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ABSTRACT

The 55th Aircraft Maintenance Squadron is based out of Offutt Air Force Base (AFB). The organization has requested testing of Air Ground Equipment (AGE) maintenance operations for heavy metals, specifically cadmium and chromium while evaluating one break area for the harmful compounds. It is hypothesized that heavy metals may be in excessive limits and could potentially harm staff and their families as take-home toxins. If left uninvestigated and evaluated, excessive exposure to heavy metals could cause injury or illness within the unit's ranks, decreasing unit effectiveness and efficiency. Sampling methods include preliminary assessments of break area and adjacent glass bead blasting chamber. Research teams will utilize NMAM 7300 and air sampling equipment with a flow rate of 2.0 L/min while subjects complete maintenance operations and utilize the break area which was always occupied by facility staff. Source and area samples will be taken from workspaces that are exposed blasting operations i.e., locker rooms, PPE doffing, and break areas. Collection of heavy metal contaminants, through the guidance of NMAM 9102 and wipe samples from furniture, subjects and high contact areas will be completed to evaluate personal hygiene and housekeeping practice. Samples will be processed and analyzed by an ALS Lab in Salt Lake City, UT and consolidated in an excel data base. Results illustrate an over exposure to cadmium and chromium while blasting operations occur. Worker was exposed to 0.0068 mg/m^3 of cadmium and a chromium exposure of 0.717 mg/m^3. Chromium exposure was 7x higher than the ceiling levels established by OSHA. Both instances exceed the national limit. Wipe samples verify a presence of heavy metals in the break area. Leading this study to believe housekeeping and hygiene practices are insufficient to prevent exposure to potentially hazardous metals. Per the UNMC IRB office no IRB support or approval was required for this project.

INTRODUCTION

This report specifically aims to identify any instance of exposure to heavy metals in workspaces and break areas of an aircraft maintenance bay onboard Offutt Air Force Base. The threat of overexposure to potentially hazardous agents could cause significant negative health outcomes amongst workers who are employed by the U.S. Airforce while diminishing operational effectiveness. Upon completion of this study, the research team will effectively be able to validate one break area and provide the organization with recommendations to reduce exposure to heavy metals through the use of engineering, administrative and PPE controls supported with empirical evidence through the use of various sampling methods. In the article "Heavy Metals Toxicity and the Environment" by Paul B. Tchounwou, it is estimated that about 2.3% of the U.S. population has elevated levels of urine cadmium (>2µg/g creatinine), a marker of chronic exposure and body burden. In previous cases around the United States, over exposure to heavy metals occurs from sanding or abrasive blasting from aircraft and automotive parts. Nonetheless, repeated exposure to heavy metals can elevate a worker's risk of developing a plethora of long-term health outcomes.

Toxicological considerations

Cadmium and chromium are some of the most toxic heavy metals as per The Agency for Toxic Substances and Disease Registry (ATSDR) ranking. Cadmium is used in a verity of items, to including electroplating, storage batteries, vapor lamps and solders. The onset of symptoms may be delayed for two to four hours after exposure. The National Organization for Rare Disorders (NORD) illustrates that cadmium overexposure could cause fatigue, headaches, nausea, vomiting, abdominal cramps, diarrhea, and fever, all very common symptoms that may be overlooked. Moreover, repeated overexposure can cause acute emphysema, pulmonary

edema, and even breathlessness (NORD, 2006). Chromium is more active in penetrating the cell membrane through passages for isoelectric and isostructural anions channels and these chromates are taken up through phagocytosis. Chromium is a strong oxidizing agent. In a study conducted by Richard Enander, it was confirmed that exposure to heavy metal dusts and other take-home toxics are very common on clothes and boots of workers who complete vehicle sanding using in non-ventilated facilities and could be easily compared to operations at Offutt AFB. Enander also illustrated lab of 0.06 (Cd) to 81 (Mg) (μg/in²) of cloth of employees who sanded vehicles without ventilated equipment (Enander, 2002). The Environmental Protections Agency (EPA) states that heavy metals such as lead, cadmium and chromium are an emerging class of carcinogenic metals that could develop liver cirrhosis, liver cancer and kidney tubular dysfunction and osteoporosis in susceptible populations stressing both healthcare, welfare and worker compensation systems (Goyer, 2001).

METHODS

Description of Study Site

The 55th Mission Support Group (MSG) provides vital mission support for Offutt Air Force Base (AFB) through engineering, defense, mission support services, supply, transportation, contracting and deployment readiness programs. In addition, the 55th MSG supports associate units, including U.S. Strategic Command, Air Force Weather Agency, National Airborne Operations Center, and presidential-tasked global reconnaissance missions**.** The 55th Aircraft Maintenance Squadron is a group of 700 military and contractor technicians dedicated to providing mission capable intelligence, surveillance, reconnaissance and national command and control aircraft and deployment teams to 12 squadrons in six countries. Offutt AFB has moved most staff and operations to the Airport in Lincoln, Nebraska to allow for

Cadmium and Chromium Evaluation of Offutt Air Force Base Aircraft Maintenance Bay surfacing of the runway at Offutt AFB. Personnel remaining within Offutt that conduct maintenance are made up of 23 males and zero females, nine of which are military and 14 civilians to continue aircraft maintenance. Maintenance personnel conduct structural maintenance minor paint/coating removal, corrosion control glass bead blasting and composite repair jobs 2-3 times per week while utilizing various Personal Protective Equipment (PPE) i.e., Dupont Tyvek Suit, Gortex Aerostar Coveralls and 3M Company 7800S Full APR with Organic Vapor/HEPA cartridges. The maintenance squadron also utilizes administrative controls to train workers on potential hazards associated with their daily jobs. Employees are trained for ergonomic awareness, personal hygiene, Hazard Communication (HAZCOM) and on cadmium and chromium Occupational Safety and Health Administration (OSHA) expanded standards on an initial and annual basis.

Preliminary assessment

A preliminary assessment of break area, blasting chamber and adjacent workspaces was performed one week prior to sample collection. Figures 1 in Appendix A outlines a contamination flow chart of the blasting area, doffing area, and locker rooms. This assessment documented potential hazards, daily operations, temperature, and humidity in these locations while determining locations of area samplers in the workspaces and means of particulate transportation into the designated break area. During this assessment a large fan was documented in the doffing area which was used on hot days to keep workers cool as seen in Figure 2 of Appendix A. This fan was removed before sampling occurred within the blasting area. Daily operations were observed, and worker was monitored in their daily tasks as seen in Figure 3 of Appendix A. The research team observed personal donning, doffing and hygiene procedures which allowed for multiple opportunities of contamination and exposure to hazardous

Cadmium and Chromium Evaluation of Offutt Air Force Base Aircraft Maintenance Bay compounds. Command leadership and Maintenance Manager, were available to support, evaluate and determine daily operations and the optimal time and days to collect samples. The primary focus of this study was to determine if potentially harmful compounds could be transported to the break area. It was observed that the worker completes blasting operations, removes gloves and helmet inside the enclosed blasting chamber, then moves to the doffing area to hang helmet and gloves. The workers then sit in a chair in a shower area off the locker room which was divided by a sliding glass door. The worker sits in a chair and removes tape and boots. Slips suit to their ankles and sits back on the contaminated chair. Finally, the worker will place socked feet on a black pat that was covered by the suit to then don street shoes, washes hands with a generic bar of soap and departs through the locker room to the break area to hydrate while on break.

Air sampling methods

National Institute of Occupational Safety and Health (NIOSH) Manual of Analytical Methods (NMAM) 7300 was used as a standard sampling method for all personal and area samplers. A 5.0-μm, 37mm SKC polyvinyl chloride (PVC) membrane with a flow rate of 2 L/min was used for all samplers. The research team utilized five GilAir Plus personal samplers provided by the Offutt AFB Bioenvironmental Department as seen in Figure 4 of Appendix A. These samplers were pre and post calibrated for 2000cc utilizing a DryCal DC lite Primary Flow Meter. Area samplers were placed in the break area, locker room, doffing area and behind the blasting chamber. These locations were strategic in determining if hazardous levels of cadmium and chromium were present in the air and how far they circulated from the main chamber door which can be found in Figures 5-7 in Appendix A. These locations would also assist the team in determining effectiveness of doffing and cleaning practices. One personal sampler was placed on the worker who entered the chamber and complete blasting operations, this sample would also

act as a source sample. Air samples needed to be swapped and refreshed to avoid overexposing sample media as seen in Figure 8 of Appendix A.

Wipe sample methods

To determine the presence of heavy metals, wipe samples from furniture, common touch points (e.g., tables, appliances, and countertops), employee hands, and socks will be sampling locations of choice with the use of Ghost Wipes. NMAM 9102 was used as a guide to collect wipes. Samples were taken from shelving units within the blasting area, and common touch points before and after cleaning which occurs in all workspaces at the end of every day. Wipe samples were collected from subject's hands, forearms, palms, and socks before and after blasting operations which will validate personal hygiene practices and operating procedures for effectiveness in reducing exposure take-home toxics and pathways of dermal contact and ingestion. Within the break area, composite wipe samples were collected from tables, desks, air vents, and counter tops to include common touch spots on microwaves and refrigerators.

Sample were collected, packaged, and sent to an ALS lab in Salt Lake City Utah for processing. Results from the samples were then consolidated in an excel data base and compared to federal standards from OSHA, NIOSH and American Conference of Governmental Industrial Hygienists (AGCIH) as seen in Table 1. The research team then developed and comprised recommendations for maintenance managers and the Offutt AFB Bioenvironmental Department.

Table 1: National Standards			
Compound	**OSHA PEL**	**NIOSH REL**	**ACGIH 2021 TLV**
	8-hour TWA	Up to 10-hour TWA	8-hour TWA
Cadmium	0.005 mg/m^3	N/A	0.01 mg/m^3 (total) 0.002 mg/m^3 (resp.)
Chromium (VI)	0.005 mg/m3	0.0002 mg/m^3	0.0002 mg/m^3
Footnote: OSHA standards Chromium Ceiling: 0.1mg/m3 ACGIH 2021 TLV STEL 0.0005 mg/m3			

RESULTS

This study focused on the work performed glass bead media abrasive blasting on AGE structures over a two-day period since it was the largest source of potential exposure. At any given time, there was five to six MSG employees in the break area at once. Table 2 illustrates empirical results from air samples taken over a two-day period. It was determined that the worker was exposed to 0.0068 mg/m^3 of cadmium on the first day and 0.0041 mg/m^3 on the second day over a course of and 8-hour shift. The main source of exposure occurred in the enclosed blasting chamber over a course of 473 minutes over two days. Samples show evidence of 0.717 mg/m^3 of chromium exposure on the first day and 0.327 mg/m^3 on the second day. PVC filters for the worker needed to be exchanged after the first 146 minutes to avoid overexposure of the media as seen in Figure 8 of Appendix A. Other area samplers in the doffing area, blasting area, locker room and break area showed limited exposure to the two metals. However, we cannot rule out that these compounds are not present in these areas after witnessing employee doffing, hygiene, and housekeeping practices. As compared to the national standards, Cadmium exposure of the worker in the blast chamber exceeded the OSHA PEL by 0.0018 mg/m^3, while chromium exposure was 7x higher than the ceiling levels established by OSHA.

Table 2: Air Sample Results

Day	Serial #	Location	Date	Temp/Humidity	Total Time (Mins)	Volume (m3)	Concentration (mg/m3)	
	1/1	Field Blank	15-Sep-21		X	X	Cd	Cr
	1/2	Personal Blasting Chmb	15-Sep-21		146	0.289299	0.0029	0.27
	1/3	Doffing Area	15-Sep-21		314	0.607119	<0.00012	0.0021
1	1/4	Blasting Area	15-Sep-21	79.5 F/56.8%	313	0.609098	<0.00012	0.0021
	1/5	Locker Room	15-Sep-21		340	0.67898	<LOD	0.0018
	1/6	Break Area	15-Sep-21		344	0.67854	<LOD	0.0018
	1/7	Personal Blasting Chmb 2	15-Sep-21		92	0.192298	0.0038	0.44
	2/2	Personal Blasting Chmb	16-Sep-21		123	0.2413875	0.0034	0.26
	2/3	Doffing Area	16-Sep-21		325	0.626275	<0.00012	0.002
2	2/4	Blasting Area	16-Sep-21	74.3 F/ 57.6%	321	0.6235425	<0.00012	0.002
	2/5	Locker Room	16-Sep-21		329	0.6571775	<LOD	0.0019
	2/6	Break Area	16-Sep-21		337	0.6704615	<LOD	0.0019
	2/7	Personal Blasting Chmb 2	16-Sep-21		112	0.2198	0.00078	0.049

Footnote: Limit of Detection (LOD) for Cd was 0.075 ug and the LOD for Cr was 1.3 ug.

Table 3 illustrates finding of cadmium and chromium from various sampling sites in the MSG facility. These samples were strategically taken to evaluate the effectiveness of housekeeping and personal hygiene practices. Wipe samples W1/1 was taken from shelving units in the blasting area which show positive traces of both metals. As seen in sample W2/1 cleaning practices are ineffective and heavy metals remain present in the area. Table 3 also illustrates positive findings of both compounds before and after the worker washed their hands. This evidence supports the organizational need to purchase soaps that are more effective at removing electrostatic heavy metals from worker's skin. Wipe samples W1/4 and W2/4 also provide evidence of possible take home toxins. As the member doffs protective clothing and boots, the suit encounters furniture, and a black pad the employees use to prevent their feet from touching the contaminated floor. The worker then inserts the contaminated sock into a street shoe that was used to walk through the contaminated blasting area to hang PPE in the doffing area. Finally, wipe samples from the break area table, desk, countertop, appliances, and air vents all show evidence and the presence of cadmium and chromium in the break area. These findings highlight housekeeping discrepancies and offer these potentially hazardous compounds additional pathways to cause acute and chronic injuries and illnesses to include dermatitis, eye and throat

Cadmium and Chromium Evaluation of Offutt Air Force Base Aircraft Maintenance Bay irritation and the development of potentially deadly diseases as they relate to workplace exposures.

Table 3: Wipe Sample Results

Day	Sample Type	Serial #	Location	Date	Mass (ug)	
					Cd	Cr
1	Wipe	W1/1	Blasting Area	15-Sep-21	2.10	5.9
	Wipe	W1/2	Worker Sleeve Pre-Clean	15-Sep-21	0.24	32
	Wipe	W1/3	Worker Sleeve Post-Clean	15-Sep-21	<0.075	1.6
	Wipe	W1/4	Socks	15-Sep-21	0.08	6.2
	Wipe	W1/5	Break Area	15-Sep-21	0.35	2.7
	Wipe	W1/6	Break Area Air Vent	15-Sep-21	0.39	1.7
	Wipe	W1/7	Eating Area/Counter/Appliances	15-Sep-21	0.29	<1.3
2	Wipe	W2/1	Blasting Area	16-Sep-21	2.30	5.4
	Wipe	W2/2	Worker Sleeve Pre-Clean	16-Sep-21	0.25	16
	Wipe	W2/3	Worker Sleeve Post-Clean	16-Sep-21	<0.075	1.9
	Wipe	W2/4	Socks	16-Sep-21	<0.075	4.3
	Wipe	W2/5	Break Area	16-Sep-21	0.21	<1.3
	Wipe	W2/6	Break Area Air Vent	16-Sep-21	0.33	1.4
	Wipe	W2/7	Eating Area/Counter/Appliances	16-Sep-21	0.24	1.7

DISCUSSION

The preliminary assessment identified potentially hazardous practices i.e., industrial sized fans within the abrasive blasting area. This employee practice offered additional methods and pathways of additional exposure throughout the area that could have exposed workers and adjacent departments to heavy metals. This practice was quickly corrected by the maintenance manager before sampling could occur, which also demonstrates management's commitment to fostering a safe environment for all workers. Sampling methods effectively identified the presence of two heavy metals in the break area and addressed areas of improvement in housekeeping and hygiene practices to reduce exposures for all workers. The research team utilized a double glove method to maintain quality control of wipe samples every wipe sample and subject. Employees became aware of their actions during this observation and made

immediate correction to reduce personal exposure and contact with contaminated surfaces to avoid transporting hazardous metals to the break area or residence. Limitations of this study include unknown respiratory protection programs within the organization. It is highly recommended the MSG adhere to and implement guidelines established by OSHA and perform periodic monitoring at least every 6 months if initial monitoring shows employee exposure at or above the action level (2.5 ug/m^3 calculated as an 8-hour time-weighted average) (OSHA, 2006). Provide appropriate personal protective clothing and equipment when there is likely to be a hazard present from skin or eye contact. This includes the use of PPE inside the workers suit and helmet to reduce additional exposure while doffing and donning dusty and contaminated equipment. It is also recommended the worker be provided an additional set of boots that can be used while cleaning and traversing any contaminated area, leaving street shoes clean and available to be worn outside contaminated areas i.e., locker rooms and break areas. Implement good personal hygiene and housekeeping practices with visible signage to reduce heavy metals exposure and take-home toxins. Use and purchase soaps with isostearamidopropyl morpholine lactate (ISML), and a weak acid (citric acid). As per NIOSH recommendations, these products will be more effective at removing electrostatic compounds that have adhered to the worker's skin (Surabian, 2009).

Biomedical monitoring

With no IRB approval, there was no supporting data available to evaluate blood and urine analysis for heavy metals amongst employees. It is also recommended that the organization make medical examinations readily available to employees on a semi-annual or annual basis to include routine blood and urine testing for heavy metal exposure. It is also an unknown source of air vent contamination. Contamination found in the air vents of the break area could be from a

potentially contaminated source, which may require further research. Finally, the contamination of common areas cannot be traced back to one single department. There are multiple departments that utilize smaller abrasive blasting units for small parts, departments also use welding and other machinery that could potentially cause additional exposure and foster the transportation of hazardous materials. This study also was limited to only cadmium and chromium. The presence of other heavy metals could not be determined by this study alone.

CONCLUSION

It can be concluded that there is a presence of heavy metals in the break area of the MSG on Offutt Air Force Base. The organization needs to develop a robust plan to minimize exposures and incorporate medical surveillance programs to effectively monitor the overall exposure and health of the work force. Further study and investigation are necessary from the supporting bioenvironmental department to identify and control heavy metal exposures discovered in this study. The mitigation of heavy metal exposure can effectively reduce acute and chronic health outcomes while enhancing unit effectiveness and readiness for all aircraft operations.

REFERENCES

ACGIH, (2021). Adopted Values. In A. C. ACGIH, *2021 Threshold Limit Values for Chemical Substances and Physical Agents* (pp. 18-22). Cincinnati: Signature Publications.

CDC, (2014, December 4). *Cadmium Compounds (as Cd)*. Retrieved from https://www.cdc.gov: https://www.cdc.gov/niosh/idlh/7440439.html

Goyer, R. (2004, August 19). *Issue Paper on The Human Health Effects Of Metals*. Retrieved from https://www.epa.gov: https://www.epa.gov/sites/default/files/2014-11/documents/human_health_effects.pdf

Industrial Hygiene Chemistry Division, (2010, May). *Validation Guidelines For Air Sampling Methods Utilizing Chromatographic Analysis*. Retrieved from https://www.osha.gov: https://www.osha.gov/sites/default/files/methods/chromguide.pdf

NIOSH, (2003, March 15). *NIOSH Manual of Analytical Methods (NMAM) method 7300, Issue 3*. Retrieved from https://www.cdc.gov: https://www.cdc.gov/niosh/docs/2003-154/pdfs/7300.pdf

NIOSH, (n.d.). *NIOSH Manual of Analytical Methods (NMAM) 9102 Issue 1*. Retrieved from https://www.epa.gov: https://www.epa.gov/sites/default/files/2015-07/documents/niosh-9102.pdf

NORD, (2006). *Heavy Metal Poisoning*. Retrieved from https://rarediseases.org: https://rarediseases.org/rare-diseases/heavy-metal-poisoning/

REFERENCES CONT.

OSHA, (1993, February 15). *Hexavalent Chromium*. Retrieved from https://www.osha.gov: https://www.osha.gov/sites/default/files/methods/id215_v2.pdf

OSHA, (2006, July). *OSHA Facts Sheet, Health Effects of Hexavalent Chromium*. Retrieved from https://www.osha.gov: https://www.osha.gov/sites/default/files/publications/hexavalent_chromium.pdf

OSHA, (2020, February 18). *Occupational Safety and Health Standards, 1910 Subpart Z, toxic and Hazardous Substances*. Retrieved from https://www.osha.gov: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1027

OSHA, (2021, September 24). *Permissible Exposure Limits – Annotated Table Z-1*. Retrieved from https://www.osha.gov: https://www.osha.gov/annotated-pels/table-z-1

Surabian, K. T. (2009, October 20). *Wipes and Methods for Removal of Lead and Other Metal Contamination from Surfaces*. Retrieved from https://www.ott.nih.gov: https://www.ott.nih.gov/bundle/tab-3391

Tchounwou, P. B. (2014, August 26). Heavy Metals Toxicity and the Environment. Retrieved from https://www.ncbi.nlm.nih.gov: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4144270/

Appendix A

Figure1: Contamination workflow chart

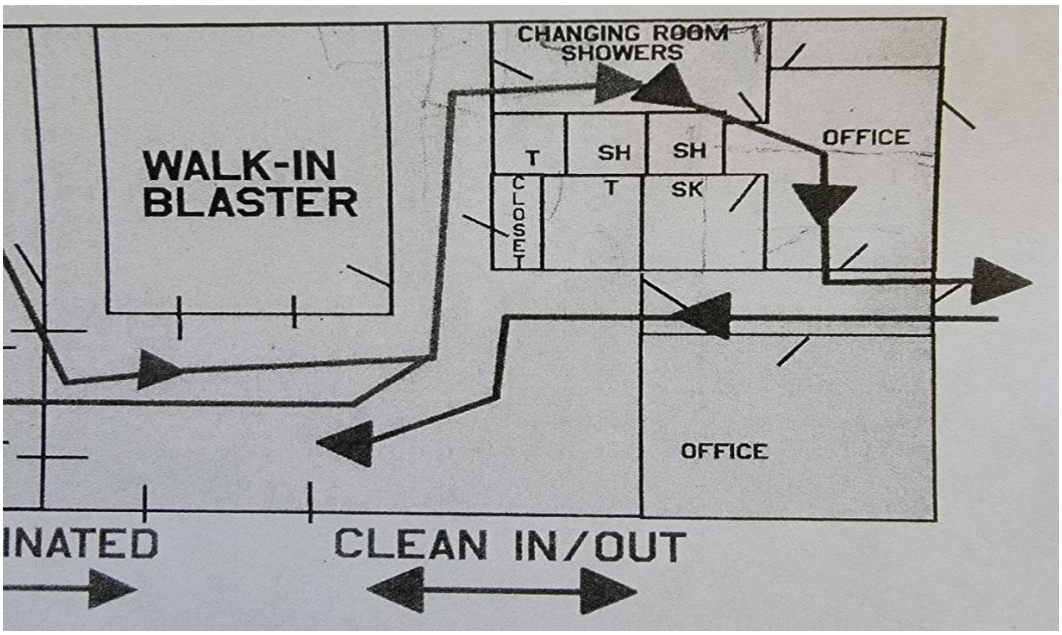

Figure 2: Blasting and doffing area

Figure 3: Glass bead blasting operations

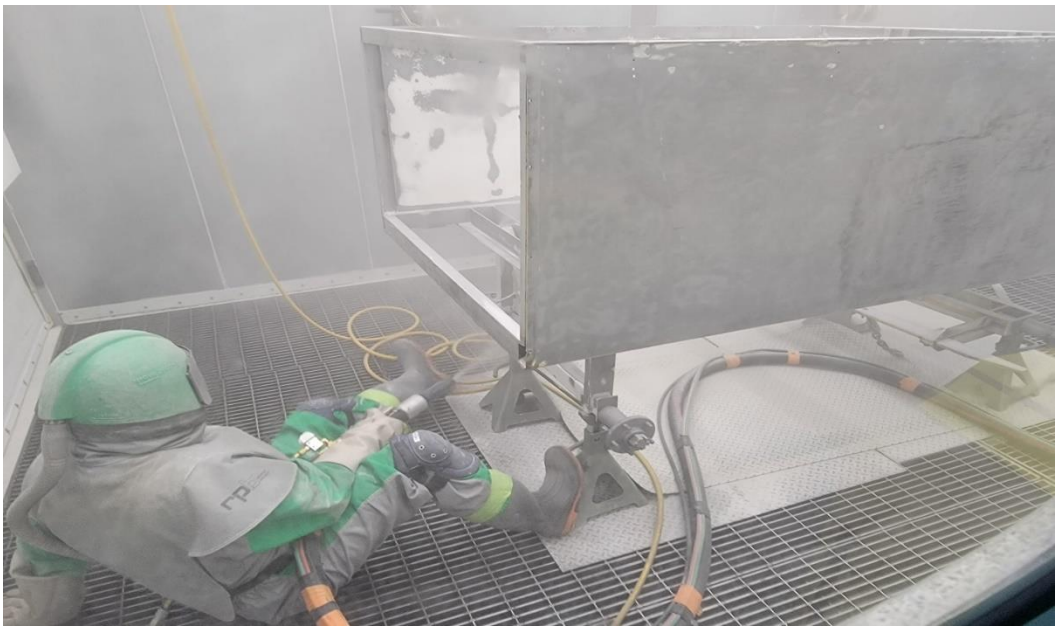

Figure 4: Personal air sampler and calibration unit

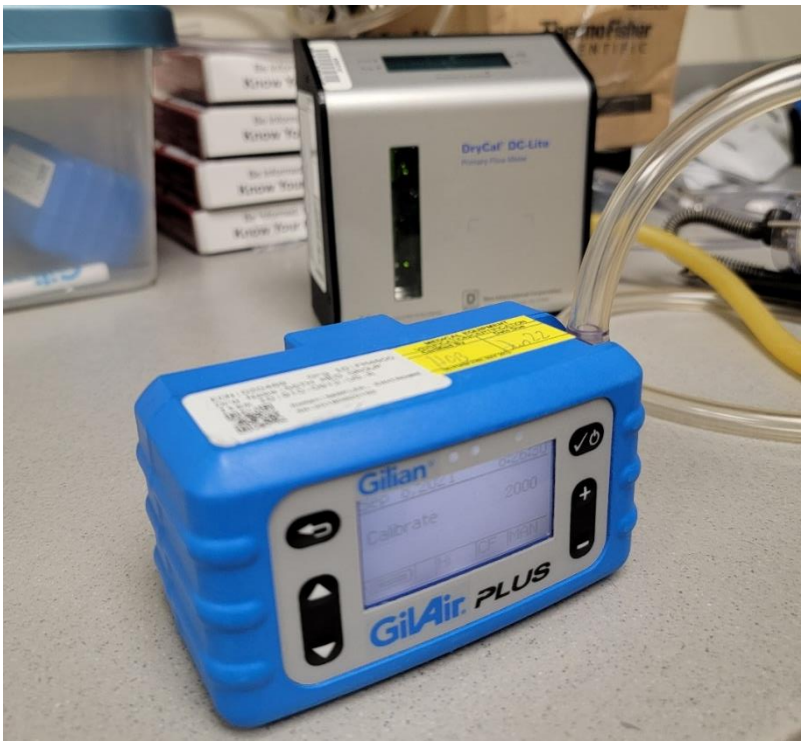

Figure 5: Area sampler posterior door of blasting chamber

Figure 6: Area sampler in doffing area

Figure 7: Area sampler stagged in break area