

METAL RECYCLING INDUSTRY PROJECT

New York State Department of Health
Center for Environmental Health
Bureau of Occupational Health

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PREVENTING LEAD EXPOSURE DURING METAL RECYCLING

New York State Department of Health
Bureau of Occupational Health

The New York State Department of Health (NYSDOH), Bureau of Occupational Health (BOH) completed a Metal Recycling Industry Project (MRIP) in June 2006. During this project, information was collected on metal recycling operations and processes from 101 metal recyclers throughout New York State. This project included measuring worker lead exposures during routine tasks, such as sorting, shearing, and torch cutting a variety of materials. Findings from this project include:

- Significant lead exposure occurred when torch cutting not only painted metals, but also unpainted metals and new steel;
- Lead contamination was found in bathrooms and lunchrooms, and on workers' hands prior to eating;
- Metal recycling companies did not recognize potential sources of lead exposure (such as new steel) and underestimated the degree of exposure; and
- Metal recycling companies that we visited made substantial improvements to their lead protection programs after receiving information and technical guidance.

Recommendations

- Institute a blood-lead monitoring program for all employees potentially exposed to lead;
- Implement engineering controls, such as replacing torch cutting with shearing, to reduce workers' lead exposures;
- Implement employee lead training programs;
- Conduct personal air monitoring to assess airborne lead exposures and the adequacy of respiratory protection;
- Provide respiratory protection to all workers who perform torch cutting, radiator disassembly or other tasks associated with high airborne lead exposures;
- Require employees to clean the interior and exterior surfaces of their respirators daily;
- Provide hygiene facilities, such as a clean lunch room, a locker room with separate "clean" and "dirty" lockers, and a shower facility;
- Prohibit eating, drinking, and smoking in any area where lead contamination may occur; and
- Perform routine housekeeping to reduce surface lead dust accumulation throughout the facility.

If you would like more information about these recommendations, contact the NYSDOH, Bureau of Occupational Health at 1-866-807-2130.

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547 River Street, Room 230
Troy, NY 12180

June 2007

EXECUTIVE SUMMARY

Significant Findings

- Significant lead exposure occurred when torch cutting not only painted metals, but also unpainted metals and new steel;
- Lead contamination was found in bathrooms and lunchrooms, and on workers' hands prior to eating;
- Metal recycling companies did not recognize potential sources of lead exposure (such as new steel) and underestimated the degree of exposure; and
- Metal recycling companies that we visited made substantial improvements to their lead protection programs after receiving information and technical guidance.

Background and Methods

Metal recycling workers can be exposed to lead, a known industrial hazard, while performing typical metal recycling tasks. The New York State Department of Health's (NYSDOH) Bureau of Occupational Health (BOH) launched a Metal Recycling Industry Project (MRIP) in June 2000. The goals of the project were to 1) collect information on metal recycling operations and processes from a representative survey population, 2) identify and evaluate metal recycling workers' exposures to lead and other hazardous metals and 3) propose feasible and effective measures to reduce the exposures if needed. The information collected and the preventive measures formulated during the survey are currently being used to develop worker educational and training materials that will be disseminated to the industry and to other stakeholders.

The project had two components: a mail survey and on-site industrial hygiene (IH) evaluations. The mail survey portion was completed at the end of September 2000 and the on-site evaluations completed in February 2001. We additionally conducted a telephone survey in 2005 to collect updated information from the companies that received our on-site evaluations. The follow-up telephone survey was completed in June 2005.

During the mail survey, questionnaires were sent to 224 metal recycling facilities in New York State and 101 (45%) completed responses were received. BOH industrial hygienists conducted on-site industrial hygiene (IH) evaluations at eight facilities that responded to the mail survey and indicated an interest in the evaluation. Each on-site evaluation included a walk-through survey, safety and health program review, personal air monitoring and collection of surface dust samples. A written evaluation report was provided to each facility. Seven of the eight facilities that received the IH evaluations completed the telephone follow-up survey in 2005 (one company was no longer in business).

Results and Discussion

At the time of our survey, companies reported recycling assorted metals such as aluminum, iron, copper, brass, steel, stainless steel, and tin. Workers reportedly performed tasks included sorting, shearing, baling, saw cutting and torch cutting of metal. Among the surveyed companies, 60 (59%) reported performing torch cutting, an operation expected to generate excessive quantities of airborne lead particulates that pose a high health risk to the workers. Despite this, when the companies were asked to assess the likelihood of employee lead exposures at their facilities, 72 (71%) stated that their employees were unlikely or definitely not exposed to lead at work.

Two of the eight companies that received an on-site evaluation required workers to use respiratory protection only when cutting galvanized or painted metals. The companies' decisions were based on the assumption that lead only existed in painted or galvanized steels. However, our personal air monitoring results demonstrated otherwise: workers may be exposed to sufficiently high concentrations of lead when cutting unpainted metal, steel without galvanized coating and even new steel. Three of the six personal air samples that were collected from the workers who performed torch cutting had average lead concentrations over sample time exceeding the Occupational Safety and Health Administration (OSHA)'s Permissible Exposure Limit (PEL) for lead. Two samples were obtained when the workers were torch cutting unpainted steel. In fact, one of the workers was cutting new steel from a local fabrication shop.

Lead is one of the elemental metals that are commonly used as an additive in the steel making process to improve the machinability of the steel. Although the quantity of lead contained in these steels is small - typically ranging from 0.15 to 0.35%, torch cutting can release substantial amount of lead fume as demonstrated by our air monitoring results.

We also found personal air lead levels during sample time in excess of the OSHA PEL during auto radiator disassembly at one facility.

Only 10% of the 101 companies that responded to the survey reported performing personal air monitoring to assess employee lead exposures. Of the 101 companies, forty-five (45%) companies did not provide their workers with any respiratory protection; twenty-eight (28%) provided only disposable dust masks. Of the 60 companies that performed torch cutting, twenty-four (40%) companies provided their workers with half-face or full-face air purifying respirators (APR). Sixty percent (60%) of the companies that had torch cutting operations did not provide workers with any respiratory protection or provided only disposable dust masks.

Fifteen (15%) companies reported that they provided blood lead testing for their employees at least once. This was slightly higher (18%) among the companies that reported torch cutting.

With regard to frequency of biological monitoring, four (4%) of the companies reported that they offered blood lead testing annually, six (6%) semiannually, and two (2%) quarterly.

More than 70% of the wipe samples collected in lunchrooms and bathrooms at the eight metal recycling sites had lead dust concentrations exceeding the Environmental Protection Agency (EPA) clearance threshold for homes following lead remediation projects. Lead was also found in wipe samples collected from the hands of workers who held different job titles, including a yard supervisor, a torch cutter, a driver, a sorter, and a laborer in a facility's new steel shop. These samples were collected after the workers washed their hands to eat lunch.

The telephone follow up survey found that the facilities have made improvements in providing workers with personal protective equipment (PPE) and hygiene facilities. The survey also found that owners of metal recycling companies did not understand the prevalence of occupational lead exposures associated with metal recycling activities.

Recommendations

We recommend that the governmental agencies, metal recycling trade organizations, safety and health professionals, workers' compensation carriers and other stakeholders work together to educate employers of the metal recycling industry and raise their awareness of occupational lead exposure in the trade.

We also encourage employers within the metal recycling industry to adopt the following to reduce workers' lead exposures:

- Institute a biological monitoring program for all employees potentially exposed to lead;
- Implement engineering controls such as replacing torch cutting with shearing to reduce workers' lead exposures;
- Implement employee lead training programs;
- Conduct personal air monitoring to assess workers' airborne lead exposures and the adequacy of respiratory protection;
- Provide appropriate respiratory protection to all workers who perform torch cutting, radiator disassembly or other tasks associated with high airborne lead exposures;
- Require employees to thoroughly clean their respirators daily;
- Provide hygiene facilities, such as a clean lunch room, a locker room with separate "clean" and "dirty" lockers and a shower facility;
- Prohibit eating, drinking, and smoking in work areas where lead contamination may occur; and
- Perform routine housekeeping to reduce surface lead dust accumulation throughout the facility.

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INTRODUCTION

A typical metal recycling facility recycles a variety of materials, including ferrous and nonferrous scrap metals, vehicles and parts, communication cables, radiators, and batteries. The recycling process includes receiving, sorting, processing, packaging, storing and shipping the materials or metals to other facilities where they can be reused or reprocessed. Sorting is either done manually or by machines such as shaker beds, cranes, or magnets. Large scrap metal parts are cut with shears or torches into smaller pieces. The scrap metal is then compressed and packaged, commonly by balers for storage and transportation.

Lead is a ubiquitous metal, and a known environmental and industrial hazard *(1)*. Many of the materials being recycled, such as batteries, radiators, and metals contain lead. It may be in the coatings on the scrap metal (lead-based paint or galvanized coatings) *(2)*. It may also be present in the metal as an additive, alloy element or contaminant *(3, 4, 5, 6)*. When metal recycling workers cut, shear, bale or sort scrap metals, they can be exposed to lead dust and fume.

Lead can be absorbed into the body by inhalation (breathing) and ingestion (eating) *(7)*. Once lead gets into the body, it travels in the blood to the "soft tissues" such as the liver, kidneys, lungs, brain, spleen, muscles, and heart before it moves to the bones and teeth where it may stay for decades *(8)*. Elevated blood lead levels in adults can damage the cardiovascular, central nervous, reproductive, hematologic, and renal systems *(7)*. The mean blood lead level (BLL) of adults in the United States is less than three micrograms of lead per deciliter of whole blood (µg/dL) *(9)*. The U.S. Department of Health and Human Services recommends that BLLs among all adults be less than 25 µg/dL *(9)*. According to the U.S. Occupational Safety and Health Administration's (OSHA) lead standard for general industry, a worker must be removed from further lead exposure when the worker's BLL is at or above 60 µg/dL[1] or the average of the worker's last three BLLs is at or above 50 µg/dL[1] *(7)*. The worker cannot return to work unless his or her BLL is reduced to below 40 µg/dL[1].

[1] OSHA used the unit of micrograms of lead per 100 grams of blood (µg/ 100 g) for blood lead level in its lead standard for general industry (29CFR1910.1025). According to OSHA, the units of µg/dL and µg/ 100 g are essentially the same (see 29CFR1910.1025: Appendix A, II, B, (3)).

The Bureau of Occupational Health (BOH) of the New York State Department of Health (NYSDOH) maintains a Heavy Metals Registry (HMR) to identify adults who have elevated biological indicators (blood or urine) of lead and other heavy metals. BOH staff work with the individuals reported to the HMR to determine the source of exposure and to prevent or reduce further intake of the metals. If the source of exposure is work related or in a work environment, the BOH industrial hygienists may work with the employers to develop and implement controls to reduce the workers' occupational exposures.

According to Census data, there were approximately 6,300 workers in the metal recycling industry in New York State in 2000. From 1990 to 2000, the HMR received reports of elevated BLLs for 65 individuals working in metal recycling companies. Of those reported, 25 had blood lead levels above 40 μg/dL, and three had blood lead levels above 100 μg/dL. Given the reports of elevated BLLs in metal recycling workers and these reports likely underrepresented the extent of the problem (since many scrap metal workers may not be tested), a Metal Recycling Industry Project (MRIP) was initiated in June 2000.

The goals of the project were to collect information on metal recycling operations and processes from a representative survey population, to identify and evaluate workers' exposures to lead and selected other hazardous metals during metal recycling processes and to propose feasible and effective measures to reduce the exposures. BOH staff worked with the Institute of Scrap Recycling Industries, Inc. (ISRI), a metal recycling industry trade association in Washington DC, in developing the project. The project had two components: a mail survey and on-site industrial hygiene (IH) evaluations. The mail survey portion was completed at the end of September 2000 and the on-site evaluations were completed in February 2001. Additionally, we conducted a telephone survey in June 2005 to collect updated information on the companies that received our IH on-site evaluations.

METHODS

Mail Survey

A survey questionnaire was designed to gather information on company operations, potential employee lead exposures, biological monitoring programs, control measures e.g. engineering controls, personal protective equipment (PPE), employee training, and housekeeping. ISRI provided valuable input in formulating the questionnaire. In an effort to maximize the response rate, we kept the survey brief, limiting it to 19 multiple choice or short answer questions.

The yellow pages provided by several internet websites were used to compile a list of potential survey participants, including all listings from the following categories: "Scrap Metals", "Process & Recycle", "Scrap Metals & Iron (wholesale)", and "Steel-used". A total of 355 companies were identified. A cover letter explaining the nature and objectives of the survey was sent with the questionnaire to each of the 355 companies in June 2000. Companies that did not respond within three weeks after the initial mailing were contacted via telephone to attempt to complete the survey. Of the 355 companies, 131 were removed from the survey for one or more of the following reasons: (1) not having a valid mailing address or phone number; (2) not in business; or (3) not in the metal recycling business. The final survey population was thus reduced to 224 companies that were active and in the metal recycling business. A total of 101 companies completed the survey either by mail or by phone, resulting in a response rate of 45%. The remaining (123) declined to participate.

On-site Industrial Hygiene Evaluations

Ten (10%) of the facilities that answered the mail survey also requested on-site evaluations from the BOH industrial hygiene group. One of these companies only agreed to a preliminary walk-through; another was in the electronics recycling business (not a typical metal recycling operation). The results of the on-site IH evaluations of the eight remaining facilities are presented in this report.

During each on-site evaluation, BOH industrial hygienists conducted a walk-through survey to observe recycling processes and employees' work activities, reviewed company lead safety programs, performed personal air monitoring, and collected surface dust samples. We also performed a thorough review of the eight companies' biological monitoring activities and their blood lead monitoring data that had been reported to the HMR. The focus of these site visits was to identify and evaluate occupational exposure to lead and other metals. Other safety and health hazards were not within the scope of the site visits. Therefore, the on-site assessments should not be viewed as a complete hazard evaluation for a specific facility or for the industry.

Personal breathing zone (PBZ) air samples were collected to measure employees' exposures to lead and other selected metals, such as cadmium, cobalt and nickel. These samples were collected during the performance of the various job tasks, such as sorting metal, driving forklifts, operating shears and balers, torch-cutting metal, and crushing cars. Sampling was task-specific (collected only during the performance of a single task) and generally lasted the duration of the task. For tasks performed all day, sample duration was limited to half of the shift.

The sampling train consisted of a personal sampling pump (Ametek Model 2500 Constant Flow Sampler), Tygon tubing and a close-faced 37 millimeter (mm) filter cassette containing a 0.8 micron (m) mixed cellulose ester filter (MCEF) with a backup pad. The cassette was clipped onto a worker's lapel. If a worker wore a face shield, the MCEF cassette was placed outside the face shield. The pump was calibrated before and after sampling with a primary flow meter (Gilibrator) at a flow rate of two liters per minute (LPM). Pump start and stop times were recorded to the nearest minute. One to two field blanks were submitted for each batch of PBZ air samples.

Surface dust samples were also collected to assess the extent of surface contamination by lead dust in non-production areas throughout each facility. Areas sampled included surfaces in lunchrooms, bathrooms, and locker rooms. The samples were collected by wiping an area of 100 square centimeters (cm^2) with an individual "baby wipe". At one facility, we collected wipes from workers' hands. This was done by thoroughly wiping the palm and fingers of one hand with an individual "baby wipe".

All of the personal air samples and wipe samples were analyzed by the Wadsworth Laboratory of the NYSDOH. National Institute for Occupational Safety and Health (NIOSH) Method 7082, flame atomic absorption spectrophotometry (FAAS) *(10)*, was used for analyzing all lead samples. NIOSH Method 7300, Inductively Coupled Argon Plasma-Atomic Emission Spectroscopy (ICP-AES) *(10)*, was used to analyze samples for other metals.

An individualized report including a survey summary and recommendations on reducing and controlling workers' lead exposures was sent to each of the eight facilities that received site visits.

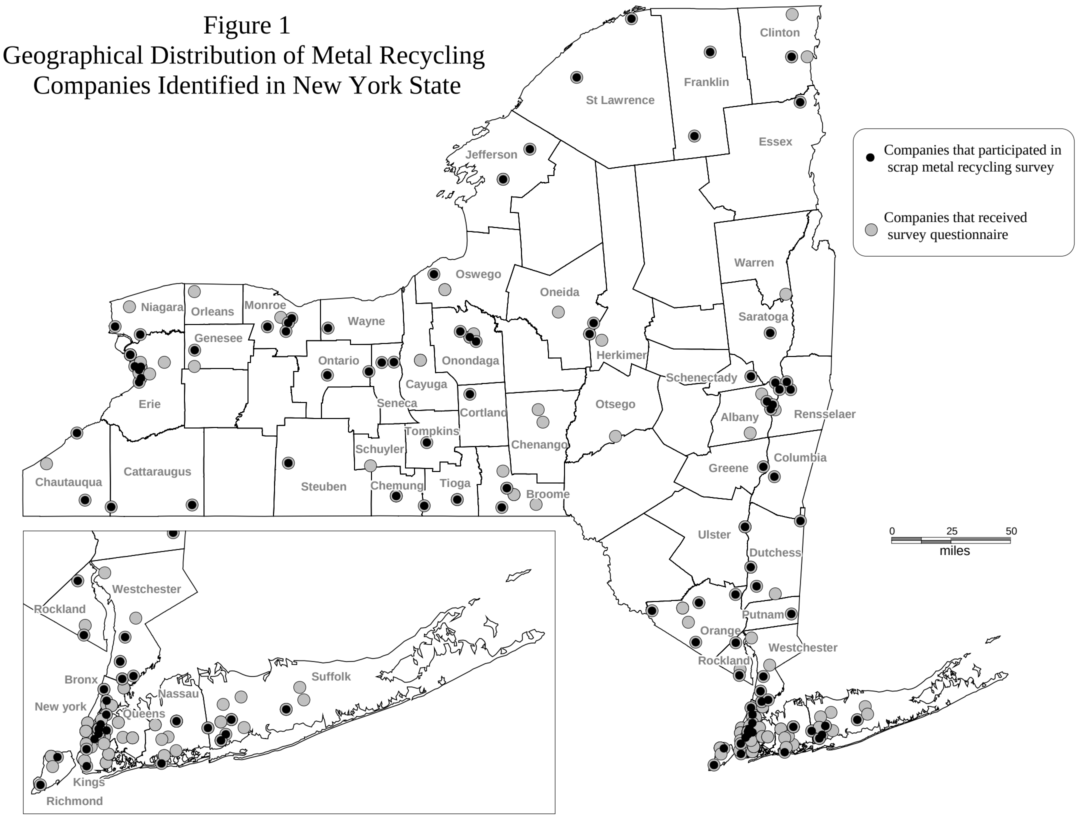
In May 2005, five years after completion of the IH on-site evaluations, BOH conducted a follow-up telephone survey to collect updated information from the eight facilities. The questionnaire was designed to collect information on current company production status and preventive measures adopted by the companies to control and reduce workers lead exposures. One company was no longer in business; the remaining seven facilities completed the telephone survey.

RESULTS

Mail Survey

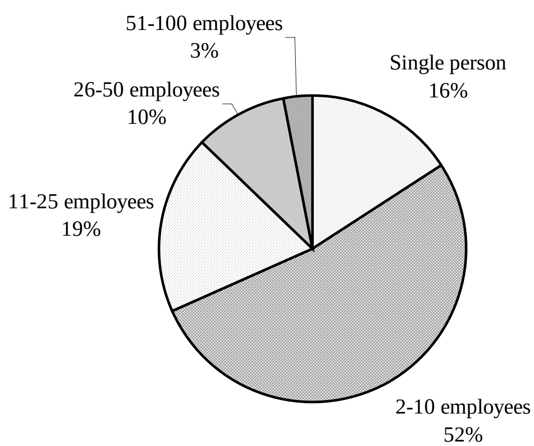
The geographical distribution of the metal recycling companies identified in New York State by the survey is illustrated in Figure 1. The companies that received survey questionnaires and those that participated in the survey are indicated with different symbols in the figure. The participation rate was not consistent throughout the state. While the overall participation rate was 45%, the rate downstate (New York City plus Long Island) was only 26%, and the rate for the rest of state was 57%.

Figure 1
Geographical Distribution of Metal Recycling Companies Identified in New York State



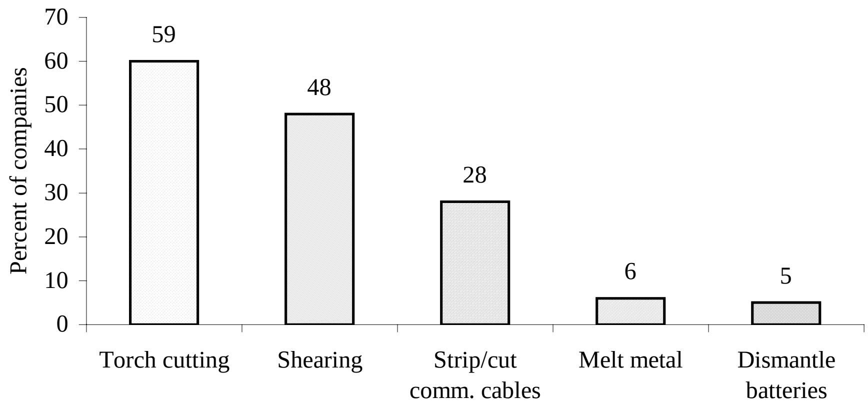
Among the 101 companies that responded to the survey, most were small facilities; 16 (16%) reported that they were a single person operation and 53 (52%) reported that they had 2-10 employees (see Figure 2). Only 3 (3%) had more than 50 employees. The surveyed companies reported that they recycled aluminum, iron, copper, brass, steel, stainless steel, and tin.

Figure 2. Number of employees in participating companies



Forty-eight (48%) companies belonged to one or more statewide or national trade associations, such as ISRI, New York Recyclers, Empire Metal Merchants or Auto Recyclers' Association of New York.

Figure 3. Metal recycling operations performed by the participating companies



Sixty (59%) survey respondents reported performing torch cutting, a task that has the potential for significant lead dust or fume exposure (Figure 3) *(11)*. The companies also reported shearing metal, stripping or cutting communication cables, melting metal and dismantling batteries. These tasks are also likely to carry a potential for lead exposure. When asked to assess the likelihood of employee lead exposures at their facility, however, 72 (71%) of the companies responded that their employees were unlikely or definitely not exposed to lead at work (Figure 4).

Figure 4. Employers' self-reported likelihood of employee lead exposure at their facilities

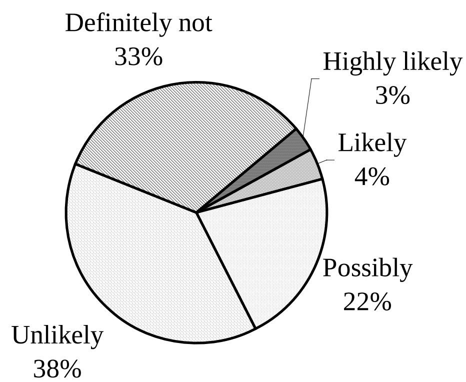


Table 1 presents the lead hazard awareness level (likelihood of employee lead exposures as reported by the company owner) in relation to the percentage of these companies that reportedly conducted personal air monitoring. Only 10% of the surveyed companies reported performing personal air monitoring to assess employee lead exposures. Of the 60 companies that performed torch cutting, only eight (13%) reported conducting personal air monitoring. Of the 72 companies that considered the likelihood of their employee lead exposure as “unlikely” or “definitely not”, only one company reported performing personal air monitoring.

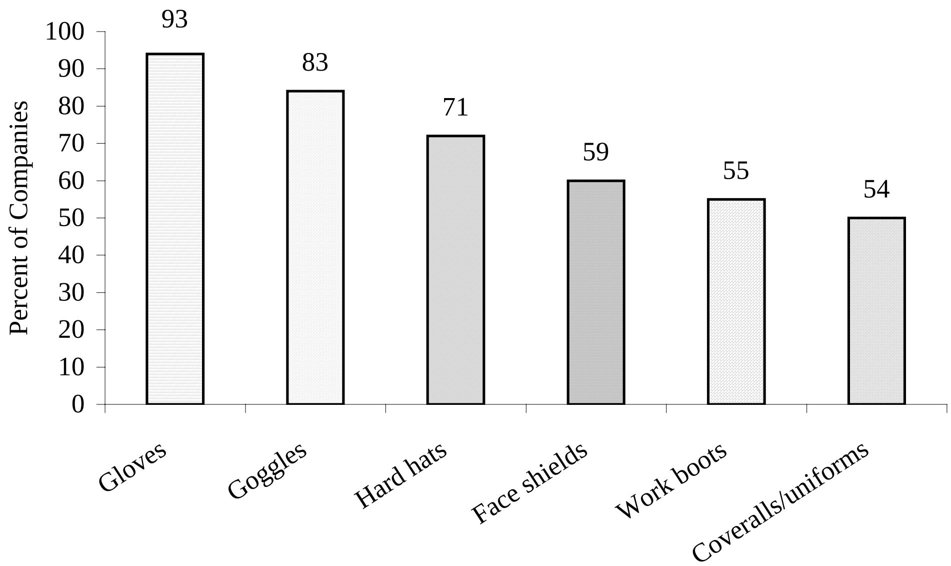
Table 1. Number of companies that reported conducting personal air monitoring in relation to their lead hazard awareness levels

Reported likelihood of employee lead exposure	Number of companies	Number of companies reporting conducting personal air monitoring	Percentage (%)
Highly likely	3	3	100
Likely	4	2	50
Possible	22	4	18
Unlikely	39	0	0
Definitely not	33	1	3

Of the 101 companies that responded to the survey, forty-five (45%) companies did not provide their workers with any respiratory protection and twenty-eight (28%) provided only disposable dust masks. Of the 60 companies that performed torch cutting, twenty-four (40%) companies provided their workers with half-face or full-face air purifying respirators (APR). Sixty percent (60%) of the companies that had torch cutting operations did not provide workers with any respiratory protection or provided only disposable dust masks.

With regard to other personal protective equipment, 94 (93%) of the 101 survey respondents provided their employees with gloves, 84 (83%) provided goggles, 72 (71%) hard hats, 60 (59%) face shields, 55 (54%) work shoes/boots, and 50 (50%) uniforms (Figure 5).

Figure 5. Personal protective equipment provided by the surveyed companies



With regard to hygiene facilities, 68 (67%) of the 101 survey respondents reported that they had lunchrooms, 81 (80%) had wash stations, 21 (21%) had showers, and 49 (49%) had lockers available.

We inquired about whether the companies had a biomonitoring program for lead. Of the 101 respondents, 15 (15%) reported that they provided blood lead testing for their employees at least once (Table 2). Eleven (18%) of the sixty companies that performed torch cutting reported having provided workers with blood lead monitoring at least once. With regard to frequency of biomonitoring, four (4%) of the companies reported that they offered blood lead testing annually, six (6%) semiannually, and 2 (2%) quarterly. The likelihood of having a biological monitoring program in place increased with the self-reported likelihood of employee lead exposure (Table 3).

Table 2. Biological monitoring reported by participating companies

	Total Number	Companies Offered Biomonitoring	Percentage (%)
Total survey population	101	15	15
Companies that torch cut	60	11	18

Table 3. Number of companies that reported providing biological monitoring in relation to their self-reported likelihood of lead exposure

Reported Likelihood of Lead Exposure	Number of companies	Reported providing biomonitoring
Highly likely	3	3 (100%)
Likely	4	2 (50%)
Possibly	22	5 (23%)
Unlikely	39	4 (10%)
Definitely not	33	1 (3%)

On-Site Industrial Hygiene Evaluations

Of the eight facilities that received IH on-site evaluations, employment ranged from four to sixty workers. Seven facilities belonged to trade associations. Six were ISRI members and one was a member of the Automotive Recyclers' Association of New York.

Two facilities recycled automobiles in addition to other scrap metals. Seven sites had torch cutting operations, seven sheared metal, four stripped communication cables, and one disassembled radiators. Overall, the eight facilities appeared representative of the mail surveyed population in terms of the types of metal recycling tasks performed by the workers.

Table 4 summarizes the employers' assessment of the likelihood of lead exposure in the workplace, whether torch cutting was conducted, and the availability of the key elements of a lead safety program at each facility. All but two companies reported that occupational lead exposures were at least possible while recycling scrap metals. Seven facilities reported performing torch cutting either weekly or monthly. One of the seven companies did not provide any respiratory protection to the torch cutters, three provided only disposable dust masks, and the remaining three provided half-face or full-face air purifying respirators (APR) with P100 (high efficiency particulate air-HEPA) filters to the workers. Two of the three companies that provided APR also provided qualitative respirator fit testing for the employees.

Table 4. Summary of employers' assessment of the likelihood of occupational lead exposures, torch cutting activity and the availability of key elements of a lead safety program

Facility	Reported Likelihood of Lead Exposure	Perform Torch Cutting	Respirator Protection	Respirator fit testing	Bio-monitoring	Showers	Require Change Clothing
G	Highly likely	No	No[1]		Yes	Yes	Yes
C	Likely	Yes	Dust mask	No	No	No	No
D	Likely	Yes	½ APR + P100, dust mask	Yes	Yes	Yes	No
A	Possibly	Yes	No		No	No	No
B	Possibly	Yes	Full APR + P100	Yes	Yes	No	Yes
E	Possibly	Yes	½ APR + P100, sup. air	No	Yes	No	No
F	Unlikely	Yes	Dust mask	No	No	No	No
H	Unlikely	Yes	Dust mask	No	No	No	Yes

[1] *Respiratory protection was not needed at site G based on the personal air monitoring results.*

Of the eight facilities visited, two (D and G) had showers available. Three (B, G and H) required their employees to change into their work clothes before the beginning of the work shift and to change back to their street clothes after work.

Air Sampling Results

A total of 27 personal air samples were collected during the eight industrial hygiene site visits. Eighteen samples were analyzed for lead only, eight were analyzed for cadmium and lead and one sample was analyzed for cadmium, cobalt, lead and nickel. The monitoring was done to evaluate workers' exposures as they performed typical metal recycling tasks. Neither cadmium nor cobalt was detected in the samples. Nickel was detected in Sample No. 5 when the worker was cutting new plate steel and the concentration during sample time was 8.1 micrograms of nickel per cubic meter of air (µg/m^3). This level is well below the OSHA's Permissible Exposure Limit (PEL) of 1000 µg/m^3, that is based on an 8-hour time weighted average (TWA) exposure *(12)*. NIOSH recommends that workers' 8-hour TWA exposure to nickel should not exceed 15 µg/m^3 *(13)*. The American Conference of Governmental Industrial Hygienists (ACGIH) has established a TWA threshold limit value (TLV) for nickel as 1500 µg/m^3 *(14)*.

The results of the personal air monitoring for lead are presented in Table 5. OSHA requires an employer to comply with the General Industry Lead Standard (29CFR1910.1025). The OSHA action level (AL) is defined as an airborne concentration of lead of 30 µg/m^3 averaged over an 8-hour period. If the OSHA AL is exceeded, employee personal air monitoring, medical surveillance and employee training are mandated. OSHA also established a PEL of 50 µg/m^3 based on an 8-hour TWA exposure. Employers are required by OSHA to keep workers' airborne lead exposures below the PEL through implementing engineering controls and providing personal protective equipment. Both NIOSH and ACGIH have recommended 50 $\mu g/m^3$ as a TWA lead exposure limit *(13, 14)*.

Personal air samples were collected on six torch cutters (Samples 1-6) at five facilities. Five of the six torch cutters used oxy-propane torches and one used an oxy-acetylene torch. The materials that were cut during the monitoring included painted machine parts, unpainted highway guard rails, unpainted new plate steel, aluminum and copper. Sample times ranged from 89 to 172 minutes. The time-weighted average of lead concentrations during the sample time (Sample Time TWA) ranged from below the laboratory's limit of detection (LOD) to 320 $\mu g/m^3$. If these workers performed essentially the same tasks as being monitored during their entire eight-hour work shift, the Sample Time TWA would be equivalent to the workers' 8-hour TWA exposures and would be compared with the OSHA PEL.

The lead concentrations for the torch cutters (Samples 4 and 5) at facility B and H were the highest: 250 $\mu g/m^3$ and 320 $\mu g/m^3$ respectively. Both workers' exposures during their sample time (166 minutes and 124 minutes respectively) exceeded the OSHA PEL. If these workers had no additional lead exposure during the duration of their 8-hour shift, the 8-hour TWAs for the torch cutters at facility B and facility H would be 86 $\mu g/m^3$ and 83 $\mu g/m^3$, respectively. At facility H, the workers were reported to perform torch cutting usually up to six hours a day; the 8-hour TWA for such a worker with the sampled concentration would be 240 $\mu g/m^3$ or 4.8 times the OSHA PEL.

Table 5. Personal air sampling results

Sample ID Number	Site ID	Job Description	Materials being Cut	Sample Time (min.)	Lead [1] Concentration ($\mu g/m^3$)	Respiratory Protection	Compare TWA exposure in sample time with PEL
1	F	Torch cutting	Unpainted new plate metal	133	2	No	<PEL
2	D	Torch cutting	Assorted scrap metal	145	29	No	<PEL
3	**A**	**Torch cutting**	**Scrap metal**	**89**	**110**	**No**	**Exceeds PEL**
4	**B**	**Torch cutting**	**Unpainted highway guard rails**	**166**	**250**	**Yes**	**Exceeds PEL**
5	**H**	**Torch cutting**	**Unpainted new plate steel**	**124**	**320**	**No**	**Exceeds PEL**
6	D	Torch cutting	Nonferrous metal	172	<11[2]	No	<PEL
7	C	Operating a baler		192	16	No	<PEL
8	D	Operating a baler		191	<11[2]	No	<PEL
9	B	Operating a crane		169	<1[2]	No	<PEL
10	F	Operating a crane		135	<1[2]	No	<PEL
11	D	Operating a forklift		167	<11[2]	No	<PEL
12	**H**	**Disassembling radiators**		**119**	**67**	**No**	**Exceeds PEL**
13	**H**	**Disassembling radiators**		**32**	**210**	**No**	**Exceeds PEL**
14	H	Sorting copper		164	13	No	<PEL
15	H	Sorting brass		146	<1[2]	No	<PEL
16	C	Operating a shear		203	13	No	<PEL
17	C	Operating a shear		202	18	No	<PEL
18	E	Manual sorting scrap		150	3	No	<PEL
19	F	Sorting in warehouse		141	3	No	<PEL
20	G	Sorting in yard		121	5	No	<PEL
21	G	Sorting in yard		121	6	No	<PEL
22	A	Sorting nonferrous		136	7	No	<PEL
23	D	Sorting scrap		192	<11[2]	No	<PEL
24	E	Welding		250	4.9	No	<PEL
25	**E**	**Abrasive blasting**		**41**	**578**	**Yes**	**Exceeds PEL**
26	C	Dumping wheel weights		22	<20[2]	No	<PEL
27	C	Repairing a saw		56	<9[2]	No	<PEL

[1] For each set of personal air samples, a minimum of one blank field blank samples was collected and all lead concentrations reported were blank corrected.
[2] The concentration of lead in this sample was below the laboratory's limit of detection (LOD).

Although six facilities indicated that the workers were provided with some kind of respiratory device (see Table 4), only one (Facility B) provided its torch cutter with respiratory protection (a full-face APR with dual P100 HEPA cartridges) at the time of the monitoring. The other torch cutters, including the one at Facility H whose exposure exceeded the OSHA PEL, were not wearing any respiratory protection during sample time.

Table 5 also presents the personal air sample results collected from 21 workers who performed metal recycling tasks other than torch cutting. While the lead concentrations measured during most of the tasks were low or even below the LOD, two samples taken during radiator disassembly and the one obtained during sandblasting exceeded the OSHA PEL during the sample time.

At facility H, two workers (Samples 12 and 13) were monitored while they disassembled auto radiators. Their tasks involved separating steel support pieces from the radiators using a hatchet and a pneumatic chisel. The air lead concentrations for the two workers were 67 $\mu g/m^3$ (worker 012) and 210 $\mu g/m^3$ (worker 013) during the sampling periods of 119 minutes and 32 minutes respectively. Neither of the workers wore respiratory protection.

Facility E had a maintenance/welding shop where workers repaired and refinished vehicles and equipment. The abrasive blaster was reported sandblasting an average of four to six hours a day. Based on the air monitoring results, the blaster's 8-hour TWA would be 289 $\mu g/m^3$ if he blasted four hours a day, assuming that he had no additional lead exposure during the other four hours of his shift. The blaster wore a supplied air blasting hood with continuous flow while he was being monitored.

Wipe Sampling Results

A total of 40 wipe samples were collected to evaluate surface contamination in non-production areas at the eight facilities. The sample results for lunchrooms, bathrooms and miscellaneous surfaces are reported in Tables 6, 7 and 8 respectively.

Sixteen wipe samples taken from lunchrooms in six metal recycling facilities had lead dust concentrations ranging from below the LOD (<45 $\mu g/ft^2$) up to 1,710 micrograms of lead per square foot ($\mu g/ft^2$) (see Table 6). The mean lead dust concentration on the surfaces in lunchrooms was 221 $\mu g/ft^2$ and the median was 89.1 $\mu g/ft^2$.

Table 6. Lunchroom surface sample results for lead

Sample ID	Site ID	Surfaces	Concentration[1] ($\mu g/ft^2$)
1	D	Coffee counter	88.2
2	F	Coffee pot	108
3	H	Locker	<45[2]
4	B	Lunch table	<45[2]
5	D	Lunch table	162
6	E	Lunch table	810
7	F	Lunch table	1710
8	G	Lunch table	<45[2]
9	F	Microwave oven	135
10	G	Microwave oven	<45[2]
11	D	Microwave oven dial	189
12	B	Microwave oven front panel	<45[2]
13	H	Microwave oven top	189
14	D	Refrigerator handle	56.7
15	B	Table	90
16	G	Window ledge	<45[2]

[1] *For each set of wipe samples collected at a facility, a minimum of one blank field blank samples was collected and all lead concentrations reported were blank corrected.*
[2] *The concentration of lead in this sample was below the laboratory's limit of detection (LOD).*

The lead dust concentrations of the fourteen wipe samples from bathrooms in six facilities ranged from below LOD to 2070 $\mu g/ft^2$ on a paper towel dispenser (Table 7). The mean concentration was 465 $\mu g/ft^2$ and median 189 $\mu g/ft^2$.

Table 7. Bathroom surfaces' sample results for lead

Sample ID	Site ID	Surfaces	Concentration ($\mu g/ft^2$)[1]
17	F	First aid kit box	162
18	E	Paper towel dispenser front	<45[2]
19	B	Paper towel dispenser, handle	71
20	F	Shelf	324
21	A	Sink	216
22	E	Sink	351
23	A	Storage shelf	162
24	C	Toilet tank	1260
25	F	Toilet tank	<45[2]
26	H	Toilet top	45.9
27	H	Towel dispenser (in non ferrous area)	153
28	H	Towel dispenser (in ferrous area)	2070
29	E	Urinal top	990
30	E	Washing machine	702

[1] *For each set of wipe samples collected at a facility, a minimum of one blank field blank samples was collected and all lead concentrations reported were blank corrected.*
[2] *The concentration of lead in this sample was below the laboratory's limit of detection (LOD).*

Table 8 presents the results of the ten wipe samples collected from surfaces in a variety of locations other than bathrooms and lunchrooms. The highest level found was 23,400 µg/ft^2 on a microwave oven in an aluminum room where workers processed scrap aluminum and stored and ate their lunches.

Table 8. Miscellaneous surface sample results for lead

Sample ID	Site ID	Surfaces	Location	Concentration[1] (µg/ft^2)
31	H	Microwave oven	Aluminum room	23400
32	D	Locker door	Clean locker room	126
33	D	Locker top	Clean locker room	4500
34	D	Cubby	Locker room	135
35	H	Microwave oven	Locker room	<45[2]
36	G	Refrigerator top	Locker room	144
37	C	Desk	Office	1080
38	C	Locker	Office	<45[2]
39	A	Vending machine	Outdoor	243
40	G	Shelf	Shower room	216

[1] *For each set of wipe samples collected at a facility, a minimum of one blank field blank samples was collected and all lead concentrations reported were blank corrected.*
[2] *The concentration of lead in this sample was below the laboratory's limit of detection (LOD).*

During one of the site visits (Site B), we also collected wipe samples from workers' hands. Five wipe samples were collected after the workers washed their hands just before their lunch break. These workers performed different job duties with varied airborne lead exposures. The results are reported as micrograms of lead per hand (µg/hand) in Table 9. Lead was positively identified from all five workers' hands. The hand wipe samples were to demonstrate that workers may be exposed to lead through hand to mouth contamination regardless of their assigned jobs and the extent of airborne lead exposures, and they could ingest lead if they did not wash their hands well.

Table 9. Hand wipe results collected at site B for lead

Sample ID	Job title	Lead Concentration[1] (µg/ hand)
W1	Yard supervisor	12
W2	Crane operator	15
W3	Torch cutter	140
W4	Sorting, non-ferrous metal shop	34
W5	Worker, new steel shop	19

[1] *For each set of wipe samples collected at a facility, a minimum of one blank field blank samples was collected and all lead concentrations reported were blank corrected.*

Workers' Blood Lead Monitoring Data

At the time of our site visits, there were approximately 100 workers at the eight sites sorting, shearing, baling and cutting scrap metals. HMR data indicated that 20 (20%) of these workers received a total of 55 blood lead tests in 2000. Some of the tests were administered by workers' private physicians rather than through company biological monitoring programs. Table 10 summarizes the eight facilities' biological monitoring status at the time of our site visits. Four sites A, C, F and H did not provide workers with blood lead tests. According to our personal air monitoring results, the torch cutters of companies A and H were exposed to airborne lead fume and dust exceeding the OSHA PEL during sample time.

Table 10. Summary of blood lead monitoring status in 2000 of the eight companies for the metal recycling yard workers

Site ID	Number of yard workers	Number of workers tested	Job titles of workers tested	Number of tests	BLL range (µg/dL)	BLL Mean (µg/dL)	BLL Median (µg/dL)	Frequency of testing
A	7	0	NA[1]	0	NA	NA	NA	NA
B	15	2	Torch cutter	12	27-161	64	49	Followed doctor's recommendations
C	7	0	NA	0	NA	NA	NA	NA
D	23	13	Torch cutter, ferrous and nonferrous yard labor	29	10-41	16	14	Baseline and semi-annual testing
E	12	1	Maintenance mechanic	1	17	17	17	No company set frequency
F	5	0	NA	0	NA	NA	NA	NA
G	4	4	Metal recycling labor	13	18-40	29	28	Semi-annual testing
H	27	0	NA	0	NA	NA		NA

[1] *Not applicable.*

Four facilities (B, D, E and G) provided blood lead monitoring for some of their yard workers during the year of 2000. Company B had two torch cutters and one of them became ill after cutting bridge steel for a few months. The worker went to see his personal physician who tested the worker's blood lead level. His initial BLL was 121 µg/dL, which is severely elevated. The company had neither performed personal air monitoring to assess the worker's airborne lead exposure, nor provided any lead awareness training to the torch cutters prior to assigning them the torch cutting job. The worker had been provided with a full-face air-purifying respirator with P100 cartridges, although he was not fit tested and the respirator did not fit well. After consulting with the BOH industrial hygiene staff, Company B began providing blood lead testing for its two torch cutters in 2000. A total of 12 tests were provided that year; the torch cutters' BLL ranged from 27 to 161 µg/dL and the mean BLL was 64 µg/dL.

In responding to a torch cutter's elevated blood lead level of 41 µg/dL, Site D offered its thirteen yard workers with baseline and semiannual blood lead tests in 2000. A total of 29 blood lead tests were administered and the mean BLL was 16 µg/dL.

Facility G did not have a torch cutting operation; four workers sorted, sheared, and baled scrap metals. The facility did not have a biological monitoring program until 1996 when two workers found out that their children had elevated blood lead levels. Of the workers' children, a 23 month-old had a BLL of 25 µg/dL and a 13 month-old had a BLL of 27 µg/dL. The Centers for Disease Control and Prevention (CDC) defines an elevated BLL as 10 µg/dL for children younger than six years-old *(15)*. The two workers subsequently requested blood lead tests through their personal physicians; their initial blood lead levels were 26 µg/dL and 53 µg/dL, respectively. Based on the information gathered through the employee interviews and from the company, the BOH determined that the likely cause of the children's elevated blood lead was take-home lead from the fathers' metal recycling work. Following BOH's recommendations, Facility G started providing routine blood lead monitoring for all four employees in 1997.

At Facility G, the workers' main routes of lead intake was ingestion according to the results of the personal air monitoring. To reduce workers' exposures to lead dust through hand to mouth contamination, the BOH industrial hygiene staff recommended that the facility provide workers with a locker room with separate "dirty" and "clean" lockers, a lunchroom that was separated from the work area, and a shower room. Facility G completed the construction and the workers started using the hygiene facilities in April 2000. The workers changed into work clothes at the beginning of their work shift, showered at the end of a workday and changed into their street clothes before leaving for home. During their lunch break, the workers removed the outer layer of their work uniforms and boots, put on clean slippers, washed their hands and then entered the lunchroom for lunch in their under shirts and pants. These measures effectively reduced the employees' lead exposures as reflected in the reduction of the workers' blood lead levels. One worker whose blood lead level had been above 40 µg/dL since 1997 had a BLL below 30 µg/dL for the first time in 2000. The workers' mean BLL in 1997 was 42 µg/dL; it declined to 29 µg/dL in 2000. The workers' mean BLL was 25 µg/dL in 2005.

During the five years (from 2001 to 2005) after our site visits, facilities B, D and G continued monitoring their yard workers blood lead levels. The number of workers being monitored, and the number of tests administered at each facility varied every year, and the testing frequencies at each facility were not consistent over the time. Among the three facilities, the number of people being tested every year ranged from one to six and the number of annual tests administered ranged from two to sixteen. There were no clear statistical trends demonstrated by the BLL data among the three facilities.

Although both Sites E and F had on-going torch cutting operations, neither provided regular blood lead testing to the workers who had lead exposures. Site E had one worker tested twice while Site F provided three workers with a total of five blood lead tests during the five years following our site visits.

Follow-up Telephone Survey

The follow-up survey found that the seven facilities still recycled the same types of materials and metals as reported during the initial survey. However, three of the seven companies reported that they increased shearing operations as a substitute for torch cutting to reduce workers' lead exposures.

Two facility representatives stated that they provided torch cutters with better respiratory protection. One of the two companies upgraded the torch cutters' respirators from half-face APR to full-face APR with P100 filters. The other facility replaced the torch cutter's disposable dust mask with a half-face APR with P100 filters and provided respirator fit testing.

According to the follow-up telephone survey, the surveyed facilities reported across the board improvements in providing employees with personal protective equipment and hygiene facilities such as lunchrooms, lockers and showers. The number of facilities that provided employee lunchrooms increased from two to four. Two more companies provided workers with lockers and showers. The reported improvement could not be verified since no on-site evaluations were conducted.

When asked whether workers would be exposed to lead while cutting new steel, six facility representatives answered no. When asked whether workers would be exposed to lead while cutting unpainted scrap, four company representatives answered no.

DISCUSSION

Employee Airborne Lead Exposures

It is important to recognize when reviewing the personal air sample results that monitoring occurred on only one day at each facility. The work conditions and contaminant concentrations could vary significantly from day-to-day or even during a work shift. Some factors that can influence workers' airborne lead exposures in the various scrap yard operations include: the types of metal (composition and coating) being processed, the amounts of those metals, the condition of the equipment and the machinery involved, the skills and techniques of the persons who conducted the tasks, and the weather. The air sampling results are representative only to the extent that the conditions on the day of monitoring were "typical" of that job.

For workers who do more than one job during a typical 8-hour shift, one needs to monitor the exposure they receive while performing each task to determine their total exposure for the work shift. The formula for calculating an 8-hour TWA that involves different tasks with varied exposures is "$C_1T_1+C_2T_2+C_3T_3+\ldots)/480$" *(12)*. "$C_1$" represents the lead concentration for the first task performed, "C_2" the concentration for the second task, etc. "T_1" represents the time (in minutes) that the first task is performed, "T_2" is the time for the second task, etc.

Among all the typical metal recycling tasks, torch cutting showed the greatest potential for serious lead exposure (see Table 5). When asked to assess lead hazards associated with torch cutting different scrap metals during the survey, the majority of the companies considered that unpainted metal presented less lead hazards and new steel presented none. The survey found that some companies only require workers to use respirators when cutting galvanized steel (lead is a common impurity in zinc that is used for galvanizing steel) or painted metals (lead-based paint). The companies' decision was based on the assumption that lead only existed in painted or galvanized coatings.

However, lead is one of the elemental metals that are commonly used as an additive by steelmakers to enhance the steel's machinability *(16)*. For example, Grade 12L14, a free-machining steel widely used throughout the world, contains up to 0.35 percent (%) lead by weight *(4,5,16)*. Lead is used in the manufacturing of other ferrous and non-ferrous metals or alloys for its unique characteristics *(5)*. Torch cutting these metals can release substantial amounts of lead fume and dust as demonstrated by our air monitoring results. Two of the samples (ID #004 and #005) had sufficiently high lead concentrations that, even if the workers were exposed to no lead for the remainder of their work shift, their 8-hour TWA would still exceed the OSHA PEL. Both workers were cutting unpainted steel; the worker (#005) at facility H was cutting new steel from a local fabrication shop.

Scrap comes to recycling facilities from a variety of sources and the exact content or composition of the materials being processed by metal recycling workers are usually unknown. Given the difficulty in predicting the specific and precise lead and other toxic metal contents in any metal, a good industrial hygiene practice is for workers to wear respiratory protection during torch cutting of any scrap metal.

Besides torch cutting, radiator disassembly is also a relatively high-risk operation and workers can be potentially exposed to lead levels exceeding the OSHA PEL.

The workers who performed sorting, shearing, baling and moving metal with vehicles were exposed to relatively low airborne concentrations (from below LOD up to 18 $\mu g/m^3$). Although the air lead concentrations during these operations may be influenced by the factors that were discussed in the first paragraph of the Discussion section, the monitoring results in this study did not exceed the OSHA action level (AL) of 30 $\mu g/m^3$ for general industry *(7)*. For the workers who performed these operations, the employers should focus on minimizing ingestion of lead through hand to mouth contamination.

Surface Lead Contamination and Workers Exposures Through Ingestion

During metal recycling processes, lead dust can be generated and dispersed through the air, eventually settling on surfaces both inside and outside the work area, and on workers' exposed hair, skin, clothes and shoes. Lead can accumulate on surfaces over time if the facility is not kept clean of lead dust. When surfaces have lead dust on them, a worker may touch those surfaces, and then may pick up food, a cigarette, or touch his mouth with his hand. This can result in the accidental ingestion (eating) of lead, which is then absorbed into the body.

The OSHA General Industry Lead Standard *(7)* contains housekeeping provisions that address the issue of surface contamination, but there are currently no threshold levels of surface contamination included in the OSHA standards. The United States Environmental Protection Agency (EPA) has defined dangerous levels of lead dust in deteriorated paint, settled dust on floors and window sills, and soil *(17)*. Although the EPA standard is often used as a reference when evaluating surface dust accumulation and the effectiveness of housekeeping, it should be noted that the EPA levels are principally intended to protect young children in the home, and may not be directly applicable to an industrial setting. Under the EPA's recent (2000) standard, the threshold concentration for floors is 40 $\mu g/ft^2$, for interior window sills is 250 $\mu g/ft^2$ and for window troughs is 400 $\mu g/ft^2$.

Many of the wipe samples that were collected on lunchroom surfaces during the site visits had measurable levels of lead dust. Given that food and beverages are consumed in those areas, this represents a risk of lead ingestion. Some of the samples obtained in the restrooms indicate similar concern. For example, finding a concentration of 2070 $\mu g/ft^2$ on a towel dispenser is problematic, given that a worker may touch his mouth or face after obtaining a towel.

In one of the facilities, some workers took their lunch break in the "aluminum room", where aluminum was sorted, sheared and baled. A microwave oven placed in the aluminum room was used by the workers to heat their lunches. The lead dust concentration on top of the microwave was very elevated at 23,400 $\mu g/ft^2$. It was recommended to the company that eating, drinking, and smoking in that area (and other lead work areas) be prohibited.

It is critical that workers wash their hands thoroughly before eating, drinking or smoking in order to minimize their risk of ingesting lead. Practicing good personal hygiene requires involvement of both management and workers. At the facility where the hand wipes were collected, certain work areas were considered by both management and employees as "clean" and "lead free", such as the "new steel" shop where only new steel was processed and handled. Hand washing was not required by management for the workers who worked in those areas or who did not perform torch cutting. All the hand wipe samples were collected after workers washed their hands and were ready to eat their lunches. The highest lead dust accumulation (140 µg) was found on a torch cutter's hand. The worker in the "new steel" shop had 19 µg of lead dust on his hand. The supervisor who did not do yard work had 12 µg of lead dust on his hand. The hand wipe sample results demonstrated that there was no such area as "clean" and "lead free" in a metal recycling facility, and that all metal recycling tasks present a potential hazard for lead ingestion. Practicing correct hand washing technique is one way to reduce ingestion of lead.

The lead dust that settled on workers' clothes and shoes can also pose a hazard. Even if a lunchroom is completely separate from all production areas, workers can track lead into the room if they don't clean the lead dust off their work clothes before entering the lunchroom. The dust should be removed with a high efficiency particulate air (HEPA) vacuum (not with compressed air) to avoid dispersing lead dust into the air.

In addition to regular cleaning, one facility (Site G) required all of its employees to remove the outer layer of their work uniforms and boots, put on clean slippers, wash their hands and then enter the lunchroom to eat in their under shirts and pants. By doing that, they were able to keep the concentration of lead dust on their lunchroom surfaces below the analytical detection limit (Table 6).

Workers can also inadvertently bring lead dust home on their clothes and in their hair, potentially exposing family members to lead. Most vulnerable are young children less than two years of age. Such take-home exposures can and should be minimized. A shower facility with separate “clean” and “dirty” lockers can help prevent cross contamination between the workplace and workers’ homes. With this system, a worker leaves the production area, enters the “dirty” locker room, removes his clothes, showers, and goes directly into the “clean” locker room before donning clean clothes, getting into his vehicle and traveling home after work.

Biological Monitoring for Lead

Our mail survey found that 85% of the metal recycling companies did not provide workers with biological monitoring for lead. Since the survey question did not differentiate between routine, on-going biological monitoring for lead that was part of a company lead safety program and sporadic or one-time blood lead testing, the percentage of the companies without regular biological monitoring for lead could be even higher.

Among the companies that provided blood lead testing, few initiated the biological monitoring for lead proactively. Some companies provided minimum testing in responding to OSHA citations, while others only started monitoring their workers’ blood lead levels after a worker or workers’ family members (including children) were diagnosed with lead poisoning by the workers’ private physicians.

Most companies that offered blood lead testing only had their torch cutters tested. Very few companies provided blood lead testing to the workers who performed metal recycling tasks other than torch cutting such as sorting, baling and shearing. The HMR data showed that workers could have lead poisoning through ingestion while handling scrap metals by hand. Workers can also inadvertently bring lead dust home and poison their family members, including children who are more susceptible to lead poisoning (as it happened at Facility G).

The BLL data of Facilities B, D and E that mainly monitored torch cutters’ blood lead levels did not demonstrate clear statistical trends during the five years following the BOH on-site consultations. This may be due to the limited numbers of workers being tested, limited number of tests administered on each worker annually and inconsistent testing frequencies. Overall, the metal recycling industry as a whole has not integrated biological monitoring for lead into its routine safety and health programs.

Air monitoring can only determine workers’ airborne lead exposures. Biological monitoring can assess workers’ exposures to lead through both inhalation and ingestion. Symptoms of lead poisoning may be subtle and non-specific at early stages of lead poisoning; timely blood lead monitoring can offer early detection. Workers elevated blood lead levels may indicate problems in engineering controls, personal protective equipment, personal hygiene or housekeeping. Early detection of workers’ elevated blood lead levels can lead to prompt industrial hygiene intervention that can prevent further exposures and protect workers from suffering irreversible health effects.

Worker Exposures to Other Metals

In addition to lead, metal recycling workers may be exposed to other metals. A NIOSH study found that besides lead, torch cutters were also exposed to elevated levels of arsenic, cadmium, copper, iron and nickel fumes and dusts *(18)*. Our personal air samples did not find significant airborne exposures to cobalt and cadmium. One worker was exposed to nickel at a concentration of 8.1 $\mu g/m^3$ while torch cutting new steel that came from a local fabricating shop. Although this level is well below the OSHA PEL of 1000 $\mu g/m^3$ and ACGIH TWA of 1500 $\mu g/m^3$, it is more than half of the Threshold Limit Value (TLV) of 15 $\mu g/m^3$ recommended by NIOSH. Nickel is often combined with other metals to form alloys. The U.S. Department of Health and Human Services (DHHS) has determined that nickel metal may reasonably be anticipated to be a carcinogen *(19)*. The general control measures for occupational lead exposures discussed above would also be used to control exposures to nickel and other metals during metal recycling processes.

Employer Awareness of Workplace Lead Exposures

Our survey found that the greater the employer's awareness of workplace lead exposures, the greater the likelihood that the employer will conduct personal air monitoring (Table 1) and implement a biological monitoring program (Table 3).

Based on our survey results, metal recycling workers are exposed to lead on a daily bases from both inhalation and ingestion. However, of the 101 companies that completed our survey, 72 (71%) of them considered that occupational lead exposure was unlikely to or definitely did not occur at their facilities. These survey results demonstrate that efforts should be made to increase the awareness on the part of scrap yard owners as to the prevalence, extent and magnitude of occupational lead exposures in the metal recycling trade.

CONCLUSIONS

Metal recycling workers can be exposed to lead through both inhalation and ingestion while performing typical metal recycling tasks. Torch cutting and radiator disassembly may generate lead dust and fume concentrations exceeding the OSHA PEL. New or unpainted steel is not "clean" or "lead free". Torch cutters' airborne lead exposures can exceed the OSHA PEL even while cutting steel that may mistakenly be assumed to be lead-free.

Ingestion is a significant potential route of lead exposure for all workers at a metal recycling facility. It is prudent to assume that all of the scrap metal handling areas and adjacent support areas, such as lunchrooms, bathrooms, and offices have lead surface contamination. Workers' hands can be contaminated with lead dust even when they work in so called "non-lead" areas, such as a new steel shop. Personal air monitoring cannot assess the extent of the workers' lead exposure through ingestion. The only method that can assess exposure in this situation is biological monitoring (conducting regular blood lead testing).

Owners of metal recycling companies did not understand the widespread nature of occupational lead exposures in their facilities and the importance of biological monitoring. The majority of the metal recycling companies in New York State are either single person operations or have less than 10 employees (see Figure 2). Educating this population presents a special challenge, since these small companies may have limited occupational safety and health resources.

RECOMMENDATIONS

1. Occupational health and safety professionals and other stakeholders should raise employers' awareness of occupational lead exposures in metal recycling operations.

Governmental agencies, metal recycling industry trade organizations, safety and health professionals, workers' compensation carriers and other stakeholders should work together to help educate the employers of the metal recycling industry and raise their awareness of occupational lead exposure in the trade. The effort should be focused on developing effective educational materials and intervention strategies, disseminating the materials to the target population, and evaluating the effectiveness of the education materials through follow up surveys.

2. Employers should implement engineering controls to reduce workers' lead exposures in metal recycling operations.

The first and best strategy is to control the hazard at its source, and engineering controls are generally recommended to achieve that goal *(20)*. Employers should eliminate workplace hazards or reduce exposure to hazards by implementing engineering controls to the extent feasible. The following engineering controls may be adopted to reduce workers' exposures to metals while performing typical metal recycling tasks:

- Replace torch cutting with other cutting methods that generate less lead fume and dust, such as shearing; and
- Provide local exhaust ventilation to the workers who disassemble radiators. Employers may want to refer to the ACGIH Industrial Ventilation manual for examples of local exhaust hood designs *(21)*.

3. Employers should implement employee lead training programs.

Employers should provide employees with lead training on a regular basis, preferably annually. Workers should be informed of the hazards of lead exposure, correct methods for using respiratory protection, good personal hygiene, the benefits of biological monitoring, and the dangers of contaminating their homes with lead from work. The workers should also learn the proper techniques and practices to minimize lead exposure for each job assignment.

4. **Employers should institute a biological monitoring program to assess employee exposures to lead.**

Employers should institute a biological monitoring program for all employees potentially exposed to lead. The metal recycling companies are encouraged to follow the guidelines developed by the New York State Occupational Health Clinic Network (OHCN) *(22)*. These guidelines, originally developed for the construction industry exceed OSHA biological monitoring requirement for the general industry and offer an early detection of blood lead poisoning:

- Initial blood lead test before beginning work involving lead;
- Blood lead test every month in the following circumstances:
  - For the first three months of work; or
  - If the previous blood lead level was greater than 25 µg/dL ; or
  - If the previous blood lead level was at least 50 µg/dL (*a follow-up test within two weeks and medical removal is strongly recommended);* or
  - If an increase of at least 10 µg/dL from the previous test is observed;
- Blood lead test every two months in the following circumstances:
  - When the blood lead level remains below 25 µg/dL for three months; and
  - If an increase less than 10 µg/dL from the previous test is observed;
- Blood lead test every six months in the following circumstances:
  - When the blood lead levels remain below 25 µg/dL for six months; and
  - If an increase less than 10 µg/dL from the previous test is observed.

The employee blood lead test results may be charted and recorded in a graph or a spreadsheet format that is easily understood and can offer a historical perspective to the worker and the company. The companies could utilize the spreadsheet to look for trends and to perform hazard evaluation for specific jobs.

5. **Employers should provide respiratory protection to all workers who perform torch cutting, radiator disassembly and other tasks with high airborne lead exposures.**

Engineering controls should be implemented first to reduce workers' airborne lead exposures to the lowest feasible. Torch cutters should be wearing respirators whenever they cut, since their exposures vary significantly.

Each facility should develop and implement a written respiratory protection program. The employees who perform torch cutting, radiator disassembly, and any other tasks that could subject them to significant lead exposures should be placed in the program. The workers should wear at least half-face respirators with dual P100 (HEPA) cartridges whenever they torch cut, or disassemble radiators. An employee who is required to use a respirator should receive a medical evaluation, a respirator fit test, and training on respirator usage and maintenance, as per the OSHA Respirator Standard (29CFR1910.134) and OSHA lead standard (29CFR1910.1025)

6. **Employers should require employees to clean the respirators and other personal protective equipment daily.**

The interior and exterior surfaces of workers' respirators and other personal protective equipment should be cleaned daily to prevent lead dust contamination and subsequent lead ingestion by the workers who use the PPE. A sink with cleaning supplies should be available for this purpose.

7. **Employers should provide hygiene facilities.**

Employers should provide clean lunchrooms separate from the production areas. Workers should store food and drink in the lunchrooms. A locker room with separate "clean" and "dirty" areas should be available to allow workers to store their work and street clothes and shoes separately to avoid cross contamination. Showers should be available for the workers who perform tasks that emit high levels of lead dust and fume. Workers should shower and change to their clean clothing and shoes after their work shift to prevent "take-home" lead.

8. **Employers should prohibit eating, drinking, and smoking in lead contaminated areas and employees should practice good personal hygiene.**

Workers should not eat, drink, or smoke in any work area where there is potential contamination with lead dust. Signs clearly prohibiting such activities should be posted prominently in those areas. Employees should clean the dust off their clothes with a HEPA vacuum (and ideally remove their outer clothing) before taking a lunch break. All the production employees should be instructed to wash their faces and hands before eating, drinking, smoking, or taking breaks.

Employers should provide a brush and hand soap for hand washing. Workers should learn and practice good hand washing techniques, such as rubbing and scrubbing with a brush vigorously, and rinsing with a copious quantity of water.

Employees who perform certain tasks with significant lead exposures, such as torch cutting and radiator disassembling, should shower at the end of their shift. All employees with lead exposures should change into work clothes and shoes at the beginning of their work shift and back into street clothes and shoes afterwards to avoid exposing their family members to "take home" lead. Work clothes should be stored and laundered separately to avoid cross contamination.

9. **Employers should develop an effective housekeeping program to reduce surface lead dust accumulation.**

The lunchrooms and bathrooms should be cleaned daily to reduce lead dust accumulation. A HEPA filter vacuum should be used to clean floors. Wet methods can prevent surface dusts from becoming airborne. Dry sweeping should be prohibited. Cleaning should be done with detergent and water.

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