Evaluation of Exposure to Metals at an Electronic Scrap Recycling Facility

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Contents

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

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from an electronic scrap recycling company. Managers were concerned about employee exposure to lead and cadmium. We evaluated the electronic scrap recycling company in June 2013, September 2013, and February 2014.

What We Did

- We observed work activities and processes.
- We tested air, work surfaces, and employees' hands for metals, including beryllium, cadmium, chromium, cobalt, and lead.
- We tested employees' blood for lead and cadmium.
- We measured employees' exposure to noise.
- We interviewed employees about their work history and health and safety concerns.

> We evaluated employee exposures to metals at an electronic scrap recycling facility. Air concentrations of metals were low. Blood cadmium and lead levels were well below occupational exposure limits. Employees were overexposed to noise. Some employees may be at risk for low back injuries. We recommended reducing noise levels, starting a hearing conservation program, and evaluating risks for musculoskeletal disorders.

What We Found

- Machine guards were not always in place when equipment was operating.
- Some employees were overexposed to noise.
- Levels of metals in the air were below their occupational exposure limits.
- None of the employees had detectable amounts of lead in their blood, and blood cadmium levels were well below the limit that would trigger Occupational Safety and Health Administration requirements.
- Employees ate near work areas where they could be exposed to lead and other hazardous contaminants.
- Some work activities involved heavy lifting, bending, and twisting, which could lead to low back injuries.
- Cultural differences related to national origin might create barriers to communication about workplace health and safety.

What the Employer Can Do

- Replace all missing machine guards before operating the shredder.
- Implement a hearing conservation program.
- Provide an employee eating area separated from work areas.

- Provide laundering facilities on site or contract with a laundering service for all employees exposed to lead.
- Evaluate the risk for musculoskeletal disorders and make changes to reduce risk.
- If shredding operations increase, evaluate the need to improve protective measures.
- Promote employee engagement in workplace health and safety.

What Employees Can Do

- Do not operate the shredder without machine guards in place.
- Wear hearing protection when required.
- Lower the radio volume if listening to music while working.
- Do not eat or drink in work areas.
- Wash hands before eating or drinking, smoking, and leaving the workplace.
- Actively participate in meetings and trainings on workplace health and safety.

Abbreviations

µg/dL	Micrograms per deciliter
ACGIH®	American Conference of Governmental Industrial Hygienists
BLL	Blood lead level
CFR	Code of Federal Regulations
dBA	Decibels, A-weighted
IARC	International Agency for Research on Cancer
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL™	Workplace environmental exposure limit

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Introduction

The Health Hazard Evaluation Program received a request from managers at an electronic scrap recycling company. The request concerned possible employee exposure to lead and cadmium. We visited the facility for the first time in June 2013. We held an opening conference and toured the facility to observe operations, work practices, and working conditions. We returned to the facility in September 2013 and in February 2014 to interview employees; collect air, surface wipe, and blood samples for metals; and evaluate noise exposures. We provided our preliminary observations and recommendations to the employer and the employee representative in July 2013 and February 2014. We notified employees of their individual sampling results and summarized these results for the employer and employee representatives in November 2013 and March 2014.

Background

The company began operating at this facility, a large warehouse structure, about 1 year before our first site visit. The facility's primary activities included recycling batteries, metals, cardboard, and ballast and capacitors (for fluorescent lights). Other activities included (1) sorting, dismantling, and shredding electronic equipment such as computers, printers, keyboards, central processing units, fax machines, cameras, medical equipment, and photocopiers; and (2) secure data destruction of electronic medical records. The facility did not recycle cathode ray tube monitors or fluorescent light bulbs but collected them for shipment to another recycling facility. The facility's shredder operated approximately 3 or fewer days per month but the company had plans to increase its use in the future. Ten employees, supervised by a production manager, worked 5 days per week in a single shift that started at 6:00 a.m. and ended at 3:00 p.m. Employees had two 15-minute breaks and a 30-minute lunch break.

Process Description

Battery Separating and Taping

Two employees removed expired batteries from their original packaging and placed the batteries in one container and the cardboard and plastic packaging in another (Figure 1). The employees placed tape over the electrodes of lithium ion style batteries and some higher voltage alkaline batteries to prevent electrodes from coming into contact with each other.

Demanufacturing

Employees manually dismantled and separated computer components, such as circuit boards, hard drives, copper wiring, and other parts that contained valuable materials (Figure 2). Each employee worked at a station, selected a piece of electronic equipment, removed the screws, and separated the components. During the first site visit, each employee sorted all of the components individually and threw them into one of six large boxes, sometimes located more than 20 feet from the employee. During the second site visit, a conveyor belt with four work stations was installed. Two employees manually dismantled the computer components and placed them on the conveyor belt or into a large box nearby. Another employee selected specific components for further dismantling. A fourth employee at the end of the conveyor separated the remaining components into one of four boxes located at the end of the conveyor belt.

Shredding

Shredding of printers, circuit boards, central processing units, and other material was a multistage process, with automated and manual tasks. The forklift operator picked up large boxes of electronics and set them next to the conveyor to the shredder. Employees manually removed electronics from the boxes and loaded them on the conveyor (Figure 3). The conveyor carried the electronics to the first tower, where they fell into the shredder (Figure 4). The shredded electronics then traveled up a second conveyor to the second tower where a magnetic conveyor belt separated magnetic from nonmagnetic electronic components. Magnetic components were expelled from the second tower directly into a large box (first visit) or onto a sorting conveyor (second visit) where two or three employees separated copper wire from its metal housing (Figure 5). Nonmagnetic scrap continued to the third tower where additional separation took place (not observed). The remaining scrap traveled to the fourth tower where eddy currents separated aluminum and plastic components (Figure 6). The separate streams of sorted scrap components were collected in large boxes to be baled and shipped off site. A local exhaust ventilation system with hard metal ductwork carried air from all towers of the shredder to a Downflo® Oval dust collection unit. Larger dust particles fell into two 55-gallon drums attached to the dust collection unit. A series of eight nanofiber filters with a minimum efficiency reporting value of 15 filtered the air; clean air was exhausted back into the work environment.

Figure 1. Battery separation: employee wears a cut-resistant glove to protect from knife cuts while removing batteries from the packaging. Photo by NIOSH.

Figure 2. Employee using a cordless screwdriver in the demanufacturing process. Photo by NIOSH.

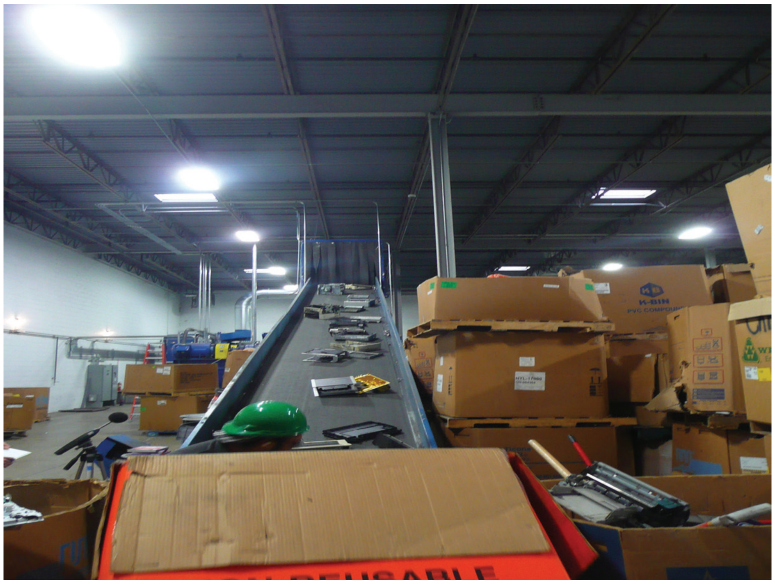

Figure 3. Load on shredder conveyor. Photo by NIOSH.

Figure 4. First tower and shredder. Photo by NIOSH.

Figure 5. Magnetic separator. Photo by NIOSH.

Figure 6. Eddy current separator (top at left, bottom on right). Photos by NIOSH.

Common Elements in Electronic Scrap Recycling

Various elements are often found in electronic scrap waste streams because of the wide variety of electronic components that are recycled. These elements include:

- Beryllium – older printed circuit boards
- Cadmium – nickel-cadmium batteries, printed circuit boards, and coating on cathode ray tube glass
- Chromium and hexavalent chromium – data tapes, floppy-disks
- Cobalt – batteries
- Copper – wiring
- Indium – smart phones and other touch screens
- Lead – cathode ray tube glass, batteries, solder, and older printed circuit boards

Methods

Our primary objective was to evaluate employee exposure to the most commonly found metals in electronic scrap streams. Our secondary objective was to evaluate employee noise exposure.

In September 2013, we collected personal and area air samples for elements (metals and minerals) and analyzed these samples according to National Institute for Occupational Safety and Health (NIOSH) Method 7300 [NIOSH 2014]. We analyzed for all 32 elements possible with this method because of the variable nature of the electronic scrap stream. All 10 employees participated both days, for a full 8-hour or 9-hour shift. We collected area air samples for elements around the shredder. We collected these samples in the same location before the shredder was operating and while it was operating to compare the results. In February 2014 we collected personal air samples on the same 10 employees for their full shifts. We analyzed these samples for beryllium, cadmium, chromium, cobalt, and lead on the basis of results from the prior analyses.

In September 2013, we used Environmental Express® pre-moistened Ghost Wipes to collect surface wipe samples from various locations in the warehouse and adjacent break areas to look for migration of elements out of the warehouse. We used a 10 centimeter by 10 centimeter disposable template on flat surfaces to ensure uniform evaluation among sample locations. For hand wipe samples, NIOSH investigators asked employees which hand was dominant, then the investigator donned a new pair of gloves to wipe each employee's dominant hand for 30 seconds, including wiping between the fingers. We conducted a full elemental scan on the wipe samples we collected in September 2013 according to NIOSH Method 9102 [NIOSH 2014]. In February 2014, we took wipe samples from employees' hands and work areas using the techniques described above. We also sampled surfaces in the break area and the sorting stations in demanufacturing. We analyzed these hand and surface wipe samples specifically for beryllium, cadmium, cobalt, chromium, and lead.

In September 2013, we interviewed all 10 employees about their work history, factors that could affect blood levels of lead and cadmium, recent changes in health, hazard communication training, and use of personal protective equipment. We obtained written informed consent to collect blood. We drew 5 milliliters of whole blood from each participant and tested it for lead and cadmium. We notified study participants individually in writing of their blood test results and explained what these results meant. We also reviewed the facility's Occupational Safety and Health Administration (OSHA) Form 300 Log of Work-Related Injuries and Illnesses for the facility's first year of operations, 2013.

In February 2014, we measured six employees' full-shift personal noise exposures while the shredder was off and five employees' full-shift personal noise exposures while the shredder was running. We used Larson Davis Spark™ model 706RC integrating noise dosimeters for these measurements. The dosimeters simultaneously collected data using three different settings to allow comparison of noise measurement results with three different noise exposure limits, the OSHA permissible exposure limit (PEL), the OSHA action level, and the NIOSH recommended exposure limit (REL). We used a Larson Davis Model 824 integrating sound level meter and frequency analyzer to measure sound levels at several different work areas and to create a noise map of the facility while the shredder was operating and while it was not operating. We also used the instrument to measure octave band noise levels (i.e., measurement of noise levels across different frequencies).

We reviewed the written work instructions for operating the shredder.

Results and Discussion

Air Sample Results

We collected 20 personal and 14 area air samples in September 2013. The shredder operated for 1.5 hours on September 10, 2013. The conveyor belt in the tower where plastic and aluminum were separated was jammed and had to be repaired before it could be used again. On September 11, 2013, the shredder operated for 3.5 hours. Personal air sample results for the most common metals found in electronic scrap are in Appendix A, Table A1. None of the personal exposure results for elements exceeded applicable occupational exposure limits (OEL) and, with the exception of beryllium, were at least an order of magnitude below the most protective OEL. Area air sampling results are found in Appendix A, Table A2 for September 10 and Table A3 for September 11. Although these airborne concentrations were low, note that more metals were detected when the shredder was running than when it was not running, indicating that shredding operations contribute to airborne exposure to these elements. The health effects of lead are discussed in Appendix C, Table C1. The health-based recommended medical surveillance levels for lead-exposed employees can be found in Appendix C, Table C2. Health effects and occupational exposure limits for the other common elements are available in Appendix C, Table C3.

In February 2014 we also found that concentrations of elements in the air were low. We collected nine personal air samples on February 4 when the shredder was off and eight personal air samples on February 14 when the shredder was on for 4 hours. Sample results from the February 2014 site visit are in Appendix A, Table A4. No employees were overexposed to beryllium, cadmium, chromium, cobalt, or lead in air. Even while the shredder was running, the air concentrations we measured were low. The highest lead concentration we measured was at least 15 times lower than the OELs.

A possible explanation for the low airborne metal concentrations is the infrequent and short-duration use of the shredder. Between the September 2013 and February 2014 visits, the facility did not operate the shredder. Typically, this facility operates the shredder 3 times per month and for no more than an hour or two at a time. If shredder operations increase in frequency or duration, employee exposures could increase.

Surface Wipe Sample Results

Few standards define acceptable levels of workplace surface contamination. Wipe samples, however, can provide information about the effectiveness of housekeeping practices, the potential for exposure to contaminants by other routes such as the skin or mouth (e.g., from surface contamination on a table where people eat and drink), the potential for contamination of worker clothing and subsequent transport of the contaminant outside the workplace, and the potential for non-process related activities (e.g., sweeping) to generate airborne contaminants.

We collected 17 surface wipe samples in September 2013. Results are shown in Appendix A, Table A5. Because of the variable nature of the electronic waste stream, we collected wipe samples in work areas where we expected to find contamination (i.e., on the shredder and demanufacturing work tables, a work glove found near the battery separator, and the area of the ventilation unit near the shredder where filtered exhaust air is recirculated back into the facility). The elements that we found on all surfaces on the facility floor included cadmium, chromium, cobalt, copper, and lead. Indium was present on the conveyor leading to the first tower and the return clean air supply of the ventilation unit near the shredder. We collected wipe samples in non-production areas to look for the spread of contaminants and identify the possibility for exposure by ingestion (hand-to-mouth contact), direct skin contact, or inhalation of aerosolized dust. All surfaces that we tested showed the presence of at least one element. Cobalt was the only element found on the bench in the outdoor break area. Cadmium was present on all surfaces, except the outdoor break area bench and conference room table. The chair in the outdoor break area and the handle of the refrigerator in the entrance/break area were positive for all elements that we tested. The air supply diffuser in the entrance room break area was positive for cadmium, chromium, cobalt, copper, and lead.

We collected six hand wipes and tested seven surfaces for metals in February 2014. Appendix A, Table A6 shows the results. Although some employees washed their hands, we still detected metals before they left work for the day. If employees wear or take dirty work gloves away from work areas, metals on the gloves could be transferred to surfaces in such places as break areas or employees' vehicles. The break areas where employees ate lunch had detectable levels of chromium, cobalt, cadmium, and lead. This finding underscores the importance of preventing exposures. Hand washing before entering the break areas and before eating, drinking, or smoking, and regular cleaning of surfaces in break areas are important in reducing such exposures.

Blood Lead and Cadmium Levels

All 10 employees had blood drawn to measure lead and cadmium levels. All blood lead results were less than the limit of detection of 3.0 micrograms per deciliter (µg/dL). Thus, all results were below 10 µg/dL, the current Centers for Disease Control and Prevention (CDC)/NIOSH reference for blood lead levels in adults [CDC 2012]. Blood cadmium results ranged from 0.5 to 1.5 micrograms per liter. Thus, all results were below the 5 microgram per liter level at which OSHA requires an employer to take action to reduce employee exposure. The low blood lead and blood cadmium results could be explained by one or more factors, such as the short duration of operations at the facility, employees' short duration of employment, and the low frequency of shredding operations. Because we found lead and cadmium in our environmental samples, higher blood lead and blood cadmium levels may be possible if the facility increases shredding operations.

Employee Interviews

We interviewed all 10 employees who worked at the facility. Employees ranged in age from 20 to 45 years. They had worked for the company from 1 day to 3.7 years. Some employees had previously worked at a different location. One had worked in the electronic scrap industry in the past but the others first began working in the industry with this company. Two had possible exposure to airborne metals in previous workplaces where welding was done. Two employees used tobacco (smoking or chewing) regularly. Eight employees were Pacific Islanders from Pohnpei; all spoke and understood English. Eight employees were male; four worked in demanufacturing, three in shipping and receiving, and one in both demanufacturing and the sorting and disassembling of larger batteries. When the shredder was running, four male employees left their usual work to operate the shredder. The two female employees worked exclusively in the opening and sorting of consumer-ready packs of dry cell batteries.

Several employees in the demanufacturing and baling areas reported that airborne dust was causing eye irritation. They stated that airborne dust could be seen when sun shines into the building. They identified the sources as toner from broken containers and printers in demanufacturing and baling dust. They reported that these areas do not have adequate ventilation. Managers reported that they were seeking an economical solution to address this concern.

Several employees reported concerns about skin damage from exposure to chemicals, such as leaking propane from hose connections when attaching propane tanks to forklifts or Freon® when cutting refrigerant tubing in recyclable items. They stated that the gloves used for other work in the facility were ineffective for protection against these chemical exposures. They reported that the face shield provided by the company was not kept near the propane storage area. Managers reported that they no longer accepted items with ozone-depleting refrigerants (e.g., Freon) because of the cost of complying with U.S. Environmental Protection Agency regulations.

Several employees reported that they lifted bulky and heavy items. They also reported having to bend when lifting items from the bottom of large cardboard boxes, which are about 4 feet deep. They reported that loading and unloading these large boxes were more easily done by two employees, but when the facility was busy, they did it alone. A few employees reported back problems. Although these employees did not relate their back problems to work, their work involved heavy lifting, bending, and twisting of the body. Managers stated that they were considering using large plastic collapsible boxes with sides that open to eliminate employees' bending. They had been considering the use of back belts, which we advised against because of the lack of evidence supporting the use of back belts in preventing back pain or injury [Wassell et al. 2000; van Poppel et al. 2004; Ammendolia et al. 2005].

Although managers reported that the daily start time was changed from 8:00 a.m. to 6:00 a.m. to avoid the afternoon heat, employees reported having to work in hot weather in the summer. They also reported that working around the shredder is hotter than working in other areas of the facility.

Shredder and baler operators were aware of the company's lockout/tagout policy. However, they reported concerns that the locks and keys were not stored close to the shredder. Managers stated that four sets of locks and keys were stored by the first-aid station near the balers, which they considered centrally located and convenient. The balers were located in the central part of the building. The shredder was located at the far end of the building, separated from the balers by a large storage area.

All employees reported having health and safety training at this workplace. All three of the employees who were asked about hand washing reported that they washed their hands before eating; however, two reported that they had not washed their hands before leaving work for the day. All employees reported using eye protection and gloves. Shredder operators reported using hearing protection when working at the shredder.

Employees reported the lack of a lunchroom. Managers reported that they were planning an employee lunch room, but the project had been delayed by plans to renovate the facility and add offices to the building.

Many employees were familiar with occupational safety and health, which they had learned at jobs with other employers. During our interviews, some employees expressed a preference for the safety and health practices they had at previous places of employment. This suggests a need for in depth discussions about workplace safety and health between management and employees. Because the workforce is mostly Pacific Islander, national origin, culture, and language may be barriers to communication. These factors could affect management's ability to consider and address employees' concerns seriously, which would limit employees' willingness to ask questions freely and voice their concerns about safety and health.

Review of OSHA Logs

No work-related injuries and illnesses were reported on the 2013 OSHA Log.

Noise Exposures and Hearing Conservation

Full-shift time-weighted average personal noise exposure measurement results are in Appendix A, Table A7. We adjusted the NIOSH REL and OSHA action level for a 9-hour shift. OSHA does not adjust the PEL for longer work shifts. Appendix B shows area sound level measurements throughout the facility while the shredder was running (Appendix B, Figure B1) and not running (Appendix B, Figure B2). The health effects associated with excessive noise exposure are discussed in Appendix C.

Full-shift noise exposures for the three employees we monitored at the shredder were above the NIOSH REL. Sound levels measured at the load-on conveyor with the sound level meter were 80–86 decibels, A-weighted (dBA) when the shredder (Tower 1) was running but scrap electronics were not being tossed onto the conveyor. Sound levels increased to 92–97 dBA when an employee tossed scrap pieces onto the shredder conveyor.

Sound levels at the sorting station conveyor where employees separated copper wiring, magnetic debris, and plastic debris were 90–94 dBA. Noise generated by the magnetic separator tower and the nearby eddy current separator contributed to noise exposures in this work area. Additionally, scrap pieces striking the angled metal redirect plate at the bottom of the chute also generated noise. The magnetic separator and nearby eddy current separator only ran for 3 hours on the day of monitoring, but sometimes run longer. If these separators operate longer it is reasonable to assume that noise exposures would be higher.

An employee working at the loading dock and two employees working in the demanufacturing area had noise exposures above the NIOSH REL. Additionally, one of the demanufacturing employees also had noise exposures that were above the OSHA action level and permissible exposure limit. The shredder was not running and therefore did not contribute to these employees' noise exposures. However, music from radios in that area could have contributed to noise exposures. The employee with the noise exposure above the OSHA action level and permissible exposure limit worked at the demanufacturing station closest to the radio. Sound levels near the demanufacturing line while the radios were on were 70–75 dBA. We noticed that employees increased the volume of the radios throughout the day; by the end of the shift we had to shout to be understood from approximately 3 feet away from the workers closest to the radio. With the shredder off, background sound levels were 76–81 dBA near the loading dock, storage area, and battery sorting area; 65–72 dBA in the demanufacturing area; and 55–69 dBA near the shredder, storage, and battery sorting area. On February 14, 2014, all three employees who operated the shredder had noise exposures above the NIOSH REL.

One-third octave band measurements showed that predominant noise frequencies at the eddy current separator were 20, 31.5, and 40 hertz. High noise occurred at these frequencies because of the vibration generated by the eddy current separator and its drive motors. The eddy current separator was bolted to a metal support frame that elevated the separator above the floor and also provided an elevated metal walkway around the separator. Vibration isolation felt was used at some of these points of attachment (Figure 7); however, in some places the separator was bolted directly to the support frame (Figure 8). Additionally, the metal support frame was bolted directly to the floor (Figure 9). Because low frequency noise is easily transmitted through equipment, walls, and floors, uninterrupted transmission of vibration from the separator through the support frame to the concrete floor affected overall noise levels in nearby work areas.

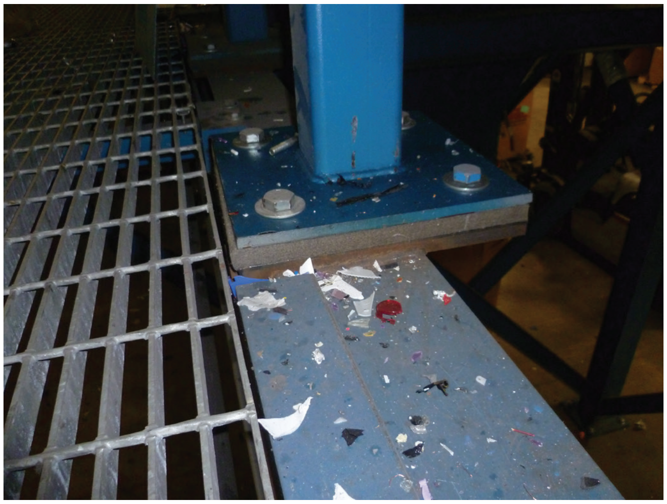

Figure 7. Eddy current separator bolted to support frame with vibration isolation felt at the point of attachment. Photo by NIOSH.

Figure 8. Eddy current separator bolted directly to support frame. Photo by NIOSH.

Figure 9. Support frame below eddy current separator bolted directly to concrete floor. Photo by NIOSH.

Most shredding employees wore foam insert ear plugs while the shredder was on; however, some employees did not wear hearing protection. We also observed that some employees did not properly insert the ear plugs deeply into their ear canal. Employees can appear to have hearing protection properly inserted, but the hearing protectors still may not fit effectively. Poorly fitting or worn ear plugs can decrease noise attenuation.

The company posted a sign at the entrance to the section of the building where the shredder was located indicating that hearing protection was required. However, the sign was misleading because hearing protection was only required when the shredder was on, but not required when it was off. The company only provided one type of hearing protection for employees to wear. Hearing protection was not required at any time in the demanufacturing area or in the battery sorting area. Employees are required to wear hearing protection while operating the shredder; however, the company did not have a hearing conservation program. Employees did not receive baseline or annual audiograms, and the company had not conducted noise exposure monitoring.

Program Reviews and Workplace Observations

This facility had a joint employee and employer safety committee that met once a month. In addition, employees attended monthly safety meetings and training on a variety of topics.

We reviewed the facility's written work instructions for operating the shredder. These work instructions described the start-up and shut-down procedures for the shredder and dust collector filter and drum change out procedures for the dust collection system. The instructions also stated that steel-toed shoes may be required when operating the shredder.

The facility had no respiratory protection program. No respirators were required, but N95 filtering facepiece respirators were available for voluntary use. The employees had not received a copy of Appendix D of the OSHA respiratory protection standard (29 Code of Federal Regulations [CFR] 1910.134), which is required when respirators are used voluntarily, and the employer lacked documentation of making sure respirators were properly stored, kept clean while in use, and did not themselves create a hazard.

The facility did not have written documentation of a hazard assessment as required by the OSHA personal protective equipment standard (29 CFR 1910.132(d)(2)). All employees wore safety glasses and usually wore cut-resistant Radnor® palm coated gloves. We observed worn patches and holes in the work gloves, and one employee reported that they reused them until they fell apart. These gloves were not designed to protect the employees from frostbite while changing propane tanks or cutting refrigerant tubing. Some employees also wore steel-toed boots, but the facility did not provide them. It was unclear when steel-toed boots were required. The facility did not provide uniforms, and the employees laundered their work clothes at home.

The company did not have shower facilities, locker rooms, or a dedicated break room. Employees ate lunch inside the building near the employee entrance or just outside the building near the work areas. During the winter, a break area was established inside the building next to the battery sorting station, balers, and the loading docks.

Forklift operators did not always wear seatbelts while operating the forklifts. Some stacks of boxes throughout the facility appeared unstable, and many were stacked on broken pallets (Figure 10). The shredder and eddy current separator (Figure 11) operated with several machine guards missing. Pieces of wood with exposed nails were on the floor in work areas. Employees also reported that they dry swept the floors if a fluorescent light bulb was broken. Dry sweeping can aerosolize mercury dust and vapor from broken bulbs.

Figure 10. Large poorly stacked cardboard boxes filled with electronic scrap. Photo by NIOSH.

Figure 11. Unguarded belt drive on eddy current conveyor. Photo by NIOSH.

In the tower that separated magnetic metals from aluminum and plastic, the main conveyor carried shredded material upward to a magnet conveyor. The magnet captured material from the main conveyor and released it into a chute to a hopper below. We saw physical hazards caused by pieces of shredded metal flying out of the chute or hopper into the work area and walkways. By the second site visit, the company had installed a conveyor belt that reduced the potential for flying metal to hit employees.

In the battery disassembly area, pallet-sized cardboard boxes of batteries were raised off the floor and the upper sides of the boxes cut off as employees emptied them, permitting employees to work without bending over into the boxes. However, in areas where components were emptied from incoming large boxes, we saw employees lifting large items from the bottom of the boxes to waist and chest level. They also bent at the waist with straight legs and twisted their body. These observations confirmed what some employees reported during the confidential employee interviews and suggest a risk for low back injuries and other musculoskeletal disorders.

Conclusions

Employee blood lead levels were below the CDC/NIOSH reference for blood lead levels in adults, and blood cadmium levels were below the OSHA action level. Beryllium, cadmium, chromium, cobalt, and lead were not detected or were present in low concentrations in personal air samples. Because our evaluation took place when shredding operations were infrequent and of short duration, employee exposures may be higher if shredder operations increase as planned. We detected these metals on surfaces, including those in break areas. The metals that we found on employees' hands before they left the facility and the practice of taking work clothes home for laundering can lead to take-home contamination. Some employees were overexposed to noise from the shredder and from loud radios when the shredder was off. We also observed activities that increase the risk for low back injuries and physical hazards that increase the risk for traumatic injuries.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the electronic scrap recycling facility to use their labor-management health and safety committee 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 specific situations at this electronic scrap recycling facility.

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

Elimination and Substitution

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

1. Store preshredded and postshredded material in a more organized and safe manner. Maintain shorter, more stable stacks when possible, and replace broken pallets. See OSHA's Materials Handling and Storage guide at https://www.osha.gov/Publications/osha2236.pdf.
2. Remove exposed pallet nails that could cause injury.

Engineering Controls

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

1. Install vibration isolation pads or springs to reduce vibration transmission from the frame of the eddy current separator to the metal support frame and from the support frame to the concrete floor.
2. Add internal or external noise damping to the discharge chute below the magnetic separator, and attach durable rubber lining to the metal redirect plate.
3. Attach a cover to the front of the magnetic separator chute to prevent pieces of shredded metal from flying out of the chute and hopper and injuring nearby employees.
4. Ensure that all machine guards are in place before operating equipment.

Administrative Controls

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

1. Develop and implement a hearing conservation program that includes annual audiometric testing, hearing protection, and training for employees overexposed to noise [29 CFR 1910.95]. More information on establishing a hearing conservation program is available at http://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf and http://www.osha.gov/Publications/osha3074.pdf. The Ohio Bureau of Workers' Compensation may be able to help in starting a hearing 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 of lead on hearing loss.

2. Require employees to keep radios at a minimum volume to avoid exceeding occupational exposure limits for noise.
3. Place scrap parts on the load-on conveyor rather than tossing them onto the conveyor to reduce noise from the impact of parts hitting the conveyor.
4. Implement a long-term strategy to reduce noise exposures by purchasing new equipment. For example, when equipment is replaced, purchase new equipment that generates less noise. Consult an experienced noise control engineer to help design noise controls. For more information, see the NIOSH Buy Quiet prevention initiative at http://www.cdc.gov/niosh/topics/buyquiet/.
5. Ensure that employees can safely wear respirators, and provide Appendix D of the OSHA respiratory protection standard (29 CFR 1910.134) to employees when they first start using filtering facepiece respirators voluntarily. Ensure that respirators are stored properly so that they do not become contaminated and present a hazard to employees.
6. Prohibit dry sweeping of floor surfaces when fluorescent bulbs break. Only use a vacuum cleaner specifically designed to collect mercury to minimize aerosolization of contaminated mercury vapor or dust. Wear disposable rubber or nitrile gloves. Use a commercial spill kit if available or scoop glass and powder safely into a sealable container. Use tape to pick up any remaining pieces of glass. Disposable wet wipes or damp paper towels may then be used to clean up the remaining dust. More information on avoiding mercury exposure from fluorescent bulbs can be found at https://www.osha.gov/Publications/osha3536.pdf.
7. Remind employees to wash hands with water and to use a lead-removing product after removing gloves; when they leave their work 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 [Esswein et al. 2011]. 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.
8. Provide a location for food storage and consumption separate from work areas. Until a break room is provided, frequently clean the areas where employees take breaks.
9. Provide laundry facilities on-site or a laundry service to ensure that contaminated uniforms are not taken home. Laundry personnel should be made aware of the potential exposure to lead and other contaminants on work clothes and take action to minimize potential exposures.
10. Require all forklift operators to wear seatbelts.
11. Assess jobs for risk of musculoskeletal disorders, and provide appropriate preventive measures.
12. Provide an environment in which employees can feel safe when expressing their concerns, making suggestions, and giving feedback on safety and health issues, such as hot environments and lockout/tagout procedures. Take into account potential barriers to communication, such as national origin, culture, and language.

13. Evaluate airborne exposures to metals periodically and whenever an increase in hazardous exposures is possible, such as an increase in shredder operations, introduction of new hazards, and increased workloads. If employee exposures increase, additional protective measures, such as showers, separate clean and dirty changing rooms, and biological exposure monitoring, may be needed.

Personal Protective Equipment

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

1. Place the signs that state "hearing protection required" closer to the shredder, and specify that using hearing protection is required for shredder operators when the shredder is operating.
2. Require all employees and supervisors working near the shredder while it is operating to wear hearing protection. Periodically inspect to ensure this requirement is followed. Train employees on proper insertion of the selected hearing protection.
3. Provide clean gloves for daily use, or use clean inner gloves (e.g., nitrile), when reusing dirty gloves. Instruct employees to leave dirty gloves in the work area. Encourage employees to replace dirty gloves frequently to minimize contamination of surfaces with metals.
4. Provide insulated propane cylinder handling gloves to protect the employees' hands while changing propane tanks on forklifts.
5. Complete a hazard assessment according to the OSHA personal protective equipment standard (29 CFR 1910.132) to determine what personal protective equipment will be required for each task. Standardize a policy for all job tasks based on this hazard assessment.

Appendix A: Tables

Table A1. Full-shift, personal air sampling results, September 2013

Task	Concentration (µg/m³)							Duration (minutes)
	Be*	Cd	Cr	Co	Cu	In	Pb	
September 10								
Battery separation	[0.02]	[0.06]	ND	0.24	0.28	ND	[0.37]	482
Battery separation	ND	ND	ND	0.19	0.22	ND	ND	483
Processing/shredding	ND	ND	ND	0.46	0.56	ND	[0.48]	491
Shipping/shredding	ND	ND	[0.09]	0.20	0.51	ND	[0.34]	487
Demanufacturing	0.04	0.14	[0.08]	0.42	0.35	ND	[0.67]	474
Demanufacturing	ND	[0.03]	ND	0.39	0.59	ND	[0.53]	486
Receiving/shredding	ND	ND	[0.18]	0.18	0.34	ND	[0.56]	486
Receiving/shredding	ND	[0.02]	[0.15]	0.94	0.69	ND	[0.85]	440
Demanufacturing	ND	ND	ND	0.18	0.79	ND	[0.41]	475
Shredding/repairs	ND	ND	ND	0.21	0.37	ND	[0.59]	431
September 11								
Battery separation	ND	ND	ND	[0.13]	0.19	ND	[0.42]	466
Battery separation	ND	ND	ND	[0.10]	0.28	ND	[0.58]	466
Taping batteries	ND	ND	[0.12]	[0.06]	0.26	ND	[0.41]	462
Shredding	ND	[0.02]	[0.12]	[0.12]	0.77	ND	1.4	473
Demanufacturing	ND	ND	[0.01]	ND	0.18	ND	[0.37]	455
Processing/shredding	ND	ND	[0.25]	[0.13]	0.78	ND	[1.1]	443
Battery taping	ND	ND	ND	[0.07]	0.25	ND	[0.92]	441
Receiving/shredding	ND	ND	ND	[0.09]	0.43	ND	[1.1]	434
Receiving/shredding	ND	ND	ND	[0.10]	0.48	ND	3.3	401
Demanufacturing	[0.02]	[0.04]	[0.11]	ND	0.59	ND	[0.51]	445
OSHA PEL	2	5	1000	100	1000	None	50	—
NIOSH REL	0.5	Ca	500	50	1000	100	50	—
ACGIH TLV	0.05	10	500	20	1000	100	50	—
MDC	0.01	0.03	0.09	0.06	0.03	0.4	0.4	461
MQC	0.03	0.08	0.10	0.19	0.07	1.4	1.3	461

ACGIH = American Conference of Governmental Industrial Hygienists

Be = beryllium, Cd = cadmium, Cr = chromium, Co = cobalt, Cu = copper, In = indium, Pb = lead

Ca = NIOSH potential occupational carcinogen

MDC = minimum detectable concentration

MQC = minimum quantifiable concentration

ND = not detected

[ ] = Values in brackets are between the MDC and MQC; more uncertainty is associated with these concentrations. The MDC and MQC were calculated using an average sample volume of 783 liters.

*Element found on field blank; results were adjusted accordingly.

Table A2. Full-shift area air samples by the shredder, September 10, 2013

Location	Concentration (µg/m³)							Duration (minutes)
	Be*	Cd	Cr	Co	Cu	In	Pb	
No shredder running								
Load on conveyor	ND	ND	ND	[0.06]	0.25	ND	[0.50]	458
1st shredding tower	ND	ND	ND	ND	0.24	ND	ND	454
Shredder final sort	ND	ND	ND	ND	[0.06]	ND	ND	451
Shredder metals separator	ND	ND	ND	0.36	0.39	ND	[0.43]	448
MDC	0.0066	0.022	0.077	0.055	0.022	0.33	0.33	—
MQC	0.022	0.07	0.25	0.17	0.059	1.2	1.1	—

[ ] = Values in brackets are between the MDC and MQC; more uncertainty is associated with these concentrations. The MDC and MQC were calculated using an average sample volume of 912 liters.

*Element found on field blank; results are adjusted accordingly.

Table A3. Short-term area air samples by shredder September 11, 2013

Location	Concentration (µg/m³)							Duration (minutes)
	Be*	Cd	Cr	Co	Cu	In	Pb	
No shredder running								
3rd tower aluminum plastic	ND	ND	[0.19]	ND	ND	ND	ND	235
Shredder load on	ND	ND	ND	ND	ND	ND	ND	235
Final separation	ND	ND	ND	ND	ND	ND	ND	235
2nd tower magnetic	ND	ND	ND	ND	ND	ND	ND	237
1st shredding tower	ND	ND	ND	ND	ND	ND	ND	229
Shredder running								
1st shredder tower	ND	0.24	0.23	0.19	5.9	ND	3.9	199
Load on station	ND	ND	0.42	ND	1.4	ND	[0.93]	254
2nd tower magnetic	ND	0.56	1.17	0.46	3.3	ND	7.1	245
3rd tower aluminum	ND	ND	0.24	0.15	0.70	ND	2.2	252
Final separation	0.08	0.24	0.55	0.40	2.2	ND	26.3	252
MDC	0.013	0.043	0.15	0.11	0.043	0.65	0.65	—
MQC	0.043	0.14	0.50	0.32	0.11	2.4	2.1	—

[ ] = Values in brackets are between the MDC and MQC; more uncertainty is associated with these concentrations. The MDC and MQC were calculated using an average sample volume of 465 liters.

*Element found on field blank; results are adjusted accordingly.

Table A4. Full-shift, personal air sampling results, February 2014

Task	Concentration (µg/m³)					Duration (minutes)
	Beryllium	Cadmium	Chromium	Cobalt	Lead	
February 4						
Demanufacturing	ND	0.10	0.28	[0.095]	1.2	528
Demanufacturing	ND	[0.050]	[0.16]	ND	0.77	527
Loading dock	ND	ND	[0.089]	[0.043]	[0.52]	533
Loading dock	ND	ND	ND	[0.039]	[0.50]	527
Sorting batteries	ND	ND	ND	ND	[0.33]	478
Sorting batteries	ND	ND	ND	ND	ND	525
Loading dock	ND	ND	[0.15]	[0.079]	[0.33]	523
Demanufacturing	ND	0.11	[0.090]	ND	0.79	448
Demanufacturing	[0.0040]	[0.060]	[0.12]	[0.067]	0.77	512
February 14						
Taping batteries	ND	[0.046]	[0.089]	ND	0.97	513
Taping batteries	ND	[0.049]	ND	ND	3.3	467
Sorting batteries	ND	ND	ND	ND	1.2	510
Shredder/loading dock	ND	[0.065]	[0.22]	0.21	2.5	506
Sorting batteries	ND	ND	ND	ND	1.1	447
Shredder/loading dock	ND	ND	[0.17]	[0.086]	1.7	506
Taping batteries	ND	ND	ND	ND	[0.67]	435
Shredder/loading dock	ND	[0.079]	[0.11]	[0.11]	1.9	488
OSHA PEL	2	5	1000	100	50	—
NIOSH REL	0.5	Ca	500	50	50	—
ACGIH TLV	0.05	10	500	20	50	—
MDC	0.004	0.030	0.080	0.040	0.20	—
MQC	0.012	0.083	0.27	0.13	0.77	—

[ ] = Values in brackets are between the MDC and MQC; more uncertainty is associated with these concentrations. The MDC and MQC were calculated using an average sample volume of 1008 liters.

Table A5. Metals detected in surface wipe samples, September 2013*†‡

Location	Cd	Cr	Co	Cu	In	Pb
Production areas						
Conveyor cover, near first tower	Yes	Yes	Yes	Yes	Yes	Yes
First shredder, on hopper	Yes	Yes	Yes	Yes	No	Yes
Demanufacturing work table	Yes	Yes	Yes	Yes	Yes	Yes
Work gloves by battery	Yes	Yes	Yes	Yes	No	Yes
Work gloves by battery taper	Yes	Yes	Yes	Yes	No	Yes
Ventilation unit near shredder	Yes	Yes	Yes	Yes	Yes	Yes
Non-production areas						
Outdoor break area, on bench	No	No	Yes	No	No	No
Outdoor break area, on chair	Yes	Yes	Yes	Yes	Yes	Yes
Door handle to break area	Yes	Yes	Yes	Yes	No	Yes
Refrigerator handle break area	Yes	Yes	Yes	Yes	Yes	Yes
Chair in entrance/break area	Yes	Yes	Yes	No	No	No
Air supply diffuser in break area	Yes	Yes	Yes	Yes	No	Yes
Door to conference room	Yes	Yes	Yes	Yes	No	Yes
Production supervisor desk	Yes	Yes	Yes	Yes	No	Yes
Conference room table	No	Yes	Yes	No	Yes	No
Limit of detection (micrograms per sample)	0.01	0.05	0.02	0.3	0.4	0.4

*No samples had detectable amounts of beryllium, thallium, or selenium.

†We detected arsenic, tellurium, zirconium, antimony, lanthanum, lithium, molybdenum, silver, titanium, and vanadium in at least one sample.

‡We detected zinc in all samples.

Table A6. Metals detected in surface and hand wipe samples, February 2014*

Location	Beryllium	Cadmium	Chromium	Cobalt	Lead
Demanufacturing					
End sorting conveyor	No	Yes	Yes	Yes	Yes
1st load on station	No	Yes	Yes	Yes	Yes
1st load on station (left)	No	Yes	Yes	Yes	Yes
2nd load on station (left)	No	Yes	Yes	Yes	Yes
Break area					
Employee table	No	No	Yes	No	Yes
Manager desk	No	Yes	Yes	Yes	Yes
Other					
Conference room table	No	Yes	Yes	No	No
Demanufacturing employees					
Employee right hand	No	Yes	Yes	Yes	Yes
Employee right hand	No	Yes	Yes	Yes	Yes
Employee right hand	No	Yes	Yes	Yes	Yes
Shredding employees					
Employee right hand	No	Yes	Yes	Yes	Yes
Employee right hand	No	Yes	Yes	Yes	Yes
Employee right hand	No	Yes	Yes	Yes	Yes
Limit of detection (micrograms per sample)	0.008	0.02	0.03	0.04	0.4

*We collected employee hand wipe samples just before the employee left work.

Table A7. Personal exposures to noise, February 2014*

Location	OSHA action level (dBA)	OSHA permissible exposure limit (dBA)	NIOSH recommended exposure limit (dBA)	Sample duration hours (hr) and minutes (min)
Shredder off (February 4)				
Demanufacturing	91.8	91.0	116.7	8 hr 55 min
Demanufacturing	78.6	73.1	86.5	8 hr 47 min
Demanufacturing	71.9	59.3	77.8	8 hr 52 min
Loading dock	79.8	76.7	87.0	8 hr 46 min
Loading dock	71.5	63.4	78.6	8 hr 43 min
Loading dock	75.8	70.1	81.9	6 hr 50 min
Shredder on (February 14)				
Taping batteries	77.1	71.0	82.2	8 hr 39 min
Taping batteries	58.1	48.1	70.3	8 hr 25 min
Shredding/taping	83.5	80.8	87.4	8 hr 26 min
Shredding/taping	80.2	76.2	86.5	8 hr 26 min
Shredding/taping	83.6	80.0	88.0	8 hr 8 min
Limit: adjusted for 9-hour shift	84.1	90.0	84.5	—

*Shading indicates that a noise exposure limit was exceeded.

Appendix B: Figures

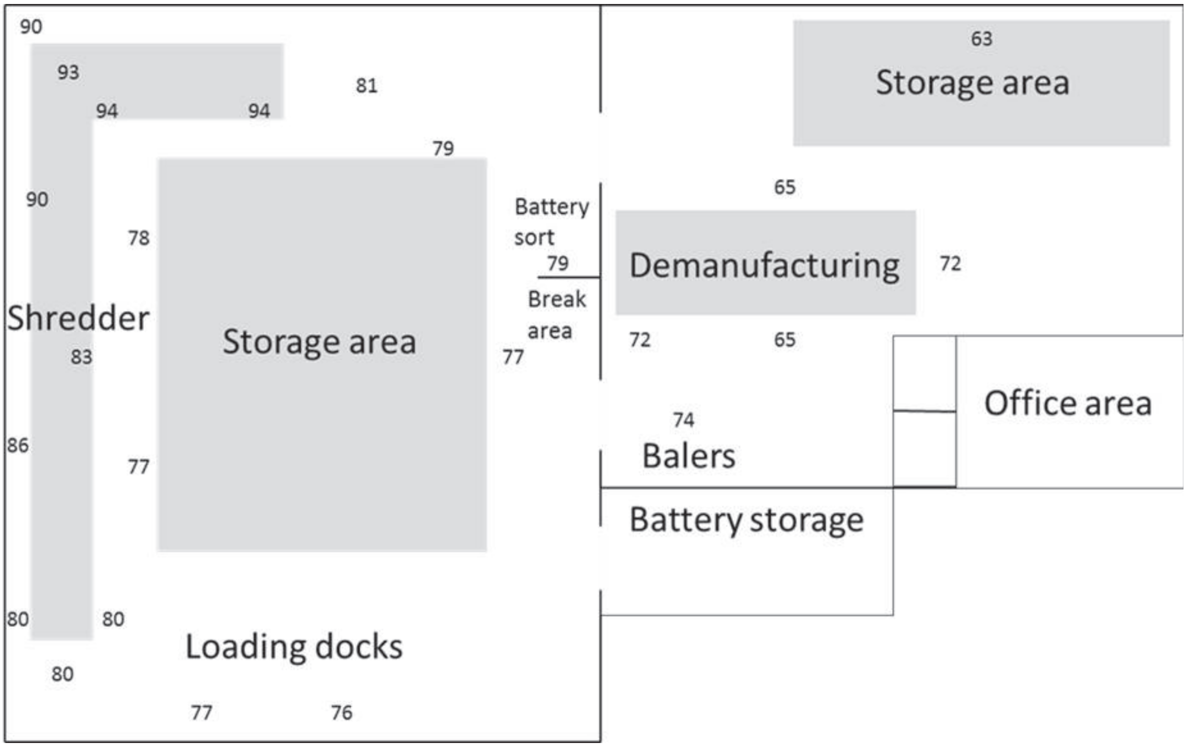

Figure B1. Noise map in decibels of the facility with shredder on, radios off.

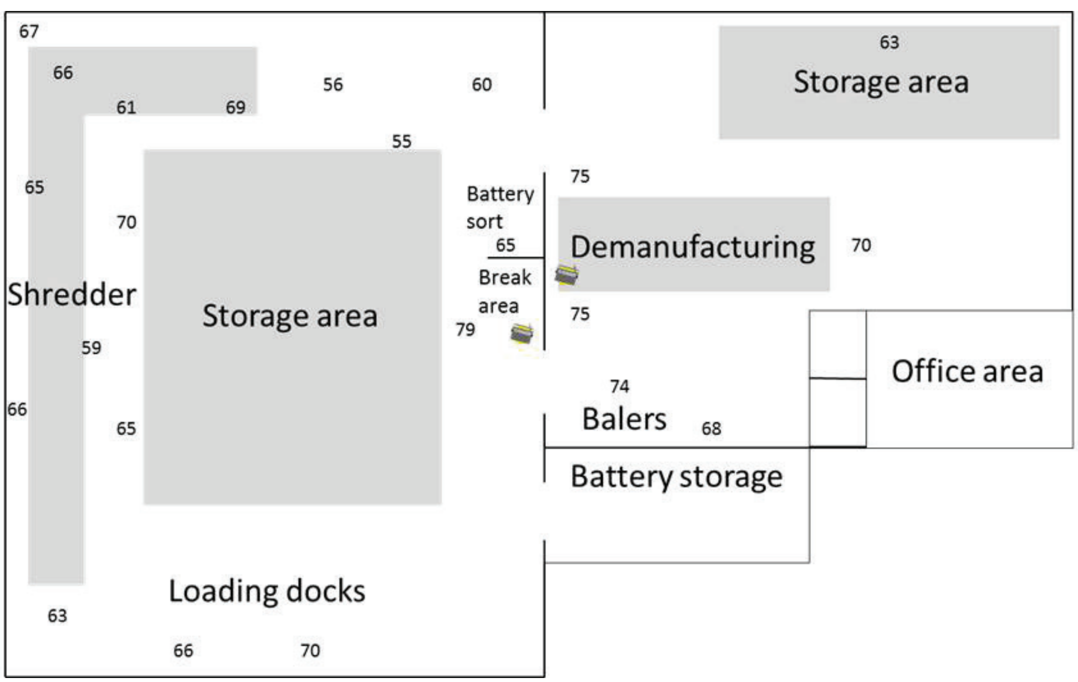

Figure B2. Noise map in decibels of the facility with shredder off, radios on.

Appendix C: Occupational Exposure Limits and Health Effects

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

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL 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 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the threshold limit values (TLVs), which are recommended by ACGIH, a professional organization, and the workplace environmental exposure limits (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH

2014]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2014].

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

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

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

Noise

Noise-induced hearing loss is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis), noise exposure produces more hearing loss than that resulting from aging alone. This noise-induced hearing loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically [Berger et al. 2003]. In most cases, noise-induced hearing happens slowly and occurs before it is noticed. Hearing loss is often severe enough to permanently affect a person's ability to hear and understand speech.

Occupational ototoxins (like lead) are chemicals that can cause hearing damage alone or in combination with noise when absorbed into the body [Hwang et al. 2009]. Low-level chronic lead exposure may be an important risk factor for age-related hearing loss, and reduction of lead exposure can help prevent or delay development of age-related hearing loss [Park et al. 2010].

Occupational Exposure Limits

The dBA is a unit for measuring sound levels to assess employee noise exposures. The dBA noise scale is similar to how human ears hear sound frequencies. Because the dBA scale is logarithmic, small increases can represent a large increase in sound energy.

The OSHA noise standard [29 CFR 1910.95] specifies a PEL of 90 dBA as an 8-hour TWA. The OSHA PEL is calculated using a 5 dB exchange rate. This means that for every 5 dB increase in noise levels, the permitted exposure time is reduced by half. You can also express an employee's daily noise dose as a percentage, and a dose over 100% exceeds the OSHA PEL. When noise exposures exceed the PEL of 90 dBA, OSHA requires that employees wear hearing protection and that an employer implement feasible engineering or administrative controls to reduce noise exposures. The OSHA noise standard also requires an employer to implement a hearing conservation program when 8-hour TWA noise exposures exceed the action level of 85 dBA. The program must include noise monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. More details on the OSHA noise standard are available at https://www.osha.gov/dts/osta/otm/noise/standards_more.html.

Lead

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].

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 1978 standard 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/m³ 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/m³ (8-hour TWA), medical removal of employees whose average blood lead level (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/m³ averaged over an 8-hour work shift [NIOSH 2010]. ACGIH has a TLV for lead of

50 µg/m³ (8-hour TWA), with worker BLLs to be controlled to, or below, 30 µg/dL. The ACGIH designates lead as an animal carcinogen [ACGIH 2014]. In 2013, the California Department of Public Health recommended that 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 Environmental Protection Agency and Housing and Urban Development limit lead on surfaces in public buildings and child-occupied housing to less than 40 micrograms of lead per square foot [EPA 1998; HUD 2012]. OSHA requires in its substance-specific standard for lead that all surfaces be maintained as free as practicable of accumulations of lead [29 CFR 1910.1025(h)(1)]. An employer with workplace exposures to lead must implement regular and effective cleaning of surfaces in areas such as change areas, storage facilities, and lunchroom or eating areas to ensure they are as free as practicable from lead contamination.

Health Effects

The National Toxicology Program recently released a monograph on the health effects of low-level lead exposure [NTP 2012]. For adults, the National Toxicology Program concluded the following about the evidence regarding health effects of lead (Appendix C, Table C1).

Table C1. 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 National Toxicology Program [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 [IARC 2006a]. According to the American Cancer Society [ACS 2014], some studies show a relationship between lead exposure and lung cancer, but these results might be affected by exposure to cigarette smoking and arsenic. Some studies show a relationship between lead and stomach cancer, and these findings are less likely to be affected by the other exposures. The results of studies looking at other cancers, including brain, kidney, bladder, colon, and rectum, are mixed.

Medical Management

To prevent acute and chronic health effects, a panel of experts published guidelines for the management of adult lead exposure [Kosnett et al. 2007]. The complete guidelines are available at http://www.cdph.ca.gov/programs/olppp/Documents/medmanagement.pdf. The panel recommended BLL testing for all lead-exposed employees, regardless of the airborne lead concentration. The panel's recommendations are outlined in Appendix C, Table C2. 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 2009] 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 C2. Health-based medical surveillance recommendations for lead-exposed employees

Exposure category	Recommendations
All lead exposed workers	• Baseline or preplacement medical history and physical examination, baseline BLL, and serum creatinine.
BLL < 10 µg/dL	• Monitor BLL monthly for first 3 months after placement, or upon change in task to higher exposure, then monitor 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: monitor 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

Beryllium, Cadmium, Chromium, and Cobalt

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

Table C3. Chemical health effects

Chemicals	Health effects	IARC	OEL (µg/m³)
Beryllium	• Beryllium exposure may cause dermatitis, lung inflammation, and chronic beryllium disease in humans [Proctor et al. 1991]. • Exposure to beryllium can lead to sensitization. • Exposure also slightly increases the risk for lung cancer [Schubauer-Berigan 2010].	Group 1: carcinogenic to humans [IARC 2012].	OSHA PEL: 2.0 NIOSH REL: 0.5 ACGIH TLV: 0.05
Cadmium	• Long-term occupational exposure to cadmium is associated with increased occurrence of lung cancer, kidney damage, and chronic obstructive lung disease [WHO 1992].	Group 1: carcinogenic to humans [IARC 2012].	OSHA PEL: 5.0 NIOSH REL: Cancer ACGIH TLV: 10 (2 respirable fraction)
Chromium	• The toxic effects of chromium exposure, including lung and nasal cancer, are primarily related to hexavalent chromium. • Skin exposure to chromium dust can cause skin irritation and skin ulceration, and allergic contact dermatitis.	Group 1: carcinogenic to humans [IARC 2012].	OSHA PEL: 1000 NIOSH REL: 500 ACGIH TLV: 500
Cobalt	• Exposure to elevated levels of cobalt can cause gastrointestinal irritation, nausea, and vomiting • Inhaled cobalt can lead to lung damage. • Skin exposure can cause irritant and allergic contact dermatitis [Vincoli 1997].	Group 2B: possibly carcinogenic to humans [IARC 2006b]	OSHA PEL: 100 NIOSH REL: 50 ACGIH TLV: 20

IARC = International Agency for Research on Cancer

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