Evaluation of Occupational Brake Dust Exposures at a Hydroelectric Dam

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Health Hazard
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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a safety manager at a hydroelectric dam. The request concerned employee's exposures to elements (metals and minerals) in dust generated when applying the brakes to hydroelectric turbine generators.

What We Did

- We evaluated brake dust cleaning activities on unit 2 of the dam.
- We tested air, employees' hands, and work surfaces for metals and minerals when brake dust was cleaned from one of three electrical generators.
- We evaluated the brake dust particles for size, shape, and elemental composition.

What We Found

- Employees were not overexposed to metals and minerals in the air.
- We found metals and minerals on the skin of utility workers at lunch and before they went home.
- We found metals and minerals on work surfaces outside of work areas.

What the Employer Can Do

- Evaluate employee's exposures to metals and minerals in the air during brake dust cleaning of the other two generators.
- Base respiratory protection requirements for brake dust cleaning on results from this report and subsequent exposure monitoring.

We measured employees' exposures to elements in the air, on their hands, and on surfaces inside and outside of work areas during generator brake dust cleaning at a hydroelectric dam. Concentrations of elements in the air were well below their occupational exposure limits. Elements were detected at low concentrations on hands and surfaces. We recommended evaluating exposures while cleaning the other two generators.

What Employees Can Do

- Wear required personal protective equipment.
- Participate in a labor-management safety and health committee.

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Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
$\mu g/m^3$	Micrograms per cubic meter of air
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure limit
TLV®	Threshold limit value
WEEL™	Workplace environmental exposure level

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Introduction

The Health Hazard Evaluation Program of the National Institute for Occupational Safety and Health (NIOSH) received a request from the safety manager at a hydroelectric dam. The manager was concerned about employee exposures to elements (metals and minerals) in brake dust when cleaning the brake and brush housings of hydroelectric turbine generators. We visited the dam in March 2015 to tour the powerhouse and learn about the planned maintenance schedules for each of the dam's three generators (units 1, 2, and 3). We visited the dam again in September 2015 during the scheduled shutdown of generator unit 2 to collect air, wipe, and bulk brake dust samples for elemental analysis. In October 2015, we sent letters to employer and employee representatives summarizing our preliminary results and recommendations. We notified participants of their sampling results in December 2015.

Background

Construction of the dam and powerhouse was completed in 1973. Figure 1 shows a cross-section of a typical hydroelectric dam, showing generators, turbines, and the penstock (a pipe that directs water from the reservoir through the turbines). The powerhouse contains three turbines. Units 1 and 2 are the same size, and unit 3 is twice the size of units 1 and 2. The configuration of this dam and powerhouse was similar to that illustrated in Figure 1.

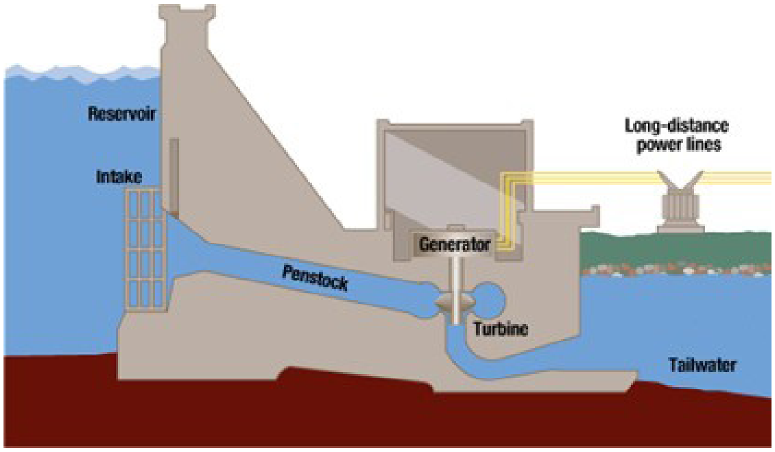

Figure 1. Cross-section of a hydroelectric power generation dam. Image courtesy of Tennessee Valley Authority, https://www.tva.gov/Energy/Our-Power-System/Hydroelectric/How-Hydroelectric-Power-Works.

Figure 2 is a diagram of a typical hydroelectric generator and turbine. The brake and brush housings (not shown in this figure) are located above the generator. The equipment at this dam was similar to that illustrated in Figure 2.

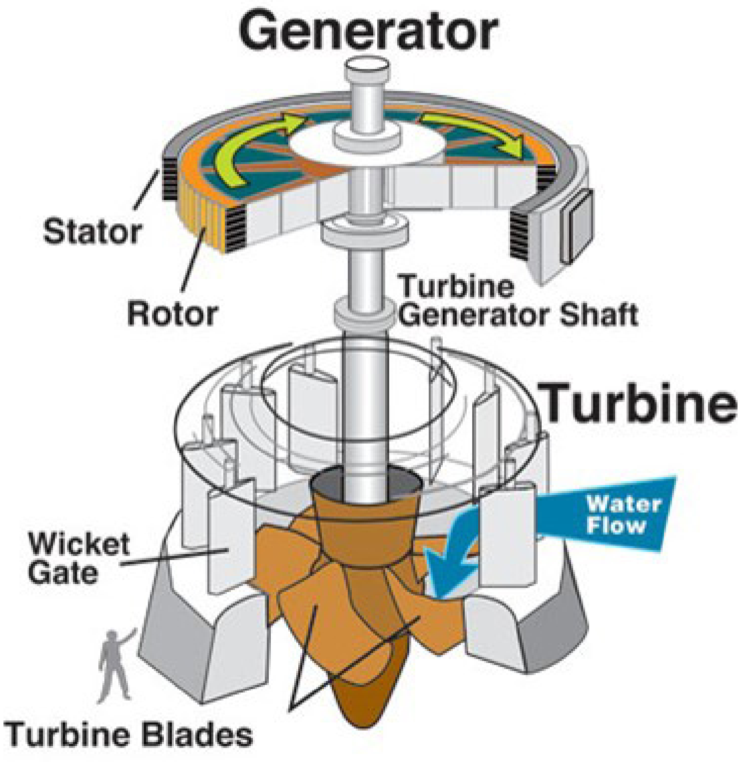

Figure 2. Diagram of a hydroelectric generator and turbine. Image courtesy of U.S. Geologic Survey, http://water.usgs.gov/edu/hyhowworks.html.

During this evaluation, 14 employees worked in the powerhouse performing maintenance tasks (i.e., electrical and plumbing repairs, carpentry, and painting) and office work. Powerhouse operators at the dam shut down each of the generators at least once annually for cleaning, inspection, and maintenance of the turbines and supporting equipment. Our evaluation was during the scheduled shutdown of unit 2.

Turbine Maintenance

When a turbine is slowed or stopped, brake dust is produced and accumulates on surfaces inside the turbine's brake housing. Managers told us that brake dust migrated from the brake housing to the brush housing, and then eventually escaped though the four vents at the top of the unit. Employees were required to remove accumulated brake dust before performing any maintenance in the brake and brush housings.

During our evaluation, two employees (utility workers) cleaned brake dust from unit 2. These employees used small vacuums equipped with high-efficiency particulate air filters, and cloth rags wetted with Hygenall® LeadOff™ surface cleaner. They wore disposable coveralls with booties, and nitrile gloves. Sticky mats were placed at the entrance to the work areas.

Methods

Our objectives were to (1) evaluate utility employees' exposures to minerals and metals while cleaning brake dust; (2) evaluate exposures among other employees working in the powerhouse; and (3) characterize the dust emissions during braking events.

Dust Sampling

We collected a sample of dust from the brake housings of units 2 and 3 and analyzed these samples following NIOSH Method 7303 [NIOSH 2017]. These samples were also evaluated using energy dispersive spectroscopy and photographed using scanning electron microphotography to supplement the laboratory analysis and the particle characterization data collected from direct reading instruments.

Air Sampling

In September 2015, we collected 49 breathing zone air samples from 12 employees for total dust over 5 days. The samples were analyzed for minerals and metals according to NIOSH Method 7303, modified to use Solu-CAP™ sample cassettes. We sampled two employees who cleaned the brake and brush housing, and 10 employees performing powerhouse duties unrelated to brake dust cleaning. The utility workers worked a 10 hour shift on the first day, and 12 hour shifts for the remaining 4 days. Most of the other employees in the powerhouse worked four 10 hour shifts, Monday through Thursday. For all employees, we removed our sampling equipment when their work (or other activities) took them off-site.

We used direct reading, data logging, laser photometers (TSI DustTrak™ DRX Aerosol Monitor 8533) to measure the aerosol mass concentration and particle sizes of brake dust in the air. We started the instruments before braking events began to determine background conditions and then measured when employees applied the brakes to units 2 and 3.

Hand and Surface Wipe Sampling

We collected nine hand wipe samples during four shifts from the two employees cleaning brake dust in the brake and brush housings of unit 2. We used SKC Inc. Full Disclosure® kits to collect the samples following NIOSH Method 9105 [NIOSH 2017].

We collected the hand wipe samples from the employees after they had removed their personal protective equipment and performed personal decontamination procedures when they left the brake or brush housing area for lunch, and at the end of their shift. We wore a new pair of nitrile gloves to open each wipe to avoid cross contamination. The employee removed and unfolded the wipe. We asked the employee to wipe both hands (wrist down to fingers including palm and back of the palm) for 30 seconds using only one side of the wipe. After the employee finished wiping their hands, we examined the wipe for visible color changes. We then stored each wipe in a separate, clean, plastic vial for shipment to the laboratory for quantitative analysis. We analyzed the wipes following NIOSH Method 7303 [NIOSH 2017].

We collected 14 surface wipe samples from work areas in the powerhouse, the offices, and the lunch room. We used SKC Inc. Full Disclosure kits. We wore a new pair of nitrile gloves for each sample we collected to avoid cross contamination. We used a 10 centimeter by 10 centimeter template to outline surface wipe sample areas where possible. For small or irregularly shaped surfaces, we estimated 100 square centimeters of sample area or took a sample of the entire area. We then stored each wipe in a separate, clean, plastic vial for shipment to the laboratory for quantitative analysis.

Results and Discussion

Dust Samples

Results are presented in Appendix A, Table A1. The minerals and metals found in these samples agreed with those listed on the safety data sheets. Barium, calcium, chromium, magnesium, and manganese were the most abundant. Scanning electron microphotographs of brake dust from units 2 and 3 showed a mix of particles and mineral fibers with different shapes and sizes, often observed as clumps ranging from 20 to 100 micrometers in diameter (Appendix B, Figures B1 and B2).

Air Samples

Appendix A, Table A2 presents personal air sampling results for all employees. All personal air sample results for elements in this evaluation were below their most protective occupational exposure limit (OEL). Personal exposures were similar between those employees who did brake cleaning and those who did not, and among the various brake and brush housing cleaning steps. Barium, calcium, iron, and magnesium were among the most abundant elements present in the air samples. Titanium and potassium were present in more than 50% of the personal samples; zirconium, chromium, iron, and manganese were present in approximately one-third of the samples, and many elements were present in only one or two samples, or were not detected at all. The highest exposure to an element relative to its lowest OEL was for manganese, and it was present at just 9% of its OEL (Appendix A, Table A3). Airborne concentrations for all of the remaining elements analyzed were less than 4% of their lowest OEL, and many were less than 1% (Appendix A, Table A3).

On the basis of direct-reading measurements, most of the airborne particles measured at both unit 2 and unit 3 were respirable, and therefore capable of depositing in the deepest parts (the alveolar region) of the respiratory tract. At unit 2, the highest respirable particle mass concentrations, 0.12 milligrams per cubic meter of air, were measured on top of the turbine after engaging the brakes; this peak concentration remained for 30 minutes. At unit 3, the highest respirable particle mass concentrations, up to 0.6 milligrams per cubic meter of air, were measured on top of the turbine after engaging the brakes; this peak concentration also remained for 30 minutes. The higher particle concentrations at unit 3 compared to unit 2 may reflect the larger physical size and mass of unit 3 and the longer duration of the braking event. We did not measure increased respirable particles above background in the powerhouse lunch room or control room, even during turbine braking.

Hand and Surface Wipe Samples

Hand wipe sample results are summarized in Appendix A, Table A4. Detectable levels of elements (predominately calcium, potassium, iron, and magnesium) were found on hand wipes. Employees involved in brake dust cleaning used company-provided Hygenall LeadOff wipes as part of their personal decontamination procedures whenever they left the work area, and employees used these wipes prior to our collection of hand wipe samples.

Surface wipe sample results are summarized in Appendix A, Table A5. Elements (predominately calcium, potassium, iron, and aluminum) were found on work and non-work surfaces. No visible lead was present (the visual limit of detection of the Full Disclosure method is 18 micrograms per sample). The highest surface sample results were from rough concrete floors at the penstock level of the powerhouse and the balcony above the carbon dioxide tanks. Rough concrete floors are more difficult to clean compared to smooth flooring, and these floors may not have been cleaned as regularly as floors nearer the turbines.

There are no OELs for elements on surfaces outside work areas such as change rooms, storage facilities, and lunch room/eating areas. Also, there are no surface contamination criteria or quantifications for skin absorption in Occupational Safety and Health Administration (OSHA) standards, however, some OSHA standards contain housekeeping provisions calling for surfaces to be "…as free as practicable…" of accumulation. During our visit, all surfaces appeared to meet this criterion.

Other Observations

The brake and brush housings in each turbine were each large enough for employees to enter. Because these spaces were not designed for continuous occupancy and had limited means of entry and egress, they were considered by the employer as permit-required confined spaces per 29 Code of Federal Regulations (CFR) 1910.146 [OSHA 2011]. These spaces also meet the NIOSH criteria for a confined space requiring an entry permitting procedure to ensure safe employee entry, work, exit, and rescue [NIOSH 2011]. Evaluating the employer's confined space safety program was outside the scope of this evaluation, and we did not review their written policy. However, we did observe that the safety manager created a permit each time a confined space was entered, and an attendant was assigned to each space whenever an entry occurred. The safety manager stated they had a properly trained and equipped (per the OSHA standard) confined space entrant extraction team on site during these entries.

A written respiratory protection program was in place for employees at the hydroelectric dam, including those employees cleaning brake and brush housings. The safety manager decided whether employees entering brake and brush housings used respiratory protection. This decision was based on professional judgement following a visual inspection of the amount of accumulated dust in brush and brake housing. No respiratory protection was required for employees while they cleaned brake dust in these spaces during our visit, but disposable filtering facepiece N95 respirators were available for voluntary use. We did not see them in use.

No written housekeeping procedures existed for the general powerhouse area; cleaning was performed as needed. Employees used vacuums equipped with high-efficiency particulate air filters to remove accumulated dust in the work areas of the powerhouse. A housekeeping company was contracted to clean the administration office areas and bathrooms, and powerhouse employees worked together to clean the lunch room. During our site visits, the powerhouse appeared clean and well organized.

Conclusions

Airborne exposures to elements in brake dust were well below their most protective OELs for all powerhouse employees, regardless of work activity or location within the powerhouse. Our particulate sampling results showed that brake dust could escape from the interior of the turbine housing, but did not enter the employee control room or lunch room. Employee hand cleaning practices, the availability of disposable clothing, and the use of sticky mats helped reduce the migration of contaminants from work areas to non-work areas such as the lunch room. On the basis of air sampling results from this evaluation, respiratory protection would not be required for employees cleaning brake dust from turbine unit 2.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage managers at the hydroelectric dam to use a labor-management health and safety committee or working group to discuss our recommendations 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 hydroelectric dam.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix C). This approach groups actions by their likely effectiveness in removing or reducing 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 personal protective equipment may be needed.

Administrative Controls

The term administrative controls refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently. NIOSH recommends the following administrative controls:

1. Monitor employee exposures during brake and brush housing cleaning of turbine units 1 and 3. Use that data, along with the results from this evaluation, to decide whether respiratory protection is necessary to safely enter brake and brush housings for all turbines. If respirators are needed, select them using NIOSH Respirator Selection Logic [NIOSH 2006], and use them as a part of a comprehensive respiratory protection program (per OSHA respiratory protection standard 29 CFR 1910.134). Update exposure monitoring data if process changes or work practice changes may increase employee exposures.

Appendix A: Tables

Table A1. Results for elements in bulk brake dust samples, in milligrams per kilogram

Element	Unit 2	Unit 3
Aluminum	6,100	13,000
Antimony	[14]	15
Arsenic	ND	8.7
Barium	19,000	14,000
Beryllium	1	1.3
Cadmium	34	48
Calcium	64,000	130,000
Chromium	550	790
Cobalt	480	700
Copper	4,300	890
Iron	170,000	220,000
Lanthanum	ND	ND
Lead	190	84
Lithium	7.4	12
Magnesium	14,000	29,000
Manganese	1,200	2,100
Molybdenum	ND	44
Nickel	24	47
Phosphorus	410	200
Potassium	1,100	1,800
Selenium	440	600
Silver	0.7	3.5
Strontium	270	140
Tellurium	34	49
Thallium	ND	ND
Tin	ND	ND
Titanium	280	610
Vanadium	27	38
Yttrium	3.8	8.2
Zinc	6,400	3,900
Zirconium	10	22

[ ] = This result is between the limit of detection (5 milligrams per kilogram) and limit of quantitation (15 milligrams per kilogram); more uncertainty is associated with this level.

ND = The element was not detected (20 milligrams per kilogram or lower)

Table A2. Personal air sampling results for selected elements in total dust, in µg/m^3

Day	Job title	Time	Barium	Chromium	Copper	Iron	Potassium	Manganese	Titanium	Zinc
1	Mechanic*	398	ND	ND	[0.11]	15	ND	[0.10]	ND	[0.97]
	Supply technician*	406	ND	ND	ND	ND	ND	ND	[0.061]	ND
	Engineer*	551	ND	ND	ND	ND	ND	ND	[0.030]	[0.33]
	Electrician 1	447	ND	[0.17]	[0.092]	ND	[0.42]	ND	[0.037]	[0.35]
	Compliance	442	ND	ND	ND	58	ND	[0.24]	0.21	ND
	Contract specialist	463	ND	ND	ND	ND	ND	ND	ND	ND
	Draftsman	549	ND	ND	ND	ND	[0.31]	ND	[0.045]	ND
	Section chief	541	ND	ND	3.3	ND	[0.53]	5.7	ND	ND
	OSH specialist	580	ND	ND	ND	ND	ND	ND	[0.043]	[0.24]
	Operator	564	ND	ND	ND	ND	ND	ND	ND	ND
	Electrician 2*	564	ND	ND	ND	ND	[1.1]	ND	[0.046]	ND
2	Mechanic	459	ND	[0.094]	ND	[4.6]	ND	ND	ND	ND
	Supply technician	526	ND	ND	ND	ND	ND	ND	[0.031]	ND
	Engineer	575	ND	ND	ND	ND	ND	ND	ND	ND
	Electrician 1	633	ND	ND	[0.11]	[2.1]	[0.35]	ND	[0.078]	0.91
	Compliance*	492	ND	[0.16]	ND	18	4.0	[0.14]	1.0	ND
	Contract specialist	544	ND	ND	ND	ND	ND	ND	ND	ND
	Draftsman	618	ND	ND	ND	ND	ND	ND	ND	ND
	Section chief	639	ND	ND	ND	ND	[0.33]	ND	[0.026]	ND
	OSH specialist	591	ND	[0.067]	ND	ND	[0.34]	ND	[0.074]	ND
	Operator	607	ND	ND	ND	ND	ND	ND	ND	ND
	Utility worker 2	560	ND	ND	0.24	4.5	0.32	ND	ND	[0.27]
	Electrician 2	607	ND	ND	7.0	ND	[0.94]	9.0	[0.054]	[1.0]
NIOSH recommended exposure limit (REL)			500	500	1,000	5,000	2,000	1,000	2,400/30†	5,000
OSHA permissible exposure limit (PEL)			500	1,000	1,000	10,000	None	5,000	15,000	15,000
ACGIH threshold limit value (TLV)			500	500	1,000‡	5,000	2,000	100/20§	10,000	2,000¶

ND = not detected; the limits of detection were 0.3 µg for barium, 0.04 µg for chromium, 0.06 µg for copper, 2 µg for iron, 0.2 µg for potassium, 0.05 µg for manganese, 0.02 µg for titanium, and 0.2 µg for zinc.

[ ] = Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations for this sample set. More uncertainty is associated with these concentrations.

*Employee did not wear sampling pump for full shift.

†The NIOSH REL for fine and ultrafine particles.

‡ACGIH TLV for copper fume is 100 µg/m^3

§The ACGIH TLV is for inhalable and respirable dust

¶The ACGIH TLV is for respirable dust.

Table A2, cont. Personal air sampling results for selected elements in total dust, in µg/m^3

Day	Job title	Time	Barium	Chromium	Copper	Iron	Potassium	Manganese	Titanium	Zinc
3	Supply technician	523	ND	[0.20]	[0.24]	[6.6]	ND	0.42	[0.063]	ND
	Electrician 1*	485	ND	[0.058]	[0.23]	[2.6]	[0.42]	ND	[0.075]	1.3
	Compliance	320	ND	ND	ND	5.4	[0.69]	ND	0.31	ND
	Contract specialist*	240	ND	ND	[0.15]	ND	ND	0.20	ND	ND
	Draftsman	400	ND	ND	ND	ND	ND	ND	ND	ND
	Section chief	440	ND	ND	ND	ND	[0.28]	ND	ND	ND
	OSH specialist*	485	ND	ND	ND	4.1	[0.85]	ND	0.20	ND
	Operator	608	ND	ND	ND	ND	ND	ND	ND	ND
	Utility worker 1	480	[0.57]	[0.11]	[0.14]	[7.1]	[0.44]	ND	ND	ND
	Utility worker 2	595	[0.68]	ND	[0.089]	7.6	[0.68]	ND	ND	ND
	Electrician 2	400	ND	[0.10]	[0.089]	ND	[0.32]	ND	ND	ND
4	Supply technician	513	ND	[0.32]	ND	2.2	ND	0.35	0.10	ND
	Compliance*	402	ND	ND	ND	[7.5]	ND	ND	0.25	ND
	Contract specialist	577	ND	[0.11]	ND	ND	[0.30]	0.37	[0.064]	ND
	Draftsman	531	ND	[0.093]	ND	ND	ND	[0.31]	[0.089]	ND
	Section chief	611	ND	[0.14]	ND	ND	[0.81]	[0.16]	0.13	[0.24]
	OSH specialist	471	7.8	0.51	0.40	162	1.1	1.3	0.38	[0.69]
	Operator	300	ND	[0.15]	ND	ND	[0.56]	[0.52]	[0.11]	ND
	Utility worker 1	722	ND	0.16	ND	[2.2]	[0.47]	0.36	0.12	ND
	Utility worker 2	611	ND	ND	ND	ND	ND	[0.12]	ND	ND
	Electrician 2	540	ND	0.24	[0.12]	2.6	[0.57]	0.56	0.11	ND
5	Contract specialist	468	ND	0.25	ND	ND	1.8	0.56	0.13	ND
	Painter	712	2.2	4.3	1.5	99	11	7.5	1.7	4.3
	Utility worker 1	715	ND	0.28	ND	[3.2]	1.0	0.76	0.16	ND
	Utility worker 2	709	[0.36]	0.54	[0.075]	6.3	1.4	0.92	0.18	[0.19]
	Electrician 2	471	ND	0.47	ND	ND	1.3	1.1	0.20	ND
NIOSH recommended exposure limit (REL)			500	500	1,000	5,000	2,000	1,000	2,400/30†	5,000
OSHA permissible exposure limit (PEL)			500	1,000	1,000	10,000	None	5,000	15,000	15,000
ACGIH threshold limit value (TLV)			500	500	1,000‡	5,000	2,000	100/20§	10,000	2,000¶

ND = not detected; the limits of detection were 0.3 µg for barium, 0.04 µg for chromium, 0.06 µg for copper, 2 µg for iron, 0.2 µg for potassium, 0.05 µg for manganese, 0.02 µg for titanium, and 0.2 µg for zinc.

[ ] = Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations for this sample set. More uncertainty is associated with these concentrations.

*Employee did not wear sampling pump for full shift.

†The NIOSH REL for fine and ultrafine particles.

‡ACGIH TLV for copper fume is 100 µg/m^3

§The ACGIH TLV is for inhalable and respirable dust

¶The ACGIH TLV is for respirable dust.

Table A3. Comparing personal air sampling results to the lowest applicable OEL, in µg/m^3

Element	Number of samples	Low	Median	High	Lowest OEL	% of OEL
Titanium	33	0.043	0.17	2.8	10,000†,**	0.028
Potassium	31	[0.28]	0.48	11	2,000*	0.55
Zirconium	23	0.011	0.030	0.22	5,000*	0.0044
Chromium	22	[0.058]	0.16	4.3	500*	0.86
Manganese	22	[0.10]	0.39	9.0	100‡	9.0
Iron [oxide]	20	[3.1]	7.1	162	5,000*	3.2
Copper	18	[0.075]	0.14	7.0	1,000*,§	0.70
Zinc	12	0.24	0.65	5.3	5,000*,¶	0.11
Barium	6	[0.36]	1.4	7.8	500*	1.6
Lead	6	0.17	0.26	2.1	50*	4.2
Yttrium	6	[0.0055]	[0.0071]	[0.0085]	1,000*	0.00085
Aluminum	3	[3.7]	6.4	8.4	1,000†	0.84
Beryllium	3	[0.0077]	[0.0077]	[0.0079]	0.5†	1.6
Antimony	2	[0.37]	[0.44]	[0.51]	500*	0.10
Calcium	2	[12]	37	61	2,000*	3.1
Magnesium	2	12	16	20	None	Not applicable
Strontium	2	[0.070]	0.13	0.20	None	Not applicable
Nickel	1	1.8	1.8	1.8	15*	12
Thallium	1	[0.74]	[0.74]	[0.74]	20†	3.7
Tellurium	1	[0.43]	[0.43]	[0.43]	100*	0.43
Tin	1	[0.21]	[0.21]	[0.21]	2,000*	0.011

[ ] = Values shown in brackets are between the minimum detectable and minimum quantifiable concentrations for this sample set. More uncertainty is associated with these concentrations. The following elements were not detected in any air sample (less than 1 µg/m^3 or lower]: arsenic; cobalt; lanthanum; lithium; molybdenum; phosphorus; selenium; silver; vanadium.

*NIOSH REL (total dust)

†ACGIH TLV (total dust)

‡ACGIH TLV for inhalable manganese. The ACGIH TLV for respirable manganese is 20 µg/m^3

§ACGIH TLV for copper fume is 100 µg/m^3

¶ACGIH TLV for respirable zinc is 200 µg/m^3

**NIOSH REL for fine particles is 2,400 µg/m^3 and 300 µg/m^3 for ultrafine particles

Table A4. Hand wipe results from employees performing brake dust cleaning, in micrograms per wipe

Day	Time	Job	Barium	Calcium	Chromium	Iron	Magnesium	Manganese
2	Before lunch	Utility worker 1	0.73	220	220	39	15	0.49
3	Before lunch	Utility worker 1	7.2	1,800	1,800	130	44	1.6
	Before lunch	Utility worker 2	6.0	1,700	1,700	98	76	1.1
4	Before lunch	Utility worker 2	4.7	850	850	86	130	0.87
	After shift	Utility worker 2	4.9	850	850	110	84	1.5
5	Before lunch	Utility worker 1	5.4	540	540	82	85	0.92
	Before lunch	Utility worker 2	2.2	310	310	50	32	0.68
	After shift	Utility worker 1	9.4	420	420	43	60	0.48
	After shift	Utility worker 2	4.1	1,000	1,000	110	170	1.3

Table A5. Results for select elements on surface wipes, in micrograms per wipe

Sample location	Barium	Calcium	Chromium	Iron	Magnesium	Manganese
Table in lunch room	[0.49]	79	0.094	ND	6.1	0.16
Table in lunch room	[0.4]	150	0.066	ND	7.6	0.09
Refrigerator handle in lunch room	1.5	100	0.68	48	13	0.67
Top of unit 2, by spindle	3.6	170	4.7	100	14	1.1
Top of unit 2, by hatch	2.2	69	1.9	290	5.6	1.3
Top of unit 2, by access panel	2.9	220	9.0	96	14	1.6
Top step of unit 2 brake housing	5.3	590	4.1	240	26	3
Mechanic shop workstation	1.8	340	2.9	120	12	2.5
On balcony above CO_2 tank	53	4,800	390	35,000	260	360
Penstock galley floor	9.9	1,700	110	1,800	100	33
Top of unit 3, floor	12	670	4.0	130	19	1.8
Surface of vent in electric shop	17	1,400	7.6	1,000	93	11
Office desk	0.72	310	0.29	32	13	0.77
Control room equipment top	0.79	370	0.24	27	16	0.4
Limit of detection	0.2	4	0.03	6.	0.1	0.02
Limit of quantification	0.7	10	0.1	20	0.5	0.08

[ ] = Values in brackets are between the LOD and LOQ; more uncertainty is associated with these levels.

Appendix B: Figures

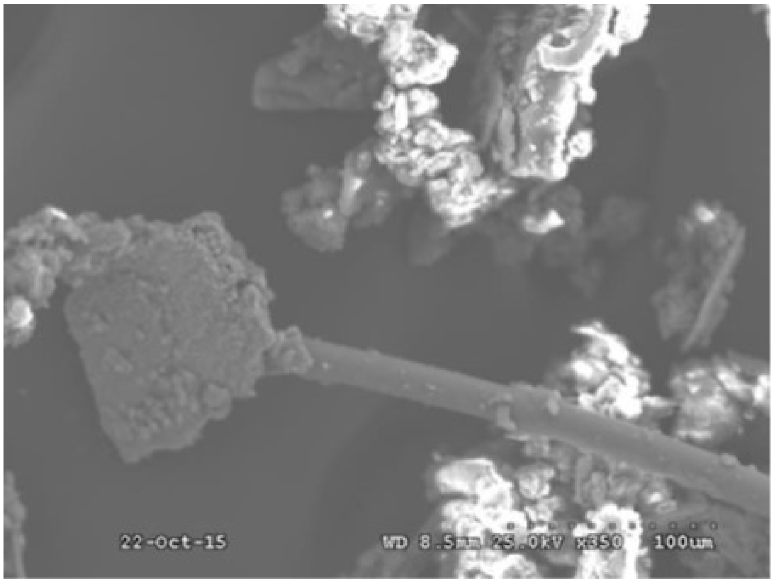

Figure B1. Particles and mineral fibers in dust from unit 2. Image by NIOSH.

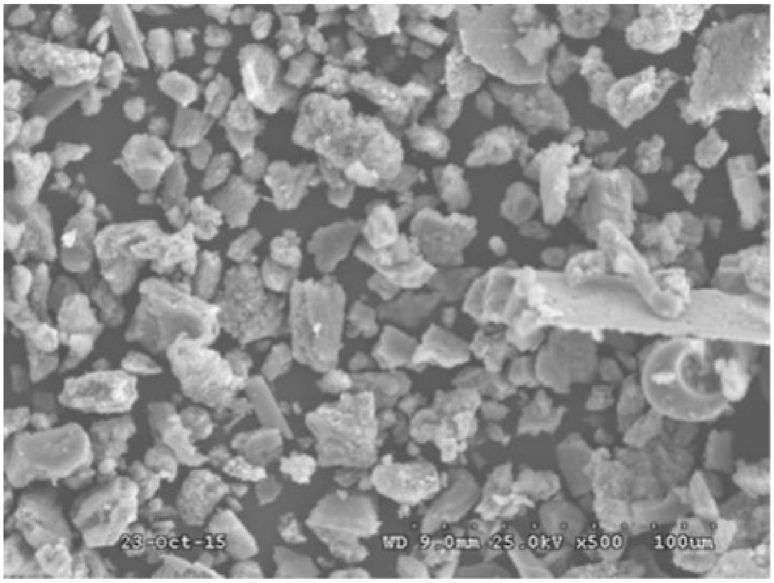

Figure B2. Particles and mineral fibers in dust from unit 3. Image by NIOSH.

Appendix C: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for 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 if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average exposure. A time-weighted average refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits or ceiling values. Unless otherwise noted, the short-term exposure limit is a 15-minute time-weighted average exposure. It should not be exceeded at any time during a workday. The ceiling limit 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; 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. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends 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.
- Another set of OELs commonly used and cited in the United States is the ACGIH TLVs. The TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They 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 2017].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/GESTIS/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 2,000 hazardous substances and is updated periodically.

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))). This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize 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. Control banding focuses on how broad categories of risk should 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 existing OELs.

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Keywords: North American Industry Classification System 221111 (Hydroelectric Power Generation); Idaho; Hydroelectric powerplant; Powerhouse; Elements; Aluminum; Chromium; Iron; Manganese; Zinc; Outage; Utilities; Respirator; Dust; Confined Space

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Copies of this report have been sent to the employer and employees at the facility. The state and local health department and the Occupational Safety and Health Administration Regional Office have also received a copy. This report is not copyrighted and may be freely reproduced.

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