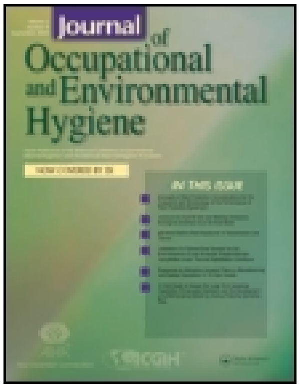


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# Case Study
# An Assessment of Metal Recycling Worker Lead Exposure Associated with Cutting Uncoated New Steel Scrap

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## INTRODUCTION

Scrap metal can generally be categorized as new or old. Junked cars and demolished bridge beams are examples of old scrap; new scrap is generated during product manufacturing processes. For example, when steel mills fabricate stock into bars, rods, plates, or sheets, new steel scrap is generated as cuttings, trimmings, and off-specification materials. Additional new scrap is generated as the material moves through a series of manufacturing and finishing processes to become a final product. New and old steel scrap is usually recycled separately at metal recycling facilities because it is sold at different prices and may go to different smelting facilities.

At a metal recycling facility, large and bulky scrap materials are often cut into smaller pieces for ease of handling or volume reduction. The torch cutting operation is performed by a worker, often referred to as a burner or a cutter, who uses either an oxygen-propane or oxygen-acetylene cutting torch. The metal is generally heated between 1400 to 1600°F (760–870°C) in the presence of oxygen. The intense heat generates large quantities of metal fumes and fine dust particles, including lead oxide.

Lead, a well-known environmental and industrial toxicant, is classified as a confirmed animal carcinogen by the ACGIH®,[1] and the International Agency for Research on Cancer (IARC) categorizes lead as a probable human carcinogen.[2] 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.[3] Elevated blood lead levels in adults can damage the cardiovascular, central nervous, reproductive, hematologic, and renal systems.[4] The Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) of 50 micrograms of lead per cubic meter of air ($\mu g/m^3$) as a time-weighted average (TWA) over an 8-hr workday.[5]

The potential lead hazards associated with cutting old scrap materials have been studied and documented.[6–8] Old scrap materials may contain lead from a number of sources; the metal may be painted with lead-based paint or soldered with lead solder. Some scrap metals may have zinc-galvanized coatings that contain lead as an impurity. A worker performing burning can inhale or ingest lead fumes and dust, potentially resulting in irreversible adverse health effects.

New steel scrap typically does not have painted or galvanized coatings and is free of visible surface contaminants. According to a survey conducted by the New York State Department of Health (http://www.health.state.ny.us/environmental/workplace/metal_recycling/metal_recycling_report.htm), many metal recycling companies assume that uncoated new steel scrap is lead free, and thus, they do not provide respiratory protection for workers who cut uncoated new steel scrap.

This column presents the results of personal breathing zone (PBZ) air samples that were collected to assess workers' lead exposure while cutting uncoated new steel scrap and old steel scrap with coatings. It describes the sources of lead in steel scrap, particularly in uncoated new steel scrap, and identifies factors that influence torch cutters' lead exposures. The intent of this column is to raise awareness in both the metal recycling trade and the environmental health and safety profession of the potential for serious lead poisoning associated with torch cutting uncoated new steel scrap, a routine and commonly performed metal recycling task.

## METHODS

To characterize workers' airborne lead exposures associated with cutting scrap metal, including uncoated new steel scrap, personal air monitoring was conducted at six metal recycling facilities (A, B, C, D, E, and F) between 2000 and 2007. Four of the six facilities recycled uncoated new steel scrap in addition to old scrap metal. The sources of the new steel scrap were steel mills, local machine or fabrication shops, and steel warehouses.

Airborne lead exposures were measured by collecting PBZ samples on eight torch cutters who cut new and old steel scrap with oxygen/propane or oxygen acetylene torches. Sampling was task specific; each sample was collected only during the performance of a single task. Sampling generally lasted for the duration of the task or for at least a quarter of a worker's 8-hr work shift, if the task lasted the duration of the shift. Workers were monitored during the periods between morning break and lunch, and/or between lunch and afternoon break. The periods of monitoring were purposely chosen to isolate the torch cutting task from other activities, such as preparation and setting up in the morning and closing activities at the end of a workday.

The types of metals being cut included uncoated new steel scrap and painted and unpainted old ferrous and nonferrous scrap. Both facility managers and workers indicated that the conditions on the days of monitoring were "typical" of the metal cutting jobs at the companies where the monitoring was conducted.

The sampling train consisted of a personal sampling pump (model 2500 Constant Flow Sampler; Ametek, Inc., Paoli, Pa.), Tygon tubing, and a closed-face, 37-mm filter cassette containing a 0.8 micron mixed cellulose ester filter (MCEF) with a backup pad. The filter 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 calibrator (Gilibrator PN #800268; Sensidyne, Clearwater, Fla.) at a flow rate of 2 L/min. Pump start and stop times were recorded to the nearest minute. One to two field blanks were submitted for the set of PBZ samples collected at each facility for the purpose of identification and assessment of possible contamination during handling, shipping, and analysis of the samples.

The samples were analyzed by a National Environmental Laboratory Accreditation Conference-accredited laboratory. National Institute for Occupational Safety and Health (NIOSH) Method 7082,[9] flame atomic absorption spectroscopy (flame AAS) was used for analyzing 7 of the 10 samples. The remaining 3 samples were analyzed using NIOSH Method 7300, inductively coupled argon plasma atomic emission spectroscopy (ICP-AES).[10]

Strict analytical quality control procedures were implemented. There was minimal bias between the two analytical methods, since both instruments used the National Institute of Standards and Technology (NIST) traceable calibration and quality control standards. Lead concentrations were within appropriate detection ranges, and sample recovery values were within specifications. The exact level of bias, however, could not be quantified. All blank samples showed lead concentrations below the laboratory analytical detection limit (LADL).

## SAMPLING RESULTS

A total of 20 personal air samples were collected on eight torch cutters from six metal recycling companies. The cutters are identified as TCA, TCB, TCC, TCD, $TC_1E$, $TC_2E$, $TC_1F$, and $TC_2F$ (e.g., torch cutter from Company A, torch cutter from Company B . . . , torch cutter 1 from Company E, and torch cutter 2 from Company E, etc.). The results are presented in Table I. Sampling periods ranged from 89 to 244 min. Nine of the 10 samples had measurable concentrations of airborne lead. The eight workers' TWA exposures over the sample times ranged from below the laboratory analytical detection limit (LADL) to 1026 $\mu$g/m$^3$. The highest exposure associated with cutting uncoated new steel scrap was 320 $\mu$g/m$^3$, collected during a period of 124 min.

The 8-hr TWA presented in the last column of the table accounted only for the exposures that the workers had experienced during the sampling periods. The 8-hr TWA exceeded the OSHA PEL for four of the eight workers (TCB, TCD, $TC_1F$, and $TC_2F$).

## DISCUSSION

Lead has long been used by steelmakers to produce steels and alloys with specific characteristics to meet manufacturing specifications. One type of steel, widely used by manufacturers and often recycled as new steel scrap, is *free machining* or *free cutting* steel. Free machining steel is machined or fabricated into industrial machinery parts, automobile parts, screws, nuts, and fittings. The automation of the manufacturing processes and the demand for mass production from consumer markets has made good machinability the most important attribute of free machining steel. Machinability describes the properties of a material that influence the machining process. Lead can enhance machinability by reducing tool wear and achieving high surface quality.[11] For example, grade 12L14, a free machining steel that is widely used throughout the world, is specified to contain 0.35% lead by weight.

**TABLE I. Summary of Personal Breathing Zone Lead Sample Results**

| Company ID | Torch Cutter ID | Sample No. | Sample Description | Sampling Time (min) | Sampling Time Lead Concentration ($\mu$g/m$^3$) | Total Sampling Time (min) | TWA Exposure During Sample Time ($\mu$g/m$^3$) | 8-Hour TWA (assuming zero exposure outside sampling periods) ($\mu$g/m$^3$) |
|---|---|---|---|---|---|---|---|---|
| A | TCA | 1 | Cutting *uncoated new* plate steel | 133 | $2^A$ | 133 | 2 | 0.55 |
| B | TCB | 2 | Cutting *uncoated new* plate steel | 124 | $320^B$ | 124 | $320^C$ | $82.7^D$ |
| C | TCC | 3 | Cutting an *old* air conditioning unit with painted coating | 89 | $110^A$ | 89 | $110^C$ | 20.4 |
| D | TCD | 4 | Cutting old unpainted highway guardrails (Old) | 166 | $250^A$ | 166 | $250^C$ | $86.5^D$ |
| E | $TC_1E$ | 5 | Cutting *old* nonferrous scrap | 172 | $<$ LADL$^B$ | 172 | <LADL | |
| | $TC_2E$ | 6 | Cutting *old* ferrous scrap | 145 | $29^B$ | 145 | 29 | 8.76 |
| F | $TC_1F$ | 7 | Cutting *old* painted machine parts for the first 15 min, then *uncoated new* plate steel for the duration | 164 | $1400^A$ | 244 | $1026^{C,E}$ | $521.6^D$ |
| | | 8 | Cutting *uncoated new* plate steel | 80 | $260^A$ | | | |
| | $TC_2F$ | 9 | Cutting *old* painted machine parts | 161 | $95^A$ | 240 | $159^C$ | $79.5^E$ |
| | | 10 | Cutting *old* painted machine parts | 79 | $290^A$ | | | |

$^A$Sample was analyzed with flame AAS.
$^B$Sample was analyzed with ICP.
$^C$TWA exposure over the sample time exceeded the OSHA PEL.
$^D$8-Hour TWA exposure exceeded OSHA PEL.
$^E$TWA exposure over the sample time exceeded maximum use concentration (MUC) for a half face air-purifying respirator.



However, most metal recyclers know little about the potential lead hazard associated with uncoated new steel scrap coming directly from steel mills, fabrication shops, or steel warehouses. They assume the uncoated new steel scrap to be clean and free of lead. This was the case for all six companies included in this study. Three of the six companies provided neither respiratory protection nor blood lead monitoring for the cutters.

One company generally provided respiratory protection and annual blood lead testing for its cutters, with the exception of newly hired torch cutters. Because of the high job turnover rate, the company did not provide newly hired torch cutters with a fitted respirator and blood lead testing at the time of employment. Rather, the new hire would receive only the respirator and blood lead testing after a trial period that might last for several weeks. During the trial period, new hires were usually assigned to cut only uncoated new steel scrap. The company representative indicated that the decision was based on the assumption that uncoated new steel scrap contained no lead and posed no lead hazard.

Our sampling results demonstrate that torch cutting of uncoated new scrap steel as well as old steel scrap with painted or galvanized coatings can potentially subject workers to high concentrations of airborne lead fume and dust. The PBZ samples of this study were collected during monitoring periods of up to 4 hr. The 8-hr TWA exposure levels were calculated assuming that there was zero exposure outside the sampling period, though in reality these workers typically perform torch cutting for up to 6 hr a day. However, even using this conservative methodology, the 8-hr TWAs for torch cutters TCB, TCD, $TC_1F$, and $TC_2F$ were 83, 86, 521, and 79 $\mu$g/m$^3$, respectively, all exceeding the OSHA PEL of 50 $\mu$g/m$^3$. Two of these workers (TCB and $TC_1F$) cut uncoated new steel scrap.

The 10 task-specific PBZ samples presented a strikingly wide range of airborne lead concentrations: from below the

LADL to 1400 $\mu$g/m$^3$. At Facility F, morning and afternoon samples were collected from each of two workers. Great variations were noted between the morning and afternoon samples collected from the same workers. Cutter $TC_1F$'s morning sample had a lead concentration of 1400 g/m$^3$ when cutting mostly uncoated new steel scrap (with the exception of the first 15 min); his afternoon sample, collected while cutting only uncoated new steel scrap, had a lead concentration of 260 $\mu$g/m$^3$. This wide range of exposure levels is understandable given the many variables associated with torch cutting scrap metals.

Variables associated with torch cutting scrap metals include atmospheric conditions such as wind speed and direction, temperature, and humidity, which can affect airborne lead concentrations. Proximity to a co-worker who is also cutting can impact one's exposure, as can the amount of settled metal dust in the work area. Additionally, the proximity of the source (cutting point) to the worker's breathing zone is a critical factor. This distance may depend on the individual's work style, cutting position (standing vs. sitting), and the length of the torches. Cutting speed and cutting temperature can also affect the worker's exposure.

The amount of lead contained in the scrap material being cut is another variable and is likely to have the greatest influence on a cutter's airborne lead exposure. Because scrap comes to recycling facilities from a variety of sources, the exact content or composition of the scrap material being processed is usually unknown. The amount of lead contained in scrap materials may vary significantly. This contributes to the difficulty in assessing torch cutters' airborne lead exposures.

Another factor that complicates efforts to predict and quantify a cutter's airborne lead exposure is the insoluble nature of lead in steel. This characteristic, in conjunction with its high density, causes lead to settle out during the solidification process and results in segregation or nonuniform distribution of the lead within the steel.[12] The implication of this phenomenon is that the workers' airborne lead exposures may vary when cutting the same batch of scrap steel or even when cutting the same piece of metal.

The OSHA lead standard for general industry requires respiratory protection only when airborne exposures, as determined by personal air monitoring, exceed the OSHA PEL. As documented by this study, airborne lead exposures associated with "typical" metal recycling operations may vary greatly. Thus, personal air monitoring as mandated by OSHA may miss the high exposures that warrant respiratory protection, potentially resulting in worker lead poisoning.

## CONCLUSION

This study demonstrates that metal recycling workers, torch cutters in particular, can be exposed to levels of airborne lead fumes and dust exceeding the OSHA PEL when cutting uncoated new as well as painted or galvanized old scrap metals. Many metal recycling companies are not aware of the lead hazard associated with cutting uncoated new steel scrap and do not provide workers with appropriate respiratory protection. This could result in significant worker lead exposure and subsequent lead poisoning.

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