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Assessment of Beryllium Exposure in Abrasive Blasting with Slag Abrasives

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Abstract

Occupational exposure to beryllium during abrasive blasting with slag abrasives may pose a risk of chronic beryllium disease (CBD) and cancer, though the extent of this risk remains debated due to the chemical form of beryllium in slag. This preliminary study quantified beryllium in air, on skin, on surfaces, and in bulk media during abrasive blasting with copper and coal slag. Five personal breathing zone air samples, 24 skin wipes (neck, arms, hands), four surface wipes, and four bulk samples were collected from abrasive blasters, laborers, and supervisors at two worksites. Samples were analyzed using EPA Method 7010 (skin, air, surfaces) and NIOSH Method 7303 (bulk). Beryllium was detected on skin despite personal protective equipment (PPE), with concentrations up to 0.456 µg/wipe (arms, abrasive blaster, coal slag). Breathing zone levels were below the OSHA PEL of 0.2 µg/m^3 (<0.0725 - <0.107 µg/m^3). Surface levels were low (<0.050 - 0.19 µg/ft^2), and bulk slag contained 0.42 - 0.73 ppm beryllium, confirming trace amounts. Supervisors showed minimal skin exposure (0.0698 - 0.0918 µg/wipe). These findings indicate dermal exposure occurs despite PPE, posing potential health risks, while airborne levels appear controlled. This range-finding study highlights the need for expanded sampling to fully characterize exposure risks and inform risk management strategies for construction workers using slag abrasives containing trace beryllium.

Keywords

Beryllium, Abrasive Blasting, Dermal Exposure, Inhalation, Occupational Health

1. Introduction

Beryllium exposure in occupational settings is linked to sensitization (BeS), chronic beryllium disease (CBD), and lung cancer [1] [2], though the specific risk in construction, particularly during abrasive blasting with slag abrasives, remains debated due to the chemical form of beryllium and lack of reported CBD cases in this context. Approximately 12,000 U.S. construction workers are at risk via inhalation, dermal contact, and ingestion [3]. The 2017 OSHA beryllium standard triggered risk management for airborne levels above the action level and dermal contact, but the 2020 revision excluded dermal contact as a trigger, citing low beryllium content in slag (<0.1% by weight), without supporting exposure data. Studies confirm health risks at low exposure levels [4], and incidental pathways like dermal and ingestion exposures may contribute significantly to total doses [5].

Deubner *et al.* (2001) [5] highlight that dermal exposure, especially through damaged skin, and ingestion via hand-to-mouth activity could lead to absorbed doses exceeding inhalation exposures, potentially contributing to sensitization. This preliminary study aimed to quantify beryllium in air, on skin, on surfaces, and in bulk media during abrasive blasting, addressing gaps in exposure assessment. We hypothesized that detectable beryllium persists on skin despite PPE, posing risks to workers.

2. Methods

Exposure assessments were conducted at two industrial painting worksites (NAICS 23832) during abrasive blasting of structural steel with copper and coal slag. Participants included five workers—two abrasive blasters, two laborers/helpers (pot tenders/clean-up crew), and one supervisor—from SSPC-certified contractors, recruited via convenience sampling based on availability during scheduled blasting operations to represent key roles with varying exposure potentials. Five personal breathing zone air samples were collected using 37-mm, 0.8-μm mixed cellulose ester filters in cassettes, attached outside Type CE blast hoods to assess total workplace exposure including potential leakage or secondary inhalation sources (e.g., resuspension), with Buck Libra L-4 pumps calibrated to 2 L/min (±5%) via a primary flow calibrator (A.P. Buck M-5) over an 8-hour workday (960 liters per sample).

Twenty-four skin wipe samples (Ghost Wipes^{TM}) were collected from workers' neck, arms, and hands at three time points: before work (baseline), post-PPE removal, and after handwashing. Four surface wipes (abrasive blast pots) and four bulk samples (virgin and spent media) were obtained using centrifuge tubes. Skin, air, and surface samples were analyzed for total beryllium via EPA Method 7010 (Graphite Furnace Atomic Absorption Spectroscopy); bulk samples were analyzed via NIOSH Method 7303 (metals) at an AIHA-accredited laboratory. Field blanks accompanied each sample type. Workers wore OSHA-mandated PPE (blast hoods, gloves, coveralls). This study was conducted with informed consent from all participating workers; an IRB waiver was not necessary due to the non-invasive nature of the exposure assessments and the use of anonymized data, in compliance with occupational health research standards. Data were reported as μg/m^3 (air), μg/wipe (skin), μg/ft^2 (surfaces), or ppm (bulk), with a detection limit of 0.0500 μg for wipes.

3. Results

Beryllium was detected on skin post-exposure across three abrasive blasting tests, as shown in Table 1. Abrasive blasters showed the highest concentrations with coal slag in Blast Test 2: 0.456 μg/wipe (arms), 0.297 μg/wipe (hands), and 0.115 μg/wipe (neck). With copper slag (Blast Test 1), levels were lower: 0.174 μg/wipe (arms) and 0.0688 μg/wipe (neck). Laborers/helpers had 0.0979 μg/wipe (hands, coal slag) and 0.0909 μg/wipe (neck), with most other sites below detection (<0.0500 μg/wipe). Supervisors showed minimal exposure (0.0698 - 0.0918 μg/wipe). Baseline wipes were below detection.

Breathing zone concentrations are presented in Table 2, ranging from <0.0725 μg/m^3 (laborer, clean-up) to 0.107 μg/m^3 (abrasive blaster, copper slag), all below the OSHA PEL of 0.2 μg/m^3. Surface wipes from abrasive blast pots (Table 3) showed 0.19 μg/ft^2 (coal slag) and <0.050 μg/ft^2 (copper slag). Bulk samples (Table 4) confirmed trace beryllium in slag: 0.73 ppm (virgin coal slag), 0.63 ppm (post-blast coal slag), 0.42 ppm (virgin copper slag), and 0.66 ppm (post-blast copper slag), all below 0.1% by weight.

Table 1. Beryllium on workers' skin by exposure group (μg/wipe).

Sample ID	Concentration	Location of Wipe	Work Task	Type of Abrasive	Description
Blast Test 1					
B-A-3	0.174	Arm (wrist to elbow)	Abrasive Blaster	Copper Slag	Post Blast
B-H-3	<0.0500	Hands	Abrasive Blaster	Copper Slag	Post Blast
B-N-3	0.0688	Neck	Abrasive Blaster	Copper Slag	Post Blast
A-A-2	<0.0500	Arm (wrist to elbow)	Laborer/Helper	Copper Slag	Post Blast
A-H-2	<0.0500	Hands	Laborer/Helper	Copper Slag	Post Blast
A-N-2	<0.0500	Neck	Laborer/Helper	Copper Slag	Post Blast
Blast Test 2					
A-A-3	0.456	Arm (wrist to elbow)	Abrasive Blaster	Coal Slag	Post Blast
A-H-3	0.297	Hands	Abrasive Blaster	Coal Slag	Post Blast
A-N-3	0.115	Neck	Abrasive Blaster	Coal Slag	Post Blast
B-A-2	<0.0500	Arm (wrist to elbow)	Laborer/Helper	Coal Slag	Post Blast
B-H-2	0.0979	Hands	Laborer/Helper	Coal Slag	Post Blast
B-N-2	0.0909	Neck	Laborer/Helper	Coal Slag	Post Blast
Blast Test 3					
B-A-4	0.293	Arm (wrist to elbow)	Abrasive Blaster	Coal Slag	Post Blast
B-H-4	0.297	Hands	Abrasive Blaster	Coal Slag	Post Blast
B-N-4	<0.0500	Neck	Abrasive Blaster	Coal Slag	Post Blast

Continued

Skin Wipes Not Associated with Air Testing				
D-1	0.0918	Hands	Supervisor	Coal and Copper Slag Post Blast (clean up only)
D-2	0.0698	Arms (wrist to elbow)	Supervisor	Coal and Copper Slag Post Blast (clean up only)
D-3	<0.0500	Neck	Supervisor	Coal and Copper Slag Post Blast (clean up only)
Baseline				
A-A-1	<0.0500	Arm (wrist to elbow)		Abrasive blaster
A-H-1	<0.0500	Hands		Abrasive blaster
A-N-1	<0.0500	Neck		Abrasive blaster
B-A-1	<0.0500	Arm (wrist to elbow)		Laborer/Helper
B-H-1	<0.0500	Hands		Laborer/Helper
B-N-1	<0.0500	Neck		Laborer/Helper

Table 2. Beryllium in breathing zone (μg/m^3).

Sample ID	Task	Concentration	Type of Abrasive	Description
A-01	Abrasive Blaster	0.107	Copper Slag	Test 1 Abrasive Blast
B-01	Abrasive Blaster	<0.0862	Coal Slag	Test 2 Abrasive Blast
B-02	Abrasive Blaster	<0.0105	Coal Slag	Test 3 Abrasive Blast
C-01	Laborer/Helper	<0.105	Copper Slag	Test 1 Abrasive Blast
C-02	Laborer/Helper	<0.0725	Coal and Copper Slag	Clean up site

Table 3. Beryllium on work surfaces (μg/ft^2).

Surfaces	N	Concentration	Type of Abrasive
Abrasive Blast Pot	1	0.19	Coal Slag
Abrasive Blast Pot	1	<0.050	Copper Slag
Abrasive Blast Hood	1	<0.050	Coal slag
Abrasive Blast Hood	1	<0.050	Copper Slag

Table 4. Slag bulk beryllium concentration (ppm).

Blast Media	N	Parts Per Million (ppm)	Type of Abrasive
Virgin Coal Slag Abrasive	1	0.73	Coal Slag
Post Blast Coal Slag Abrasive	1	0.63	Coal Slag
Virgin Copper Slag Abrasive	1	0.42	Copper Slag
Post Blast Copper Slag Abrasive	1	0.66	Copper Slag

4 Discussion

This preliminary study detected beryllium on workers' skin after abrasive blasting with copper and coal slag, despite OSHA-required PPE, suggesting dermal exposure risks persist. Abrasive blasters showed the highest skin concentrations (e.g., 0.456 μg/wipe on arms with coal slag; **Table 1**), followed by laborers/helpers (0.0979 μg/wipe on hands), while supervisors had minimal exposure (0.0698 - 0.0918 μg/wipe). Coal slag yielded higher skin levels than copper slag, possibly due to higher beryllium content (0.73 ppm in virgin coal slag vs. 0.42 ppm in copper slag; **Table 4**).

These findings align with Deubner *et al.* (2001) [5], who reported that incidental pathways, such as dermal contact and hand-to-mouth ingestion, may contribute significantly to total beryllium doses, potentially exceeding inhalation exposures (e.g., up to 4.11 μg/workday via ingestion vs. 1.63 μg/workday via inhalation at the OEL of 2 μg/m^3). They emphasize that dermal exposure, particularly through damaged skin common in abrasive blasting, can lead to substantial absorption (7.8% - 38.8%), potentially contributing to sensitization—a precursor to CBD. Similarly, Naylor *et al.* (2021) [6] assessed dermal exposure to metals, including beryllium, in construction settings, noting increased uptake risks due to frequent surface contact and skin abrasions, and derived a conservative surface limit for beryllium (8.0×10^{-5} μg/100cm^2, cancer, inhalation pathway), highlighting its high toxicity even at trace levels.

Skin-wipe concentrations from this study (up to 0.456 μg/wipe, or 0.0456 μg/100cm^2) exceed the Naylor *et al.* (2021) [6] health-based surface limit, indicating a potential dermal risk. The ACGIH surface threshold limit value (TLV) of 0.2 μg/100cm^2 is a guideline for surface hygiene to prevent indirect exposure (e.g., ingestion or inhalation), and while our skin-wipe levels are below this value, they suggest that inadequate surface control may contribute to skin contamination, necessitating improved hygiene measures.

Breathing zone levels in our study were below the OSHA PEL of 0.2 μg/m^3 (<0.0725 - 0.107 μg/m^3; **Table 2**), though prior studies report exceedances during blasting [7] [8]. Sampling outside the blast hood may underestimate inhalation exposure within the hood, and future studies should measure inside with protection factor data (e.g., assigned protection factor of 1000 for Type CE hoods) to quantify leakage effects more precisely.

Surface levels were low (0.19 μg/ft^2 for coal slag, <0.050 μg/ft^2 for copper slag; **Table 3**), yet Deubner *et al.* (2001) [5] note that resuspension from contaminated clothing can contribute non-trivial inhalation doses (0.0926 - 0.461 μg/workday), and Naylor *et al.* (2021) [6] highlight that even low surface levels can contribute to dermal exposure over time, advocating for wipe sampling to assess risks—consistent with our methodology. Bulk samples confirmed trace beryllium in slag, but detectable skin levels challenge the 2020.

OSHA exclusion of dermal contact as a risk management trigger [3], a concern supported by broader calls for improved worker protection, such as those by Mehta *et al.* (2023) [9], who highlight beryllium as an occupational carcinogen that has influenced policy and emphasize the need for integrating epidemiological data to enhance safety in industries like construction. Beryllium in slag (e.g., beryllium oxide) is often less soluble than beryllium metal or salts, and Stefaniak *et al.* [10] demonstrated that poorly soluble forms can dissolve in artificial sweat, particularly under acidic conditions or with damaged skin, contributing to dermal absorption and supporting the need for protective measures.

Despite these findings, industry experts have argued that no cases of CBD have been reported in abrasive blasting, attributing this to the chemical form of beryllium in slag (typically insoluble beryllium oxide), which they claim has low bioavailability and thus poses minimal risk [3]. In contrast, NIOSH contends that CBD remains a potential risk, as even low levels of beryllium exposure, regardless of chemical form, can lead to sensitization and disease in susceptible individuals, particularly given the potential for dermal and inhalation exposure during abrasive blasting [1] [11]. This debate underscores the uncertainty surrounding CBD risk in abrasive blasting and the need for further epidemiological studies to clarify the relationship between chemical form, exposure pathways, and health outcomes in this specific context. These findings align with studies linking low-level exposure to BeS and CBD in other occupational settings [4] [12]. The small sample size and convenience sampling reflect this study's range-finding intent and may introduce selection bias, but they highlight gaps in dermal exposure assessment.

Future studies should expand sampling and adopt frameworks like those in Naylor *et al.* (2021) [6] to quantify risks from surface-to-skin transfer in abrasive blasting contexts.

5. Conclusion

This study confirms that abrasive blasters and laborers encounter detectable beryllium on their skin (up to 0.456 μg/wipe) during operations with coal and copper slag, despite PPE, highlighting a dermal exposure risk. Breathing zone levels (<0.107 $\mu g/m^3$) were below the OSHA PEL, and bulk slag contained trace beryllium (0.42 - 0.73 ppm). These preliminary data suggest current protections may not fully prevent dermal exposure, challenging OSHA's 2020 exclusion of skin contact as a risk management trigger. Further research is needed to quantify risks from incidental pathways and genetic factors, improving safety measures for construction workers using slag abrasives.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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