1027]. Measurements of the system's effectiveness in controlling exposure must be made within 5 days of any change in production, process, or control which might result in a change in employee exposure to lead [29 CFR 1910.1025]. The cadmium standard contains a similar provision, but does not specify how often ventilation system measurements should be made [29 CFR 1910.1027]. These requirements should be taken into account when choosing among control options. Any controls would also need to meet relevant local, state, and federal pollution regulations.

Potential metal dust exposures during manual removal of the electron gun from the CRT could be controlled by moving the hose inlet of a HEPA vacuum cleaner or the inlet of a portable source extraction system near the electron gun when it is removed from the CRT. Controls in place would need to make sure that contaminated air is not recirculated into the workplace.

The manufacturer's manual for the downdraft table used for a portion of the CRT buffing and grinding stated "This machine will not protect against lead-paint dust or asbestos fibers. These materials must be collected with special equipment because of the high hazard to human health. Do not attempt to collect these materials with this machine." Based on this statement we informed the facility that this table was not designed to control lead dust from CRT buffing and grinding. We also saw an employee incorrectly inserting the HEPA filter into the downdraft table and recommended in our letter dated March 22, 2012 that employees stop using this table until it was evaluated by a ventilation expert. This table was not in use on our last two visits. Control options for the CRT buffing and grinding may include a locally-exhausted grinding table, an on-tool dust extraction system, or a portable dust extraction system. These options are described in Appendix C. Controls in place would need to make sure that contaminated air is not recirculated into the workplace.

Exhaust ventilation for the three bays at the CRT Angel was provided by two Donaldson Co., Inc., model DF03-3 air handlers. Ventilation smoke tests showed that the workstations were appropriately under negative pressure relative to the surrounding areas, meaning that air flowed into the CRT Angel to contain process emissions. However, the air exhausted by the two air handlers serving the CRT Angel was recirculated back into the workplace after passing through minimum efficiency reporting value-13 filters. Because no HEPA filter was used and no controls were in place to determine the efficacy of the cleaning of recirculated air or shut off the system in the event of filtration failure, contaminated air could have been recirculated into the workplace from the CRT Angel.

No LEV was in place at the shredding operations. Control options include the use of LEV or dust collection systems. Controls in place would need to prevent contaminated air from recirculating into the workplace.

Document Review

The CRT Angel operators and maintenance personnel received preplacement and annual BLL testing from a contractor hired by the facility. In 2011, the BLLs among five employees who broke CRT glass, along with one maintenance employee, ranged from 8.5–21 µg/dL; five were above 10 µg/dL. An elevated BLL in adults is defined as 10 µg/dL (Appendix A).

We reviewed a Ohio Bureau of Workers' Compensation report on noise monitoring dated July 21, 2011. The report indicated that one employee had an exposure above the OSHA PEL of 90 decibels, A-scale (dBA), and five employees had noise exposures above the OSHA action level of 85 dBA. Although the report recommended starting a hearing conservation program, no such program existed as of our last site visit in early 2013. Several years of uncontrolled noise exposures, with the added effects of lead exposure, could greatly contribute towards chronic hearing loss, which can be debilitating for an employee.

We also reviewed an air monitoring report dated July 19, 2011, from the Ohio Bureau of Workers' Compensation. Seven employees had exposures below the OSHA PEL for total particulates, respirable dust containing silica, crystalline silica, and mercury. One employee during CRT grinding exceeded the OSHA PEL for lead, and the CRT Angel operator exceeded the OSHA action level for lead. On the basis of these results and from our evaluation, the OSHA lead standard (CFR 1910.1025) should have been implemented for employees in CRT grinding, including but not limited to medical surveillance, showering, uniforms, and required respiratory protection.

The draft respiratory protection program dated October 4, 2010, stated that the company only used NIOSH certified N95 respirators. It is not clear what was meant by an "N95 respirator" since that only describes the filtration capability, not the protection level of the respirator. The program did not mention the use of half-mask respirators with P100 filters as we observed being worn by the CRT Angel operators or respirators with HEPA filters as required by the OSHA lead standard [OSHA 2013]. The program mentioned that respiratory protection for the CRT Angel operators would be determined on the basis of a hazard assessment and that all other employees could voluntarily wear an N95 filtering facepiece respirator or a half-mask respirator. The hazard assessments were adequate and summarized in the lead compliance program. The program stated that for those employees voluntarily using respirators the company would provide training on care, usage, and storage and Appendix D of the standard. The respiratory protection program did not include a specific change-out schedule.

The company's lead compliance program included summaries of lead monitoring results and controls implemented in 2009 and 2010 to decrease exposures at the CRT Angel. The compliance program did not discuss other metal exposures.

The lead dust procedure was detailed, however we observed that most steps were not followed, including maintaining airtight barriers under negative pressure in the cleanup area and using wet clean-up methods.

The company reported having a health and safety committee in place but without employee representation. We believe that a joint management-employee committee provides a forum for communication, information gathering, research, and joint problem-solving by including those who are performing the jobs and promptly may recognize when new health and safety issues arise.

Use of Personal Protective Equipment

CRT Angel operators and maintenance employees working on the CRT Angel were required to wear elastomeric half-mask air purifying respirators with P100 filters and safety glasses at the time of our evaluation. Employees doing CRT buffing and grinding and shredder sorting could voluntarily wear disposable N95 filtering facepiece respirators. Face shields were available but not required for CRT buffing and grinding. Safety glasses and Kevlar® cut-resistant gloves and sleeves were offered and used by some employees. Hearing protection (foam insert plugs, comfort fit with a noise reduction rating of 32) was available but not required throughout the facility. We did not see employees using hearing protection during our evaluation. CRT Angel operators wore Tyvek® suits or company provided uniforms that were laundered by a contractor. The employee working on the third bay of the CRT Angel was required to use safety glasses that had ultraviolet protection because the third bay used UV light for detection of the phosphorus.

We observed inconsistent PPE use. For example, employees cutting metal bands off the CRTs did not always use face shields, respirators, or cut-resistant sleeves. Respirators were used incorrectly, for example in Figure 1 the top strap of the respirator should be under the hat. Some employees wore N95 filtering facepiece respirators incorrectly (e.g., head straps were twisted or not used and the respirator covered the mouth but not the nose). Employees' Tyvek suits tore under the stress of bending and reaching during the CRT Angel cleaning operation. We saw employees reusing gloves until they were damaged, and sometimes wearing natural rubber latex gloves under cut-resistant gloves. Natural rubber latex can cause Type I allergy, such as hives, rhinitis, asthma, and anaphylaxis. Gloves made of other materials are preferred in this situation. Some employees pushed their cut-resistant sleeves down to their gloves, exposing their arms from the top of the cut-resistant sleeve to the sleeve of their shirt to possible injury or contaminants.

Other Observations

The facility had no showers and only a few sinks for employees to wash their hands, arms, and face before lunch, breaks, or going home. We observed open beverage containers in the CRT glass breaking area. Eating, drinking, or smoking in the work area can lead to ingestion of contaminants.

The facility provided a change-out room with lockers for the CRT Angel operators. However, this room was not near the CRT Angel area and was not separate from the production area. The design of the change-out room did not allow employees to store their potentially contaminated work clothing and PPE separately from their non-work clothing or personal items. The location and poor design of the change-out room could result in contamination spreading from the CRT Angel area and employees transferring contamination to their vehicles, outside of the work facility, and into their homes, potentially exposing family members.

When the production areas including the CRT Angel area were cleaned by dry sweeping, airborne dust was generated. We observed dust leaking from the HEPA vacuums during the CRT Angel cleaning. We also observed an employee standing on two wood planks to clean the CRT Angel with a vacuum; this positioning placed him at risk of falling. The CRT Angel had only one power supply for the LEV and lighting, preventing the machine from being locked out and tagged out during cleaning and maintenance. Pallets of materials blocked access to at least two fire extinguishers in the storage building. Some forklift drivers did not wear seat belts.

Conclusions

We measured an overexposure to lead during shredder sorting, and overexposures to cadmium on two employees during CRT buffing and grinding. We measured overexposures to noise on employees during CRT buffing and grinding, shredder sorting, forklift driving, and baling. We found metal contamination on surfaces throughout the facility, and air, potentially contaminated with metals, being recirculated into the production area. Some employees had elevated BLLs, and there was potential for taking lead and other contaminants outside of the workplace. Employees were exposed to a combination of ergonomic risk factors including extreme working postures, forceful exertions, and repetitive motions.

Recommendations

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

Our recommendations are based on an approach known as the hierarchy of controls. 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. We recommend the following:

Engineering Controls

Engineering controls reduce the potential for exposure by isolating employees from the hazards. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Hire a ventilation engineer to modify LEV systems in accordance with the OSHA

lead standard, CFR 1910.1025. Any LEV option must avoid recirculating potentially contaminated air. Recommendations for LEV controls include the following:

   a. During CRT demanufacturing, position the LEV near the electron gun when it is removed from the CRT.
   b. During CRT buffing and grinding, use a grinding table designed to handle heavy metals, install an on-tool dust extraction system, or use a portable dust extraction system.
   c. During shredding operations, use LEV or other dust collection systems.

2. Replace vacuums that leak and determine if the vacuums used to clean the CRT Angel are appropriately sized for this cleaning task.
3. Isolate the glass breaking area from the rest of the facility to reduce the contamination of other areas.
4. Hire a qualified engineer to inspect the office ventilation system to make sure that it is free of contaminated dust, is working as designed, and considers the following:
   a. Keep the office under positive pressure relative to the warehouse (meaning that air flows from the offices into the warehouse).
   b. Ensure that adequate outdoor air is being introduced into each office space and exhaust air is not entrained from the warehouse into the office outdoor air intake [ANSI/ASHRAE 2014].
5. Consider replacing the office carpet with a nonporous floor covering that would be easier to clean and would help reduce the dust level in offices. NIOSH addresses issues related to maintaining acceptable indoor air quality during building renovation at http://www.cdc.gov/niosh/topics/indoorenv/ConstructionIEQ.html.
6. Redesign the mixed glass station so that:
   a. Boxes are made using lighter materials and equipped with side handles.
   b. Boxes being emptied are not lifted at or above shoulder height.
   c. The receiving receptacle completely seals during the glass dumping process.
   d. A ramp or a scissor table is used to help workers reach appropriate working heights.
7. Separate the power supply for the LEV and lighting on the CRT Angel so the machine can be locked out and tagged out for cleaning and maintenance.
8. Provide antifatigue mats for employees who stand 90% or more of their working hours.
9. Ensure that employees lifting objects weighing more than 22 pounds perform the lifts at a height of 10″–39″ inches above the floor. If a step is provided to shorten the height, the step should be large enough so that it provides a stable working platform.
10. Require employees to get a second employee to help when lifting objects weighing 51 pounds or more. Determine whether mechanical lifts and hoists would be a better option for heavy loads.
11. Use long-handled cutting tools and, if possible, attach them to the table instead of using wire cutters. This will reduce the amount of force needed to cut cable ends.
12. Use inline tools to disassemble televisions instead of pistol-shaped cordless tools to

lessen the awkward positions.

13. Design standing workstations as follows:
    a. Keep the standing hand working height between 38″–47″ if adjustable or at 42″ if fixed.
    b. Place boxes and bins used to sort electronic parts in front of the employee with a reaching distance of less than 16″ and at a vertical height of 24″–70″.
    c. Locate more frequently used items or heavy items 38″–49″ above standing surface.
    d. Perform work within 22″ of the edge of the workstation (horizontal work distance guideline) to eliminate extended reaches.

Administrative Controls

Administrative controls refer 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. Follow the OSHA lead standard [29 CFR Part 1910.1025], which is required by law. Recognize that this standard does not protect employees from adverse health effects from lead exposure. Take the additional measures identified in this report to maintain employees' BLLs below 10 µg/dL.

2. Perform baseline medical surveillance on all employees who may be exposed to lead or other hazardous metals prior to beginning a job. We recommend using the guidelines in Appendix A in addition to complying with the OSHA medical surveillance requirements for preplacement and periodic medical surveillance. Include production employees outside the CRT processing area in the medical surveillance program. Employee's BLLs should be kept as low as possible or at least below 10 µg/dL.

3. Relocate the change-out room closer to the CRT glass breaking area to reduce spread of contamination.

4. Redesign the locker room so that employees' clean clothes and personal items are not stored with their work clothes and equipment.

5. Provide adequate storage for work shoes and clothing. Do not allow production employees to leave the workplace with these articles.

6. Provide uniforms for all employees exposed to lead. Employees also could be provided with scrubs for wearing under their work uniforms and when uniforms are removed during breaks and lunch. Uniforms and scrubs should be laundered onsite or using a contract service.

7. Require employees to change shoes or wear disposable shoe covers when leaving the production area to minimize tracking metals and other contaminants to non-production areas of the facility.

8. Install showers and require all production employees to shower and change into clean

clothes before leaving work.

9. Provide more hand washing facilities. Employees should wash their hands with water and a lead-removing product after removing gloves; when they leave the production area; and before eating, drinking, or smoking. NIOSH research shows that washing hands with soap and water is not completely effective in removing lead (and other toxic metals) from the skin [NIOSH 2014d]. Learn about commercially available lead removal products by reading "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.
10. Stop dry sweeping. Use wet sweeping or HEPA vacuuming instead.
11. Modify written procedures for cleaning in the CRT Angel area to reflect cleaning procedures that are feasible and effective.
12. Provide training on the hazards of lead and other potential contaminants and the possibility of taking lead and other contaminants home, especially if employees live with young children. Training should be done on the native language of employees.
13. Finalize the company's draft "2010 respiratory protection program" to align with the requirements of the OSHA respiratory protection standard [29 CFR 1910.134]. Include information on respiratory protection levels that are needed for specific work areas and processes and develop a change-out schedule for replacing respirator filters. The program should be updated yearly.
14. Develop a hearing conservation program for employees overexposed to noise [29 CFR 1910.95]. More information on workplace noise exposures is available at http://www.cdc.gov/niosh/topics/noise/. Information on starting a hearing conservation program can be found at http://www.osha.gov/dts/osta/otm/noise/hcp/index.html and http://www.osha.gov/Publications/osha3074.pdf. The Ohio Bureau of Workers' Compensation may be able to help in starting a noise conservation program. Inform the professionals who review the employees' audiometric testing results about the potential for lead exposure, in addition to noise, because of the interactive effect on hearing loss. In some cases, affected employees may need a referral for further testing and medical evaluation [Morata 2007].
15. Ensure employee representation on the health and safety committee [29 CFR 1960.40]. The employee representative should be a volunteer. Guidelines and suggestions for developing an effective health and safety committee can be found at https://pantherfile.uwm.edu/groups/sa/usa/public/Safety/safcomm.pdf and http://www.nj.gov/health/peosh/documents/jlmhsc.pdf.
16. Do not allow employees to drink, eat, or chew gum in production areas.
17. Encourage employees to have their children and other family members tested for lead in blood because of the potential for take home exposures to lead. Children are especially susceptible to lead.

Personal Protective Equipment

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

1. Require employees who perform CRT buffing and grinding and shredder sorting to wear an N100 or P100 filtering facepiece or a half-mask respirator with N100 or P100 filters until engineering controls can reduce lead exposures below occupational exposure limits.
2. Provide clean cut-resistant gloves for daily use, or use clean inner gloves (e.g., nitrile, cotton) when reusing dirty outer gloves. Ensure that dirty, reusable cut-resistant gloves do not leave the work area. Do not use latex gloves.
3. Provide a laundry service for reusable cut-resistant gloves and sleeves and track their usage to ensure they continue to meet manufacturers' recommendations.
4. Use face shields during buffing and grinding.

Appendix A: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or 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 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 threshold limit values (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 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/en/gestis/limit_values/index.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., LEV, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

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

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 found in batteries, printed circuit boards, and CRTs. CRTs are made from two types of glass joined by a high lead glass solder known as frit [Florida Department of Environmental Protection 2014]. Lead is also used in the CRT rear funnel glass to protect users from potentially harmful exposure to x-rays. An average 18.63-inch CRT has a lead content that varies from 2.14 pounds to

2.63 pounds [EIA 2014]. 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 [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 2012]. Very high BLLs are defined as BLLs ≥ 40 µg/dL. From 2002–2011, occupational exposures accounted for 91% of adults with very high BLLs (where exposure source was known) [CDC 2014]. There is a 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 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^3 averaged over an 8-hour work shift [NIOSH 2014b]. 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. The ACGIH designates lead as an animal carcinogen [ACGIH 2013]. In 2013, the California Department of Public Health recommended that Cal/OSHA lower the PEL for lead to 0.5 to 2.1 µg/m³ (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 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); OSHA 2003]. 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 (Table A1).

Table A1. 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 Table A2. 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 A2. 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 < 10 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 10–19 µg/dL	As above for BLL < 10 µg/dL, plus: BLL every 3 months; evaluate exposure, engineering controls, and work practices; consider removal. Revert to BLL every 6 months after three BLLs < 10 µg/dL
BLL ≥ 20 µg/dL	Remove from exposure if repeat BLL measured in 4 weeks remains ≥ 20 µg/dL, or if first BLL is ≥ 30 µg/dL Monthly BLL testing Consider return to work after two BLLs < 15 µg/dL a month apart, then monitor as above

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 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 2007]. Employees may inhale cadmium dust when sanding, grinding, or scraping cadmium-metal alloys or cadmium-containing paints [ACGIH 2007]. In addition to inhalation, cadmium may be absorbed via ingestion; non-occupational sources of cadmium exposure include cigarette smoke and dietary intake [ACGIH 2007]. 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 µg/m³ as an 8-hour TWA [29 CFR 1910.1027]. The ACGIH has a TLV for total cadmium of 10 µg/m³ (8-hour TWA), with employee blood levels to be controlled at or below 5 µg/L and urine levels to be below 5 µg/g/Cr, and designation of cadmium as a suspected human carcinogen [ACGIH 2013]. 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 µg/m³ as an 8-hour TWA, for more than 30 days per year [29 CFR 1910.1027]. OSHA defines acceptable blood cadmium levels as < 5 µg/L, urine cadmium levels as < 3 µg/g/Cr, and beta-2-microglobulin levels as < 300 µg/g/Cr. The geometric mean blood cadmium was 0.3 µg/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 µg/L [Martin et al. 2009]. The geometric mean urine cadmium for men in 2009–2010 was 0.2 µg/g/Cr [CDC 2013b]. For employees meeting 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; a 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 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 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.

Biological monitoring is also required for all employees who may have been exposed at or above the action level unless the employer can demonstrate that the exposure totaled less than 60 months. In this case it must also be conducted 1 year after the initial testing. The need for further monitoring for previously exposed employees is then determined by the results of the biological monitoring.

Ergonomics

Musculoskeletal disorders are those conditions that involve the nerves, tendons, muscles, and supporting structures of the body. They can be characterized by chronic pain and limited mobility. Work-related musculoskeletal disorder refers to (1) musculoskeletal disorders to which the work environment and the performance of work contribute significantly, or (2) musculoskeletal disorders that are made worse or longer lasting by work conditions. A substantial body of data provides strong evidence of an association between musculoskeletal disorders and certain work-related factors (physical, work organizational, psychosocial, individual, and sociocultural). Therefore, an ergonomic evaluation determines how these individual work-related factors are associated with work-related musculoskeletal disorders. Strong evidence shows that employees with high levels of static contraction (moving muscles without actually moving), prolonged static loads (slowly applying mechanical force during assembly or to an object), or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder musculoskeletal disorders [NIOSH 1997]. Further strong evidence shows that highly repetitious, forceful hand/wrist exertions increase risk for hand/wrist tendonitis [NIOSH 1997]. Finally, strong evidence shows that low-back disorders are associated with work-related lifting and forceful movements [NIOSH 1997]. Personal factors can also influence the risk factors for musculoskeletal disorders, including age, sex, smoking, physical activity, strength, and body measurements. However, studies in high-risk industries have shown that the risk associated with personal factors is small compared to that associated with occupational exposures [NIOSH 1997]. The preferred method for preventing and controlling work-related musculoskeletal disorders is to design jobs, workstations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the employee. Proper design can reduce or eliminate exposures to potentially hazardous risk factors.

Appendix B: Tables

Table B1. Personal air sample results for lead and cadmium for CRT activities

Job task	Time (minutes)	Lead concentration (µg/m³)	Cadmium concentration (µg/m³)
CRT Angel operation	317	16	0.20
	441	14	0.11
	447	9.4	0.34
	493	8.5	0.16
	447	6.3	(0.090)*
	479	6.1	0.15
CRT buffing and grinding	477	27	1.0
	497	22	10
	460	17	0.18
CRT buffing	493	12	0.80
	491	9.8	7.3
	491	SE	SE
CRT demanufacturing	434	5.3	(0.024)
	377	4.5	(0.026)
	482	3.5	(0.021)
	489	3.5	(0.081)
	488	2.9	(0.082)
	471	2.6	(0.043)
	478	2.5	(0.084)
	495	2.4	(0.020)
	482	2.1	(0.021)
NIOSH REL-TWA		50	Ca
OSHA PEL-TWA		50	5
ACGIH TLV-TWA		50	10
MDC		0.6	0.02
MQC		2.0	0.090

Ca = NIOSH potential occupational carcinogen. Exposures should be kept as low as possible.
SE = Sampling error; no sample result is reported.
*Values in parentheses indicate concentrations above the MDC but below the MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 0.465 cubic meters was used to calculate the MDC and MQC.

Table B2. Personal air sample results for lead and cadmium for activities outside the CRT area

Job task	Time (minutes)	Lead concentration (μg/m^3)	Cadmium concentration (μg/m^3)
Bulb and battery sorting	462	(1.5)*	ND
	470	(1.2)	ND
	457	(0.89)	ND
Forklift driving and baling	506	3.9	(0.039)
	466	2.8	(0.065)
Maintenance	442	4.1	(0.046)
	492	3.9	0.10
	446	2.2	ND
	435	(1.9)	(0.070)
	459	(1.4)	(0.022)
Shredder sorting	463	67	0.84
	448	17	0.24
	492	4.2†	(0.020)
	464	3.3	(0.044)
	503	2.8	0.12
	502	2.6	(0.040)
	482	2.7	(0.021)
	497	(1.6)	(0.020)
	479	(1.9)	ND
NIOSH REL-TWA		50	Ca
OSHA PEL-TWA		50	5
ACGIH TLV-TWA		50	10
MDC		0.6	0.02
MQC		2.0	0.086

Ca = NIOSH potential occupational carcinogen. Exposures should be kept as low as possible.
ND = Not detected; result is below the MDC.
*Values in parentheses indicate concentrations between the MDC and MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 0.465 cubic meters was used to calculate the MDC and MQC.

Table B3. Area air sample results for lead and cadmium

Location	Time (minutes)	Lead concentration (µg/m^3)	Cadmium concentration (µg/m^3)
CRT Angel	468	8.3	0.11
	503	5.3	(0.059)*
	480	5.4	0.22
CRT demanufacturing	468	4.3	(0.021)
	498	2.8	(0.020)
	480	3.3	0.11
Large equipment demanufacturing	450	2.5	(0.022)
	483	(1.6)	(0.021)
	463	(1.6)	(0.022)
Shredder and demanufacturing	469	3.4	(0.022)
	490	(1.1)	ND
	469	(1.7)	ND
Bulb and battery sorting	479	2.0	ND
	475	(1.2)	ND
	457	(1.4)	ND
Break room	372	NS	SE
	485	0.77	ND
	472	0.91	ND
MDC		0.6	0.02
MQC		1.9	0.084

ND = Not detected; result is below the MDC.
SE = Sampling error; no sample result is reported.
*Values in parentheses indicate concentrations between the MDC and MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 0.476 cubic meters was used to calculate the MDC and MQC.

Table B4. Personal air sample results for mercury

Job task	Time (minutes)	Concentration (µg/m³)
Bulb and battery sorting	475	0.72
	461	ND
	305	SE
NIOSH REL-TWA		50
OSHA PEL (Ceiling only)		100
ACGIH TLV-TWA		25
MDC		0.20
MQC		0.75

ND = Not detected; result is below the MDC. A sample volume of 0.93 cubic meters was used to calculate the MDC and MQC.

SE = sampling error; no sample result is reported.

Table B5. Area air sample results for mercury

Location	Time (minutes)	Concentration (µg/m³)
Bulb and battery sorting	460	1.3
	397	(0.55)*
	478	(0.54)
CRT Angel	482	(0.20)
	471	ND
	505	ND
Large equipment demanufacturing	465	1.3
	452	(0.34)
	486	(0.23)
Shredder	475	0.73
	490	ND
	472	(0.47)
MDC		0.2
MQC		0.66

ND = Not detected; result is below the MDC.

*Values in parentheses indicate concentrations between the MDC and MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 0.105 cubic meters was used to calculate the MDC and MQC.

Table B6. Personal air sample results for respirable dust and crystalline silica in CRT area

Job task	Time (minutes)	Respirable Dust (µg/m³)	Respirable Silica (µg/m³)
CRT buffing	289	SE	SE
	491	(63)*	(3.5)
	491	140	(4.9)
CRT buffing and grinding	491	170	(7.3)
	490	(64)	ND
	498	140	(7.2)
CRT Angel operation	452	(110)	ND
	446	(110)	ND
	447	(110)	ND
	491	160	ND
	479	(75)	ND
	494	160	(6.3)
CRT demanufacturing	472	140	(9.6)
	479	130	(7.0)
	434	140	(4.3)
	482	(55)	ND
	495	(82)	(3.2)
	482	(65)	(3.8)
	478	150	(7.5)
	489	(110)	(5.8)
	488	(88)	(3.5)
MDC		40	3
MQC		130	10
OSHA PEL			1136†
NIOSH REL			50
ACGIH TLV			25

SE = sampling error; no sample result is reported.
ND = Not detected; result is below the MDC.
*Values in parentheses indicate concentrations above the MDC but below the MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 1.98 cubic meters was used to calculate the MDC and MQC.
†The OSHA PEL for crystalline silica is determined according to the amount of crystalline silica in the dust applied to the following formula: Respirable PEL (µg/m³) = 10,000 µg/m³ / (percent silica in dust + 2). In this evaluation we found that the maximum percentage of silica in the dust was 6.8%; this equates to a PEL of 1136 µg/m³.

Table B7. Personal air sample results for respirable dust and crystalline silica outside CRT area

Job task	Time (minutes)	Respirable dust (µg/m³)	Respirable silica (µg/m³)
Bulb and battery sorting	470	(91)*	ND
	411	(53)	ND
	462	(73)	ND
Forklift driving and baling	506	(76)	(3.0)
	465	130	(6.2)
Maintenance	491	SE	SE
	440	160	(6.0)
	445	(130)	ND
	461	160	(7.3)
	435	(94)	ND
Shredder sorting	492	150	(6.8)
	464	490	10
	448	170	(7.0)
	503	(100)	ND
	502	(43)	ND
	482	550	ND
	498	190	(9.2)
	489	220	12
	463	150	(7.7)
MDC		40	3
MQC		130	10
OSHA PEL			1136†
NIOSH REL			50
ACGIH TLV			25

ND = Not detected; result is below the MDC.
SE = sampling error; no sample result is reported.
*Values in parentheses indicate concentrations above the MDC but below the MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 1.98 cubic meters was used to calculate the MDC and MQC.
†The OSHA PEL for crystalline silica is determined according to the amount of crystalline silica in the dust applied to the following formula: Respirable PEL (µg/m³) = 10,000 µg/m³ / (percent silica in dust + 2). This equates to a PEL of 1136 µg/m³.

Table B8. Area air sample results for respirable dust and crystalline silica

Location	Time (minutes)	Respirable dust (µg/m³)	Respirable silica (µg/m³)
Bulb and battery sorting	457	(100)*	ND
	479	(98)	(5.9)
	421	(46)	(4.0)
Break room	472	ND	(9.6)
	372	ND	(5.1)
	485	(45)	(4.4)
Shredder	472	(97)	ND
	469	(91)	ND
	490	(67)	(2.9)
Large equipment demanufacturing	463	(110)	ND
	450	(110)	(3.3)
	483	(69)	(3.2)
CRT demanufacturing	468	180	ND
	498	(62)	ND
	480	(80)	ND
CRT Angel	468	(110)	ND
	480	(70)	ND
	503	(78)	(3.5)
MDC		40	3
MQC		130	10

ND = Not detected, result is below the MDC.
*Values in parentheses indicate concentrations above the MDC but below the MQC. Parentheses are used to indicate there is more uncertainty associated with these values. A sample volume of 1.957 cubic meters was used to calculate the MDC and MQC.

Table B9. Results from the surface wipe samples for selected elements

Location	Lead (µg/100 cm²)	Cadmium (µg/100 cm²)	Chromium (µg/100 cm²)	Nickel (µg/100 cm²)
Ledge of bay 1, CRT Angel	1100	0.46	130	30
Top of mixed glass station	810	4.8	3.3	7.9
Shredder 2nd tower (magnetic separator)	370	7.7	45	200
Shredder floor at workstation 1st tower	310	2.1	9.9	87
Floor in front of bay 1, CRT Angel	190	0.59	0.97	2.4
Conference room supply diffuser	100	0.2	0.83	1.4
Warehouse floor in front of office entryway	86	0.74	30	8.2
Baling machine	74	1.0	3.9	18
Break room floor (last cleaned previous day)	64	0.51	3.2	5
Break room floor at door after lunch	44	0.29	1.4	2.6
Break room refrigerator and door handle*	24	0.48	0.95	2.6
Break room door	16	0.15	1.8	2.3
Door handle to women's restroom*	15	0.24	0.81	26
Inside shredder conveyors	14	0.12	0.69	2.5
Carpet between production floor and office	12	0.14	0.29	0.99
Break room – back table after lunch	5.7	0.07	0.12	ND
Men's restroom counter and faucet handles	4.2	0.11	0.28	1.6
Water fountain	3.4	0.06	0.24	(0.4)†
Shredder	3.1	(0.04)	0.4	1.4
Office coffee machine	2.4	(0.02)	0.08	(0.22)
Door push bar to employee exit*	2.1	(0.04)	0.14	(0.43)
Refrigerator handle	(0.95)	0.1	0.24	(0.45)
Break room table	(0.55)	(0.04)	0.07	ND
LOD (µg/sample)	0.3	0.02	0.02	0.2
LOQ	1.1	0.050	0.060	0.70

ND = Not detected, result is below the LOD.
*Approximated 100 cm² surface area
†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.

Table B10. Personal noise dosimetry results

Job Task	Duration (minutes)	8-hour TWA noise exposure, in dBA		
		OSHA action level	OSHA PEL	NIOSH REL
CRT buffing and grinding	487	87	85	92
Shredder sorting	491	86	83	90
Shredder sorting	463	86	82	89
Baling	499	85	82	89
Forklift driving and baling	508	84	80	88
Shredder sorting	453	83	77	86
CRT buffing	473	81	77	86
Forklift driving and baling	467	80	73	85
CRT demanufacturing	470	79	76	84
Shredder sorting	494	77	72	83
Baling	481	79	71	84
CRT demanufacturing	464	76	68	81
Forklift driving and baling	Dosimeter malfunction – logged only 1.5 hours			
Exposure Limits		85	90	85

Appendix C: Cathode Ray Tube Buffing and Grinding Engineering Control Options

Option 1. Use a locally-exhausted grinding table ideally exhausted to the outside [ACGIH 2010]. A window pane or skylight panel could be removed to permit the exhaust duct to exit the building. A local engineering contractor with experience in industrial ventilation systems could design a table that would fit the process and provide exposure control.

Option 2. Use tools equipped with LEV for CRT buffing and grinding. LEV-equipped tools can be purchased or after-market exhaust hoods and dust collectors can be used to retrofit existing tools. In either case, the dust collector or hood is connected to either a fixed or portable dust collection system. The selection of the dust collection system is critical. The system must be capable of providing sufficient exhaust flow to capture dust at its source and to exhaust it ideally to the outside. ACGIH recommends an exhaust volume of 25–60 cubic feet per minute (cfm) per inch of diameter or width for hand-held surface grinders (i.e., 100 cfm to 240 cfm for a 4-inch diameter grinding wheel) [ACGIH 2010]. ACGIH also recommends 10–30 cfm per inch diameter for disc sanders [ACGIH 2010].

Option 3. Use a portable dust extraction system that can be positioned near the CRT buffing and grinding tasks and exhausted to the outside. Various portable dust extraction systems are available; all consist of a dust-collection hood, flexible duct, an air cleaner, and an exhaust fan.

References

ACGIH [2007]. 2007 Documentation of the threshold limit values and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

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

ACGIH [2014]. 2014 TLVs® and BEIs®: Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2014]. AIHA 2014 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

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]. Date accessed: July 2014.

ACS [2014]. Lead. Atlanta, GA: American Cancer Society. [http://www.cancer.org/cancer/cancercauses/othercarcinogens/athome/lead]. Date accessed: July 2014.

ANSI/AIHA [2007]. American National Standard for recirculation of air from industrial process exhaust systems. ANSI/AIHA Z9.7-2007. Fairfax, VA: American Industrial Hygiene Association.

ANSI/ASHRAE [2014]. Ventilation for acceptable indoor air quality. American National Standards Institute/ASHRAE standard 62.1-2014. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ATSDR [1999]. Toxicological profile for cadmium. Atlanta, GA: U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.

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

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). [http://www.healthresearchforaction.org/sites/default/files/PDF_PERSPECTIVES_IndecentExp%20FNL_0.pdf]. Date accessed: July 2014.

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]. Take-home lead exposure among children with relatives employed at a battery recycling facility–Puerto Rico, 2011. MMWR *61*(47):967–970.

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]. Fourth national report on human exposure to environmental chemicals updated tables: March, 2013. [http://www.cdc.gov/exposurereport/pdf/FourthReport_UpdatedTables_Mar2013.pdf]. Date accessed: July 2014.

CDC (Centers for Disease Control and Prevention) [2014]. Adult blood lead epidemiology and surveillance (ABLES). [http://www.cdc.gov/niosh/topics/ABLES/description.html]. Date accessed: July 2014.

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

CSTE [2014]. Public health reporting and national notification for elevated blood lead levels. 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]. Date accessed: July 2014.

EIA [2014]. EIA, Electronic Industries Alliances, lead in cathode ray tubes (CRTs) information sheet. [https://www.premierinc.com/quality-safety/tools-services/safety/topics/computers/downloads/k_3_lead_in_crts.pdf]. Date accessed: July 2014.

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.

Florida Department of Environmental Protection [2014]. Cathode ray tube (CRT) glass – a recycling challenge. [http://www.dep.state.fl.us/scrap/categories/electronics/pages/lead.html]. Date accessed: July 2014.

Franzblau A [2005]. Cadmium. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, eds. Textbook of clinical occupational and environmental medicine. 2nd ed. Philadelphia, PA: Elsevier Saunders, pp. 955–958.

Hornung RW, Reed LD [1990]. Estimation of average concentration in the presence of nondetectable values. Appl Occup Environ Hyg *5*(1):46–51.

Hwang YH, Chiang HY, Yen-Jean MC, Wang JD [2009]. The association between low levels of lead in blood and occupational noise-induced hearing loss in steel workers. Sci Total Environ *408*(1):43–49.

IOM [2012]. Potential health risks from recurrent lead exposure of DOD firing range personnel. Washington, DC: National Academies Press.

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.

Lauwerys RR, Hoet P [2001]. Biological monitoring of exposure to inorganic and organometallic substances. In: Industrial chemical exposure: guidelines for biological monitoring. 3rd ed. Boca Raton, FL: CRC Press, LLC, pp. 21–180.

Martin CJ, Antonini JM, Doney BC [2009]. A case report of elevated blood cadmium. Occup Med *59*(2):130–132.

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.

Morata TC [2007]. Promoting hearing health and the combined risk of noise-induced hearing loss and ototoxicity. Audiol Med *5*(1):33–40.

NIOSH [1984]. Current Intelligence Bulletin #42: cadmium. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH)/DOL (OSHA) Publication No. 84-116.

NIOSH [1995]. Report to Congress on the workers' home contamination study conducted under the Workers' Family Protection Act (29 USC 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/]. Date accessed: July 2014.

NIOSH [1997]. Musculoskeletal disorders and workplace factors: a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, (DHHS) Publication No. 97-141. [http://www.cdc.gov/niosh/docs/97-141/]. Date accessed: July 2014.

NIOSH [2014a]. NIOSH manual of analytical methods (NMAM®). 4th ed. Schlecht PC, O'Connor PF, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 94-113 (August 1994); 1st Supplement Publication 96-135, 2nd Supplement Publication 98-119; 3rd Supplement 2003-154. [http://www.cdc.gov/niosh/docs/2003-154/]. Date accessed: July 2014.

NIOSH [2014b]. NIOSH manual of analytical methods (NMAM®). Consideration of sampler wall deposits. Inclusion of material adhering to internal cassette surfaces during sampling and analysis of airborne particles. [http://www.cdc.gov/niosh/docs/2003-154/cassetteguidance.html]. Date accessed: July 2014.

NIOSH [2014c]. 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/]. Date accessed: July 2014.

NIOSH [2014d]. Indoor firing ranges. [http://www.cdc.gov/niosh/topics/ranges/]. Date accessed: July 2014.

NTP [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]. Date accessed: July 2014.

NTP [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.

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]. Date accessed: July 2014.

OSHA [2013]. Lead and cadmium standards – recirculation of exhaust air. Private e-mail message from Sven Rundman (rundman.sven@dol.gov) to Echt A (ase0@cdc.gov), February 25, 2013.

Peters-Michaud N, Katers J, Barry J [2003]. Occupational risks associated with electronics de-manufacturing and CRT glass processing operations and the impact of mitigation activities on employee safety and health. International Symposium on Electronics and the Environment, 19–22 May, pp. 323–328.

Schwartz BS, Hu H [2007]. Adult lead exposure: time for change. Environ Health Perspect *115*(3):451–454.

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.

Siegel JD, Rhinehart E, Jackson M, Chiarello L, and the 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]. Date accessed: July 2014.

Sliwinska-Kowalska M, Zamyslowska-Szmytke E, Szymczak W, Kotylo P, Fiszer M, Wesolowski W, Pawlaczyk-Luszczynska M, Bak M, Gajda-Szadkowska A [2004]. Effects of coexposure to noise and mixture of organic solvents on hearing in dockyard workers. J Occup Environ Med *46*(1):30–38.

Stauber JL, Florence TM, Gulson B, Dale L [1994]. Percutaneous absorption of inorganic lead Compounds. Sci Total Environ *145*(1–2):55–70.

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.

Thun MJ, Elinder C, Friberg L [1991]. Scientific basis for an occupational standard for cadmium. Am J Ind Med *20*(5):629–642.

WHO [2006]. IARC Monographs on the evaluation of carcinogenic risks to humans, vol. 87. Inorganic and organic lead compounds. Summary of data reported and evaluation. World Health Organization, Geneva, Switzerland. [http://monographs.iarc.fr/ENG/Monographs/vol87/volume87.pdf]. Date accessed: July 2014.

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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.

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