CDC Workplace Safety and Health

Evaluation of Metal and Carbon Monoxide Exposures During Steel Slab Cutting and Slitting – Indiana

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Health Hazard Evaluation Report
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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
NIOSH *National Institute for Occupational Safety and Health*

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

µg/m^3	Micrograms per cubic meter
ACGIH®	American Conference of Governmental Industrial Hygienists
CO	Carbon monoxide
CFR	Code of Federal Regulations
GA	General area
HHE	Health hazard evaluation
Lpm	Liters per minute
mL	Milliliter
MDC	Minimum detectable concentration
MQC	Minimum quantifiable concentration
NIOSH	National Institute for Occupational Safety and Health
NAICS	North American Industry Classification System
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
PBZ	Personal breathing zone
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
WEEL	Workplace environmental exposure limit

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a request from the United Steelworkers for a health hazard evaluation at a large Indiana steel mill. The union was concerned about metal dust and fume exposure to employees working at the No. 1 caster/slitter. Bloody nose and dirty nasal passages were listed as health concerns.

What NIOSH Did

- We sampled the air for minerals, metals, and carbon monoxide in the caster/slitter and shipping areas from April 3–4, 2008.
- We spoke privately with 22 employees in the No. 1 caster/slitter area and asked them about their health concerns related to their work.
- We checked the ventilation in the shipping shanty, two employee break rooms, and the cut-off and slitter pulpits.

What NIOSH Found

- No. 1 caster/slitter employees were not exposed to minerals, metals, or carbon monoxide in the air above occupational exposure limits.
- Employees reported less dust in the slitter pulpit after ventilation was added.
- Sixteen of 22 employees we spoke with did not report work-related symptoms. Six employees reported work-related cough, sore throat, nosebleeds, anxiety, headaches, and eye irritation.
- Employees with possible work-related symptoms had not reported them to the employer.
- Cough, sore throat, and nosebleeds are consistent with upper respiratory irritation due to dust exposure. These symptoms are also common in the general population and cannot be directly linked to work exposure.
- A voluntary use respirator program was in place for No. 1 caster/slitter employees. Some employees were seen wearing respirators that were visibly dirty.
- The interiors of mill-side and load-side crane cabs were dusty even though recent changes had been made to their ventilation systems.

What Managers Can Do

- Seal gaps in the mill-side and load-side crane cab enclosures. Air intakes and exhausts should also be checked.
- Keep the pipe fitter break room in the caster/slitter area under positive pressure (air should flow from the break room to the surrounding production area).

- Encourage cut-off and slitter operators and shippers to do as much work as possible inside their pulpits or shanty.
- Enforce proper use and change outs of voluntary use respirators.
- Encourage employees to report any health problems that are potentially work related.

What Employees Can Do

- Report any health problems that are work related to the employer.
- Cut-off and slitter operators and shippers should do as much work as possible inside their enclosed pulpits and shanty to reduce dust exposure.
- Crane operators should make sure gaps in the cab enclosure are sealed and that air filters are installed and working properly.
- If you choose to wear an N95 filtering facepiece respirator voluntarily when working outside the pulpits or shanty, wear it properly. Make sure the respirator fits well, which includes your being clean-shaven, and exchange it for a clean one daily or sooner if it becomes difficult to breathe through.

Summary

NIOSH was asked to evaluate metal dust and fume exposure to employees working at the No. 1 caster/slitter and shipping areas at a steel mill. We sampled the air and found that employees were not exposed to minerals, metals, or carbon monoxide. The symptoms reported by some of the employees (cough, sore throat, and nosebleeds) are consistent with upper respiratory irritation due to dust exposure. These symptoms are also common in the general population and cannot be directly linked to work exposure.

In January 2008, NIOSH received an HHE request from the United Steelworkers concerning metal dust and fume exposure from the semiautomated No. 1 caster/slitter operation at an Indiana steel mill. Health concerns listed on the request included bloody nose and dirty nasal passages. We met with employer and employee representatives and observed work processes, practices, and workplace conditions on April 2–4, 2008. We reviewed the results of previous environmental sampling conducted by the steel mill and held confidential interviews with employees to discuss health and workplace concerns. We collected PBZ and GA air samples for minerals, metals, and CO and evaluated the ventilation systems in the cut-off and slitter pulpits, the shipping shanty, and two break rooms.

The PBZ and GA air samples were analyzed for 31 minerals and metals. Airborne particulate in the No. 1 caster/slitter and shipping areas was primarily iron oxide, but other metals such as copper, manganese, molybdenum, and nickel were also present in measurable amounts. Employees' exposures were below applicable OELs, although the iron oxide TWA exposures for the crane operators (range: 1900 to 2800 $\mu g/m^3$) approached or exceeded one half of the OSHA PEL and NIOSH REL of 5000 $\mu g/m^3$. All CO concentrations were below the OSHA PEL and NIOSH REL. The cut-off and slitter pulpits, the shipping shanty, and the iron worker break room were under positive pressure in relation to the surrounding production areas. The pulpits, shanty, and break rooms were provided with air ducted from outside the building.

Twenty-two of 28 employees scheduled to work on the days of our evaluation participated in the confidential medical interviews. All but two were male, and the average age was 45 years. Of 22 employees interviewed, 17 (77%) were either current or former smokers. Of the 22 employees interviewed, 16 reported no work-related symptoms, but many noted having black nasal secretions and phlegm. The remaining six employees reported work-related symptoms including eye irritation (1), cough (1), sore throat (2), nosebleeds (2), anxiety (1), and headache (2). Cough, sore throat, and nosebleeds are consistent with upper respiratory irritation due to dust exposure. These symptoms are also common in the general population and cannot be directly linked to work exposure. These six employees had also reported workplace dustiness to their supervisors but had not reported their health symptoms to either the employer or to the on-site occupational health clinic. However, no interviewed employees reported feeling pressured by the employer not to report symptoms. Interviewed employees reported that there was less dust in the slitter pulpit after the ventilation system was improved and that ventilation changes to the crane cabs and shipping shanty were less effective than the changes to the slitter pulpit in reducing dust. Dust was reported as worse in the winter when the doors were closed.

On the basis of this evaluation we recommended sealing gaps in the crane cab enclosures and evaluating the fit and effectiveness of the air filters installed in the crane cab enclosures. We recommended that the cut-off and slitter operators and shippers perform as much of their work as possible within their ventilated pulpits or shanty. Employees should wear the voluntary use respirators properly and replace them at least daily or more often if the respirator becomes difficult to breathe through. We also recommended that employees report any work-related health problems to the on-site occupational health clinic. Additionally, because employees were allowed to smoke in the work place, the steel mill should implement a smoking cessation program because smoking can have many adverse health effects.

Keywords: NAICS 332312 (Fabricated Structural Metal Manufacturing), steel mill, dust, fume, metal, iron oxide, carbon monoxide, ventilation, bloody nose

Introduction

NIOSH received an HHE request from the United Steelworkers concerning metal dust and fume exposure from the No. 1 caster/slitter operation at a steel mill in Indiana. The semiautomated caster/slitter began operation in 2007 and was the first of its type for this steel mill. NIOSH investigators conducted an evaluation on April 2–4, 2008. We met with employer and employee representatives; observed work processes, practices, and workplace conditions; reviewed the results of previous environmental sampling conducted by the steel mill; and held confidential interviews with affected employees to discuss health and workplace concerns. We collected PBZ and GA air samples for minerals, metals, and CO and evaluated the ventilation systems in the cut-off and slitter pulpits, the shipping shanty, and two break rooms used by iron workers and pipe fitters. An informational letter summarizing our activities during this evaluation was sent to the company and union in April 2008.

Process Description

A steel slab of uniform thickness is conveyed from the continuous caster to the No. 1 caster/slitter area and is cut to length (approximately 40 feet) by an automated oxygen/fuel torch that is remotely controlled by the cut-off operator working inside a nearby enclosed pulpit. The cut-off operator occasionally leaves the pulpit to check the slab cutting or to communicate with nearby crane operators. The cut slabs roll to an adjacent table to cool.

Cut slabs are moved from the cooling table to a staging (inventory) area by an overhead mill-side crane operator using an electromagnet. After inventory, the slabs are moved (again by the mill-side crane operator) to one of eight elevated tables where they are slit lengthwise.* The slitter operator verifies that the slab is positioned correctly on the slitting table and adjusts the laser-guided, computer-controlled oxygen/fuel slitting torch. Once the torch slitting begins, the slitter operator moves to the next slitting table, a process that is repeated throughout the shift. This operation is monitored from an enclosed pulpit, but the slitter operator may spend approximately 50% of his time outside the pulpit to check that the torches are slitting properly and to make any needed adjustments. Each slab takes approximately 45 minutes to slit, and a maximum of eight slabs can be slit at one time.

The mill-side crane operator moves the slit slabs with an electromagnet from the slitting table to a staging (shipping) area.

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* Prior to 2007 slab slitting was performed manually on the mill floor.

Introduction (continued)

A shipper manually attaches an identification tag to each slab. During the shift the shippers perform their work from either inside a nearby enclosed shanty or outside the shanty next to the staged slabs. In the final step of this process, the slabs are moved from the staging area by the mill-side crane operator and positioned for shipment. Two enclosed break rooms in the No. 1 caster/slitter area are used by iron workers and pipe fitters.

At the time of this evaluation the steel mill had two 8-hour production shifts in the No. 1 caster/slitter area (day and evening), with 7 to 10 employees per shift. In addition to the mandatory requirement of hard hats, safety shoes, hearing protection, and eye protection for employees working in this area, the company also allowed the voluntary use of N95 filtering facepiece respirators. Employees were offered annual physicals and could report any health problems to the steel mill's on-site occupational health clinic.

Assessment

Full-shift PBZ air samples for minerals, metals, and CO were collected in the No. 1 caster/slitter operation and shipping area over the day and evening shifts on April 3–4, 2008. We sampled the cut-off and slitter operators, shippers, and mill-side and load-side crane operators. In addition to PBZ air samples, GA air samples were collected for minerals and metals in work areas adjacent to the No. 1 caster/slitter operation that were frequented by maintenance employees.

Air samples were collected at an airflow rate of 2.0 Lpm onto 37-millimeter diameter, 0.8-micrometer pore size mixed cellulose ester filters contained in plastic cassettes. The samples were analyzed using inductively coupled argon plasma-atomic emission spectroscopy per NIOSH Method 7303 [NIOSH 2010]. The analytical method was modified by adding 2.5 mL of hydrochloric acid to each sample instead of adding 1.25 mL each of concentrated hydrochloric and nitric acid. After heating the samples on a hot block, the analytical method was further modified by adding 2.5 mL instead of 1.25 mL of nitric acid to each.

The CO concentrations were measured using Toxi Ultra direct-reading CO detectors (Biosystems, Middletown, Connecticut). These detectors use an electrochemical cell to detect CO levels and were calibrated on site prior to use. The CO levels were recorded in real time at 1-minute intervals; this data set was then used to calculate full-shift TWA exposures and peak exposures. The detectors are capable of measuring CO levels of 0–1000 ppm; the generally accepted accuracy of electrochemical sensors is ± 5% or

± 2 ppm, whichever is greater. The appendix titled "Occupational Exposure Limits and Health Effects," contains additional OEL and health effect information on iron oxide (the predominant metal found in the air samples) and CO.

Ventilation smoke tubes were used to qualitatively evaluate air flow patterns in the cut-off and slitter pulpits, the shanty used by the shippers, and two employee break rooms. The steel mill had recently installed (within 2 weeks of this NIOSH evaluation) rigid ductwork to provide outdoor air to the air handling units in the cut-off and slitter pulpits, the shipping shanty, and break rooms.

All day shift No. 1 caster/slitter employees and maintenance employees primarily assigned to this area were invited to participate in confidential medical interviews.

Results

Elements and Carbon Monoxide

The PBZ and GA air samples collected were analyzed for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lanthanum, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, strontium, tellurium, thallium, tin, titanium, vanadium, yttrium, zinc, and zirconium [NIOSH 2010]. As shown in Tables 1 and 2, airborne particulate in the caster slitter and shipping areas was primarily iron oxide. Although all iron oxide exposures were below their OELs, the PBZ exposures for the mill-side and load-side crane operators (range: 1900 to 2800 $\mu g/m^3$) approached or exceeded one half of the OSHA PEL and NIOSH REL of 5000 $\mu g/m^3$ as an 8-hour TWA.

Table 1. Element concentrations in the caster/slitter and shipping areas, day shift, April 3, 2008

Job	Sample Time (min)	Sample Volume (L)	Concentration, µg/m³					
			Cu*	Fe*	Pb*	Mn*	Mo*	Ni*
PBZ air samples								
Slitter Trainee	357	733	1.6	340	ND†	2.7	ND	(0.34)‡
Slitter Operator	460	945	1.3	300	ND	2.6	ND	ND
Crane Operator, load side	499	1025	15	1900	(0.38)	11	0.78	0.15
Crane Operator, mill side	487	1004	19	2300	(0.50)	11	0.13	0.18
Cut-Off Operator	473	963	(0.30)	42	ND	0.37	ND	ND
Shipper, mill side	388	797	1.9	440	6.3	6.4	ND	ND
Shipper, load side	406	832	2.8	580	8.8	7.2	ND	(0.19)
GA air samples								
Slitter #4, south side	449	875	29	6100	(0.68)	31	3.0	5.0
Slitter #5, south side	511	895	39	9300	(0.82)	46	2.9	5.6
Maintenance, mill side	454	940	6.5	1600	ND	10	0.69	0.90
Maintenance, load side	453	930	3.7	1000	ND	9.2	(0.32)	0.51
MDC		800	0.09	3	0.4	0.06	0.1	0.1
MQC		800	0.30	14	1.3	0.19	0.41	0.34
NIOSH REL			1000	5000	50	1000	10000	15
OSHA PEL			1000	5000	50	5000	15000	1000

*Cu = copper, Fe = iron, Pb = lead, Mn = manganese, Mo = molybdenum, Ni = nickel

†ND = not detected, the concentration was below the MDC

‡ Concentrations between the MDC and MQC are shown in parentheses to acknowledge that there is more uncertainty surrounding concentrations below the MQC.

Elements that are not reported above but were measured between the MDC and MQC and below the MDC:

aluminum, ranging from ND (<0.5 µg/m³) to 7.7 µg/m³); antimony, ranging from ND (<0.8 µg/m³) to between the MDC and MQC (1.9 µg/m³); arsenic, ranging from (ND (<1 µg/m³) to between the MDC and MQC (6.0 µg/m³); barium, ranging from ND (<0.04 µg/m³) to 5.2 µg/m³; cadmium, ranging from ND (<0.04 µg/m³) to 0.40 µg/m³; calcium, ranging from 12 to 103 µg/m³; chromium, ranging from ND (<0.3 µg/m³) to 3.9 µg/m³; cobalt, ranging from ND (<0.04 µg/m³) to 1.0 µg/m³; magnesium, ranging from 3.7 to 17 µg/m³; phosphorus, ranging from ND (<3 µg/m³) to between the MDC and MQC (13 µg/m³); potassium, ranging from ND (<1 µg/m³) to between the MDC and MQC (4.6 µg/m³); strontium, ranging from ND (<0.03 µg/m³) to between the MDC and MQC (0.075 µg/m³); tin, ranging from ND (<0.9 µg/m³) to 9.0 µg/m³; vanadium, ranging from ND (<0.04 µg/m³) to 0.23 µg/m³; and zinc, ranging from ND (<0.5 µg/m³) to 3.0 µg/m³

Elements that are not reported above and were not detected (below the MDC):

beryllium (<0.03 µg/m³); lanthanum (<0.03 µg/m³); lithium (<0.04 µg/m³); selenium (<3 µg/m³); silver (<0.03 µg/m³); thallium (<1 µg/m³); titanium (<3 µg/m³); yttrium (<0.03 µg/m³), and zirconium (<0.1 µg/m³)

Table 2. Element concentrations in the caster/slitter and shipping areas, night shift, April 3–4, 2008

Job	Sample Time (min)	Sample Volume (L)	Concentration, µg/m³					
			Cu*	Fe*	Pb*	Mn*	Mo*	Ni*
PBZ air samples								
Slitter Operator	424	869	1.8	840	ND†	7.2	(0.18)‡	(0.18)
Crane Operator, load side	Pump failure		No sample results					
Crane Operator, mill side	467	952	1.8	2800	(0.45)	15	1.2	1.8
Cut-Off Operator	382	776	ND	50	ND	0.42	ND	ND
Shipper, load side	429	877	2.1	560	5.2	5.0	(0.22)	(0.18)
Shipper, mill side	325	665	1.7	450	1.7	5.2	ND	(0.17)
GA air samples								
Slitter #4, south side	438	895	17	4800	ND	19	1.6	1.5
Slitter #5, south side	435	875	78	6100	ND	27	1.1	2.4
Maintenance, mill side	427	886	5.4	1800	ND	11	(0.41)	0.41
Maintenance, load side	437	899	2.9	1045	ND	9.4	(0.26)	0.44
MDC		800	0.09	4	0.4	0.06	0.1	0.1
MQC		800	0.15	14	1.3	0.19	0.41	0.33
NIOSH REL			1000	5000	50	1000	10000	15
OSHA REL			1000	5000	50	5000	15000	1000

*Cu = copper, Fe = iron, Pb = lead, Mn = manganese, Mo = molybdenum, Ni = nickel
†ND = not detected, the concentration is below the MDC
‡ Concentrations between the MDC and MQC are shown in parentheses to acknowledge that there is more uncertainty surrounding concentrations below the MQC.
Elements that are not reported above but were measured between the MDC and MQC and below the MDC:
aluminum, ranging from ND (<0.5 µg/m³) to 7.7 µg/m³); antimony, ranging from ND (<0.8 µg/m³) to between the MDC and MQC (1.9 µg/m³); arsenic, ranging from (ND (<1 µg/m³) to between the MDC and MQC (6.0 µg/m³); barium, ranging from ND (<0.04 µg/m³) to 5.2 µg/m³; cadmium, ranging from ND (<0.04 µg/m³) to 0.40 µg/m³; calcium, ranging from 12 to 103 µg/m³; chromium, ranging from ND (<0.3 µg/m³) to 3.9 µg/m³; cobalt, ranging from ND (<0.04 µg/m³) to 1.0 µg/m³; magnesium, ranging from 3.7 to 17 µg/m³; phosphorus, ranging from ND (<3 µg/m³) to between the MDC and MQC (13 µg/m³); potassium, ranging from ND (<1 µg/m³) to between the MDC and MQC (4.6 µg/m³); strontium, ranging from ND (<0.03 µg/m³) to between the MDC and MQC (0.075 µg/m³); tin, ranging from ND (<0.9 µg/m³) to 9.0 µg/m³; vanadium, ranging from ND (<0.04 µg/m³) to 0.23 µg/m³; and zinc, ranging from ND (<0.5 µg/m³) to 3.0 µg/m³
Elements that are not reported above and were not detected (below the MDC):
beryllium (<0.03 µg/m³); lanthanum (<0.03 µg/m³); lithium (<0.04 µg/m³); selenium (<3 µg/m³); silver (<0.03 µg/m³); thallium (<1 µg/m³); titanium (<3 µg/m³); yttrium (<0.03 µg/m³), and zirconium (<0.1 µg/m³)

The results of the CO sampling are shown in Table 3. All TWA concentrations were below the OSHA PEL and NIOSH REL.

Table 3. Carbon monoxide concentrations in the caster/slitter and shipping areas, April 3–4, 2008

Job	Sample Time (min)	Concentration, ppm	
		TWA	Ceiling
Day Shift			
Slitter Trainee	458	3	14
Slitter Operator	464	3	13
Crane Operator, mill side	474	4	9
Crane Operator, load side	532	5	30
Evening Shift			
Slitter Operator	424	4	16
Cut-Off Operator	381	3	13
Crane Operator, mill side	472	5	12
Crane Operator, load side	469	5	24
Shipper, load side	325	7	124
NIOSH REL		35	200
OSHA REL		50	N/A

Ventilation

Ventilation smoke tubes were used to visually evaluate the airflow patterns at the employee door(s) leading to the pulpits, shipping shanty, and two break rooms in the No. 1 caster/slitter area (Table 4).

Table 4. Ventilation assessments in the caster/slitter area, April 3, 2008

Location	Comments
Cut-off and slitter pulpits	Slight positive pressure* at the door in relation to the surrounding area.
Shipping shanty	Positive pressure at the top of both pulpit doors and negative pressure† at the bottom of each door. The airflow varied when both doors were opened at the same time.
Iron worker break room	Positive pressure at the door in relation to the surrounding area.
Pipe fitter break room	Negative pressure at the door in relation to the surrounding area.

* Positive pressure means that air flowed from the pulpit, shanty, or break room into the surrounding work area.
† Negative pressure means that air flowed into the shanty or break room from the surrounding work area.

Medical

Of 28 employees scheduled to work, 22 participated in the confidential medical interviews. All but two were male, their average age was 45 years, and 17 of 22 (77%) were either current or former smokers. Job titles included crane operator, slitter operator, cut-off operator, shipper, and maintenance. The average duration of employment in their current job title was 3.3 years, with an average duration of employment at this steel mill of 19.5 years.

Of the 22 employees interviewed, 16 (73%) reported no work-related symptoms. Six reported work-related symptoms including eye irritation (1), cough (1), sore throat (2), nosebleeds (2), anxiety (1), and headache (2). These six employees had reported workplace dustiness to their supervisors but had reported their health symptoms to neither the employer nor to the on-site occupational health clinic. The six employees did not characterize the black nasal secretions and phlegm as "health problems" but considered them more a consequence of poor equipment maintenance. This belief was shared by many of the remaining 16 employees who denied having any work-related health symptoms but noted having black nasal secretions and phlegm. No employee reported feeling pressured by the employer not to report symptoms to the occupational health clinic. The occupational health clinic staff confirmed no clinic visits by employees for dust-related health issues.

Interviewed employees described a decrease in dustiness in the slitter pulpit after installation of ventilation ductwork to bring outdoor air to the pulpit. However, ventilation changes to the mill-side and load-side crane cabs and at the shipping shanty were described by interviewed employees as ineffective in reducing dustiness. For example, mill-side and load-side crane operators reported the air quality in their cabs worsened when the new air-conditioning units were operating. Employees reported not seeing any improvement in the dustiness after the shipper pulpit was placed under positive pressure in relation to the surrounding mill. Several shippers noted 1-inch gaps at the north wall of the shipper shanty.

In general, employees believed that the dustiness in the No. 1 caster/slitter area was worse in the winter when the doors were closed. Several reported increased dustiness because the semiautomated slitter operation was on a raised slitting platform to accommodate the automated "spiders" that removed accumulated slag under the freshly slit slabs.

Because of the dust generated by the No. 1 caster/slitter operation, the steel mill allowed employees to use N95 filtering facepiece respirators on a voluntary basis. Although all employees were aware of

RESULTS (CONTINUED)

the voluntary use respirator program, only two interviewed employees reported using a respirator. One of these employees brought the respirator he was currently using to the interview, and the filter was visibly dirty.

DISCUSSION

The production rate in the No. 1 cutter/slitter area during this evaluation was slightly above average. Twenty eight steel slabs were processed (slit) during the day shift on April 3, 2008, compared to an average of 23 for the 5 prior days. Although this evaluation was conducted on a cool day, many of the exterior doors were open for most of the day shift. Both north end doors were open from the beginning of the day shift, while the east and west doors were closed at the beginning of the day shift then opened at 9:30 a.m. for the remainder of the shift.

Iron oxide was the primary airborne exposure to the cut-off, slitter, and crane operators and to the shippers in the No. 1 cutter/slitter area. However, no employees were overexposed on the basis the PBZ air sample results obtained from this evaluation. Although other researchers have found that employees exposed to iron oxide may also be exposed to chromium, nickel, and vanadium [Nemery 1990], we did not find overexposures to these other metals.

Our air sampling results suggest that the pulpit used by the slitter operators (and to a lesser extent the pulpit used by the cut-off operator and the shanty used by the shippers) contributed to reducing PBZ exposures to iron oxide and other metals. For example, three of the four GA air samples collected on the slitter platform during slab slitting exceeded the OEL for iron oxide of 5000 µg/m^3, and iron oxide concentrations from GA air samples collected in the maintenance areas ranged from 1000 to 1800 µg/m^3. In comparison, the PBZ exposures for the cut-off and slitter operators and the shippers ranged from 42 to 840 µg/m^3. The addition of air ducted from outside the building to the cut-off and slitter pulpits, the shipping shanty, and the iron worker break room likely improved the effectiveness of these enclosures in reducing employee exposures by maintaining these areas under a positive pressure in relation to the surrounding production areas. The one exception that we noted in our evaluation was the pipe fitter break room. This room remained under negative pressure in relation to the surrounding production area despite the addition of air ducted from outside the building.

The mill-side and load-side crane operators had the highest iron oxide exposures, with PBZ TWA exposures that ranged from 1900 to 2800 µg/m^3. This was not unexpected considering that (1) these employees are situated above the No. 1 caster/slitter operation, (2) the hot metal

Discussion (continued)

dust and fume generated during slab cutting and slitting thermally rise to the top of the building, and (3) the crane operators typically remain in their cabs for most of their work shift (because of the time required to climb from the production floor to the crane). Although the mill-side and load-side crane cabs were enclosed and air-conditioned, both cabs had visible gaps in their enclosures, and crane operators commented in our interviews that they were dissatisfied with the effectiveness of the air filtration for their crane cabs. Additionally, two of eight crane operators interviewed reported work-related symptoms.

Our sampling found no overexposures to iron oxide that would require a mandatory respiratory protection program. However, employees voluntarily wearing respirators should be aware that they may not be receiving the full protection from the respirator if the filter is clogged or if the employee has facial hair preventing a good seal. We observed both of these situations during this evaluation. If employees are concerned by nasal secretions and/or phlegm darkened by inhaling particulate, they may choose to wear a respirator when they work outside of their shanty, pulpit, or break room.

Most interviewed employees did not report work-related symptoms. Six employees had cough, sore throat, and nosebleeds, symptoms consistent with upper respiratory irritation due to dust exposure. However, these symptoms may also occur in the general population and cannot be directly linked to work exposures. The steel mill employees did not consider the black nasal secretions and phlegm a health problem, and air sampling revealed no iron oxide overexposures. Although interviewed employees chose not to report work-related symptoms to the occupational health clinic or to managers, by following up with the on-site occupational health clinic the employees may determine over time whether the symptoms are work-related and associated with particulate exposure from the No. 1 caster/slitter.

Conclusions

Employees working at the No. 1 caster/slitter at this steel mill were not exposed to minerals, metals, or carbon monoxide above OELs on the days of this HHE. Cough, sore throat, and nosebleeds are consistent with upper respiratory irritation due to dust exposure. These symptoms are also common in the general population and cannot be directly linked to work exposure. However, the black nasal secretions and phlegm reported by employees are likely due to nonrespirable iron oxide particulate trapped in the nose and upper airways. Engineering and administrative controls and the voluntary use of respirators may further reduce particulate exposures to No. 1 caster/slitter employees.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the steel mill to use a labor-employer health and safety committee or working group to discuss the recommendations in this report and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the steel mill. Our recommendations are based on the hierarchy of controls approach that 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/or personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee.

1. Seal gaps in the mill-side and load-side crane cab enclosures.
2. Evaluate the air intake and exhaust for the crane cab enclosures to determine if they are correctly installed and functioning properly.
3. Evaluate the fit and effectiveness of the air filter installed in both the load-side and mill-side crane cab enclosures.
4. Evaluate the ventilation system for the pipe fitter break room in the No. 1 caster/slitter area. This room remained under negative pressure in relation to the surrounding production area despite the addition of air ducted from outside the building.

Administrative Controls

Administrative controls are employer-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production.

1. Encourage the cut-off and slitter operators to perform as much of their work as possible within their respective pulpits.

2. Encourage shippers to conduct as much of their work as possible inside their shanty.
3. Encourage employees to report work-related health problems to the steel mill's occupational health clinic. Reporting maintenance issues to the employer should not occur in place of appropriate medical assessments.
4. Implement a smoking cessation program because smoking can have many adverse health effects. Additional information on smoking cessation programs can be obtained by calling 1-800-QUIT NOW (1-800-784-8669) or from the NIOSH Current Intelligence Bulletin 54, *Environmental Tobacco Smoke in the Workplace* available at http://www.cdc.gov/niosh/91108_54.html.

Personal Protective Equipment

PPE is the least effective means for controlling employee exposures. Proper use of PPE requires a comprehensive program and calls for a high level of employee involvement and commitment to be effective. The use of PPE requires the choice of the appropriate equipment to reduce the hazard and the development of supporting programs such as training, change-out schedules, and medical assessment if needed. PPE should not be relied upon as the sole method for limiting employee exposures. Rather, PPE should be used until engineering and administrative controls can be demonstrated to be effective in limiting exposures to acceptable levels.

1. Encourage the proper wearing of voluntary use respirators.
2. Require employees who wear respirators voluntarily to be clean shaven in the area of the face seal and to replace their respirator when it is visibly clogged or becomes difficult to breathe through.

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Appendix: Occupational Exposure Limits and Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed 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 from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the employee to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that 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, while 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 enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2005]. NIOSH also recommends different types of 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 from these hazards. Other OELs that are commonly used and cited in the United States include the TLVs recommended by ACGIH, a professional organization, and the WEELs 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. They are not consensus standards. ACGIH 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 2010]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2010].

Outside the United States, OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States available at http://www.dguv.de/bgia/en/gestis/limit_values/index.jsp. The database contains international limits for over 1250 hazardous substances and is updated annually.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. 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))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified 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 that focuses resources on exposure controls by describing how a risk needs to 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 the OELs, when available.

Iron Oxide

The predominant metal measured in the dust and fume generated by the No. 1 caster/slitter area was iron oxide, although all exposures were below OELs. Acute (short-term) health effects may occur immediately or shortly after exposure to iron oxide and include a flu-like illness with symptoms of metallic taste, fever and chills, aches, chest tightness, and cough. Over longer exposure periods, iron oxide fume or dust can cause a benign pneumoconiosis called siderosis. With this condition, dust deposition casts a shadow in an x-ray of the lung but does not damage the lung. This is usually not seen by x-ray before 6 to 10 years of exposure [Hathaway et al. 2004]. In a study of 25 welders exposed to iron oxide fume concentrations ranging from 650 to 47,000 $\mu g/m^3$, approximately one third developed symptoms consistent with siderosis [Kleinfeld et al. 1969].

Carbon Monoxide

A colorless, odorless, tasteless gas, CO can be a product of the incomplete combustion of organic compounds. It combines with hemoglobin and interferes with the oxygen-carrying capacity of blood. Symptoms of overexposure include headache, drowsiness, and dizziness. Symptoms following much higher CO exposures than were measured at this steel mill include nausea, vomiting, collapse, myocardial ischemia, and death [Hathaway et al. 2004]. The NIOSH REL for CO is 35 ppm for up to an 8-hour TWA. NIOSH also recommends a ceiling limit of 200 ppm that should not be exceeded at any time during the workday [NIOSH 2005]. The OSHA PEL for CO is 50 ppm for an 8-hour TWA, and the ACGIH TLV for CO is 25 ppm as an 8-hour TWA [29 CFR 1910.1000; ACGIH 2010].

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Acknowledgments and Availability of Report

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Administration (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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