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Characterization of the Aerosol Generated During Abrasive Blasting with Copper Slag

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The National Institute for Occupational Safety and Health (NIOSH) recommends that substitute materials be used for silica sand in abrasive blasting operations. Copper slag is commonly used as a substitute for silica sand. These slags have been reported to contain heavy metals. Our research aims were to identify exposure-related differences between slag sources, quantify health-related aerosol fractions for comparison with occupational exposure limits and correlate total and inhalable aerosol with metal concentrations. Two commercially available copper slags were used to perform indoor and outdoor abrasive blasting. Personal samples were collected using 37 mm cassettes and a Respicon sampler and analyzed for total, inhalable, thoracic and respirable aerosol and heavy metals. Lead and arsenic concentrations exceeded applicable OELs in 37 and 15 min, respectively. Inhalable and respirable aerosol concentrations exceeded applicable OELs in 15 min. Statistically significant differences between slag sources were found for arsenic, lead, chromium and titanium concentrations in the total, inhalable, thoracic and respirable fractions. Total and inhalable aerosol regressions with selected metals showed r^2 values of 0.91–0.98. The results of this study raise questions concerning the efficacy of using copper slag as a substitute abrasive based solely on the premise that it contains <1% free silica.

Keywords: abrasive blasting; copper slag abrasive

INTRODUCTION

Abrasive blasting is the cleaning of a surface using a stream of abrasive applied by pressure or force. NIOSH has recommended that silica sand be prohibited as an abrasive blasting material and offers corundum, glass beads, pumice, sawdust, walnut shells, steel grit and shot and slags as suggested replacements (National Institute for Occupational Safety and Health, 1974, 1992). Copper slag is a widely used substitute for silica sand. Copper slag has been shown to contain heavy metals and the chemical composition of slags can vary with changes in source material (Mackay *et al.*, 1980; Stettler *et al.*, 1982; National Institute for Occupational Safety and Health, 1998).

The aim of our study was to assess worker exposure to copper slag aerosol during abrasive blasting in ventilated indoor locations and outdoors using copper slag from two different sources.

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MATERIALS AND METHODS

The copper slags used in this research were Best Grit and Nevada Black. Both slags come from waste smelter furnace slag and are marketed as an abrasive low in free silica. Both slags are reported to contain a mixture of hematite (Fe_2O_3), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), calcium oxide (CaO), magnesium oxide (MgO) and mercuric oxide (HgO) in a tightly bound glassy matrix. The Occupational Safety and Health Administration Permissible Exposure Limit (OSHA PEL) and American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH TLV) are reported on the material safety data sheets (MSDS) for each slag to be 15 and 10 mg/m^3, respectively. A medium grit size of 16/30 was chosen for both copper slag sources [16/30 is a mixture of grit sizes 16 (1.168 mm) and 30 (0.589 mm)].

Our research consisted of two phases. In phase one, Best Grit slag was evaluated for arsenic, lead and total particulate. Fifteen short-term personal samples were collected in a small ventilated booth and outdoors using 37 mm cassettes with pre-weighed mixed cellulose ester (MCE) membrane filters. The booth

Table 1. Summary statistics for total particulate and metal concentrations for Best Grit and Nevada Black slags

Chemical agent	Summary statistic (n = 15)	Abrasive blasting location			
		Room		Booth	Outdoor
		Best Grit	Nevada Black	Best Grit	Best Grit
Arsenic	Mean (mg/m^3)	0.15	0.28	0.72	0.37
	SD[a]	0.06	0.11	0.54	0.23
Lead	Mean (mg/m^3)	0.65	1.43	3.18	1.98
	SD	0.36	0.60	2.24	1.23
Titanium	Mean (mg/m^3)	0.52	0.97		
	SD	0.33	0.47		
Beryllium	Mean (mg/m^3)	<0.001[b]	<0.001[b]		
	SD				
Cadmium	Mean (mg/m^3)	<0.001[b]	<0.001[b]		
	SD				
Chromium	Mean (mg/m^3)	<0.002[b]	0.27		
	SD		0.13		
Vanadium	Mean (mg/m^3)	<0.002[b]	<0.002[b]		
	SD				
Total particulate	Mean (mg/m^3)	776	851	5078	2655
	SD	493	382	3586	1585

[a]Standard deviation.
[b]Below analytical detection limits.

measured 1.7 × 1.1 × 2.4 m high and was designed with two exhaust ducts at the front of the booth with a minimum duct velocity of 15.4 m/s. The outdoor abrasive blasting was performed in an open area away from buildings. In phase two, Best Grit and Nevada Black slags were sampled during abrasive blasting in a larger ventilated indoor enclosure measuring 3.1 × 3.1 × 2.4 m and equipped with a portable high efficiency particulate air (HEPA) filtered exhaust unit to provide negative pressure to the room. All indoor surfaces were covered with Visqueen to facilitate cleaning between slag source sampling events. Fifteen short-term personal samples were collected using 37 mm cassettes and a Respicon sampler (TSI Inc.) during abrasive blasting with each slag source. (The Respicon sampler is a virtual impactor which separates the inhalable, thoracic and respirable fractions.) All 37 mm samples were analyzed for total particulate and for arsenic, lead, beryllium, cadmium, chromium, titanium and vanadium. The Respicon samples were analyzed for inhalable, thoracic and respirable aerosol and six randomly selected samples for each slag source were analyzed for arsenic, lead, beryllium, cadmium, chromium, titanium and vanadium. Pre-weighed MCE membrane filters were employed as the sampling medium.

Abrasive blasting was performed with a portable blast cleaning machine with the air pressure set at 700 kPa. An abrasive airstream was delivered through an 11 mm orifice size blast nozzle to a 6.4 mm industrial aluminum (99.7% pure) plate chosen for durability and to eliminate heavy metal contamination from the surface being blasted. Abrasive slag material was supplied to the portable blast machine via a 6 m^3 gravity fed hopper. A 87 l/min Ingersoll Rand air compressor provided pressurized air. The blast nozzle was held perpendicular 45 cm from the aluminum plate surface. The abrasive blaster wore a NIOSH approved supplied air helmet, protective suit, leather gloves, safety shoes and hearing protection. Support personnel wore half-mask, negative pressure air-purifying particulate respirators.

Statistical analysis

Summary statistics using arithmetic and log-transformed data were tabulated for both dust and metal concentrations for each slag source and blasting location. Time-weighted average (TWA) concentrations were compared against applicable standards. Summary statistics and differences in mean concentrations of metals between slag sources and blasting locations were evaluated using t-tests. Linear regression analysis was performed to model the relationships between total particulate and metal concentrations.

RESULTS AND DISCUSSION

Nevada Black slag generated higher total particulate levels than Best Grit slag, but the difference was not significant statistically. Total particulate concentrations in the room location were significantly lower than for both the booth and outdoor locations (see Table 1). Statistically significant differences were found for total arsenic, lead, chromium and titanium

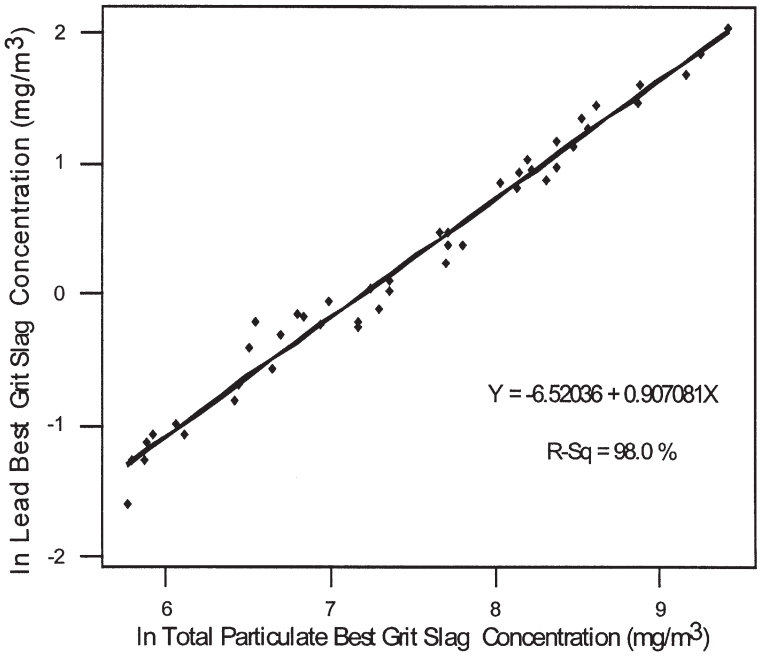

Fig. 1. Regression plot of lead and total particulate concentrations for Best Grit slag.

Table 2. Summary statistics for inhalable, thoracic and respirable aerosol fractions and metal dust concentrations found in each fraction for Best Grit and Nevada Black slags

	Mean (mg/m^3)	95% LCL[a] (mg/m^3)	95% UCL[b] (mg/m^3)
Best Grit slag			
Inhalable fraction	626.13	546.73	736.92
Thoracic fraction	258.86	197.83	386.55
Respirable fraction	21.77	148.04	391.32
Arsenic	0.09	0.06	0.11
Lead	0.41	0.26	0.55
Titanium	0.33	0.22	0.44
Chromium	0.10	0.09	0.10
Nevada Black slag			
Inhalable fraction	749.21	630.50	933.42
Thoracic fraction	372.52	297.22	509.89
Respirable fraction	295.29	225.30	442.52
Arsenic	0.11	0.03	0.19
Lead	0.56	0.12	0.85
Titanium	0.39	0.05	0.63
Chromium	0.06	0.02	0.17

[a]LCL, lower confidence limit.
[b]UCL, upper confidence limit.

concentrations between slag sources and arsenic levels were significantly higher in the booth location when compared with blasting outdoors (see Table 2).

Nevada Black slag generated greater aerosol concentrations in the inhalable, thoracic and respirable fractions, but the differences were not significant statistically. Nevada Black slag also generated significantly higher concentrations of arsenic, lead, titanium and chromium than Best Grit slag in all aerosol fractions (see Table 2). The higher aerosol and metal dust concentration found with Nevada Black slag may be due to the metal content of the slag or to the physical characteristics of the slag (such as grain size), which can affect feed rates through the hopper. We found that at the same feed rate setting, Nevada Black fed through the hopper at a greater rate than Best Grit slag.

TWA concentrations calculated for each slag source showed that the OSHA PELs for total particulate, arsenic and lead were exceeded in 15, 15 and 63 min, respectively, for Best Grit slag and the same PELs were exceeded in 15, 28 and 44 min, respectively, for Nevada Black slag. The chromium PEL was also exceeded in 105 min for the Nevada Black slag. During the outdoor blasting with Best Grit slag the PEL for total particulate was exceeded in 40 min and the PELs for arsenic and lead were exceeded in 1 h of blasting. The ACGIH respirable TLV of 3 mg/m^3 and the OSHA respirable PEL of 5 mg/m^3 were exceeded in 17 and 12 min, respectively, for Best Grit slag in the room location. The ACGIH inhalable TLV of 10 mg/m^3 was exceeded in 8 min for this same slag. For Nevada Black slag the ACGIH respirable TLV and the OSHA respirable PEL were exceeded in 7 and 12 min, respectively, and the inhalable TLV was exceeded in 8 min.

The results of linear regression analysis demonstrated a good correlation between the selected metals and total particulate for both slag sources. When lead, arsenic and total particulate concentrations were combined for all three blasting locations for Best Grit slag, r^2 values were 93% for arsenic and 98% for lead. Figure 1 shows the linear regression plot for lead and total particulate for Best Grit slag. These results indicate that lead and arsenic concentrations could be predicted reasonably well from total particulate concentrations regardless of the blasting location. For Nevada Black slag regression analysis showed r^2 values of 91, 97 and 98% for arsenic, lead and titanium, respectively.

CONCLUSION

The use of copper slag abrasive can expose workers to dangerously high levels of metals and particulate if adequate protection is not provided. The results of this study raise questions concerning the efficacy of using copper slag as a substitute abrasive based solely on the premise that it contains <1% free silica.

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REFERENCES

Mackay GR, Stettler LE, Kommineni C, Donaldson HM. (1980) Fibrogenic potential of slags used as substitutes for sand in abrasive blasting operations. Am Ind Hyg Assoc J; 41: 836–42.

National Institute for Occupational Safety and Health. (1974) Abrasive blasting respiratory protective practices, DHHS (NIOSH) publication no. 74-104. Cincinnati, OH: NIOSH.

National Institute for Occupational Safety and Health. (1992) NIOSH alert, request for assistance in preventing silicosis and deaths from sandblasting, DHHS (NIOSH) publication no. 92-102. Cincinnati, OH: NIOSH.

National Institute for Occupational Safety and Health. (1998) Evaluation of substitute materials for silica sand in abrasive blasting, DHHS (NIOSH) contract no. 200-95-2946. Cincinnati, OH: NIOSH.

Stettler LE, Donaldson HM, Grant GC. (1982) Chemical composition of coal and other mineral slags. Am Ind Hyg Assoc J; 43: 235–8.