Rare but Significant Exposures: Treating Corroded Cadmium Plating in a Museum Setting

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Overview of Talk

- Hazards and Exposure Risks
- Cadmium at NASM
- Tests conducted
- Biomonitoring
- Results
Hazards of Cadmium, CAS 7440-43-9

- Toxic
- Carcinogen

Dangers:
- Inhalation
- Ingestion
- Contamination

LD50 >5000mg/kg as a pigment
General Sources of Cadmium Exposure

**Smoking:** 1000-3000 ppb in smoke, absorb 1-3 mcg per pack- doubles body burden.

**Food:** Consume 8-30 mcg US/EU diet or 40 ppb- Retain: 1-3 mcg in the body. (EPA drinking water 5ppb)

**Industry:** Smelting (Zn/Cu), electroplating, plastics, Batteries

**Pigments:** CdSe, CdSe+CdS, CdS, CdS+ZnS (especially with pastels or mixing powder to paint/ glaze).
Work related exposures

Major route: Inhalation of Fumes and Dust.

- Incidental ingestion from contaminated hands, food, smoking.
- Heated operations have highest risk (fumes from electroplating, welds, smelting)

Absorption rates by Route

- Breathing: 5-50%
- Ingestion: 1-10%, more if iron or mineral deficient.
- Skin: negligible

Elimination by Route

- Stored in Liver and Kidney, leaves slowly through Urine and Feces.
Cadmium as a coating

- Electroplated to iron, copper, aluminum, or titanium alloys
- Corrodes before base metal
- Pervasive in 20th century technological collections
  - Limited use today

Electroplating baths

Cadmium-plated steel
Military grade AN5 bolts
Project Overview: *Flak-Bait*

Martin B-26B-25-MA Marauder

Nose Interior, Before Treatment
Flak-Bait Nose Insulation Panels

50+ panels needed interventive treatment
Insulation Panel Hardware

Corroded cadmium-plated steel buttons

Snap into aircraft ribs and around instruments
Cadmium Standard Operating Procedures

- Reduce corrosion with damp cotton swabs by hand
- Coat metal to prevent future corrosion

Buttons also needed:
- Spray paint removal
- Iron corrosion treatment

15 - 20 minutes per button
650 buttons
20.3 to 24.4 days!!
Other Treatment Methods Tested:

- Chemical bath: Metal Rescue
  - Manufacturer: Workshop Hero
  - Promising results
  - But, stripped paint

Example Button
Before and After Treatment

Metal Rescue Product Line
Other Treatment Methods Tested:

- Foredom Flex-Shaft rotary tool
  - Mechanized cleaning
  - 220 grit radial bristle disc
- Asked OSHEM to attend tests to conduct air sampling
Foredom Flex Shaft Tests

Treatment tests conducted by Meghann Girard

Air monitoring and wipe samples collected by Chuck Fry
**Foredom Flex Shaft Tests**

**Air Sample Results:**
(8-hour time-weighted average)
settled Cd dust
0.004 mg/m$^3$

OSHA PEL:
0.005 mg/m$^3$

OSHA Action Level:
0.0025 mg/m$^3$

**Key Takeaways:**
- OSHA Action Level triggered
- HEPA vacuum reduced dust by ~85%

**Wipe Sample Results:**

*Note: no OSHA guidance on settled Cd dust*

<table>
<thead>
<tr>
<th>Location</th>
<th>Concentration (mg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table, Before HEPA Vacuum</td>
<td>2850 μg/ft$^2$</td>
</tr>
<tr>
<td>Table, After HEPA Vacuum</td>
<td>445 μg/ft$^2$</td>
</tr>
<tr>
<td>Meghann’s arms, Before Hand Washing</td>
<td>247 μg/ft$^2$</td>
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Occupational Exposure Limits

OSHA: 5 mcg/m³ average over 8 hours.

Under the standard, occupational exposure is defined as an employee's exposure to airborne cadmium in the workplace that is independent of the employee's use of respiratory protective equipment.

Acute inhalation above 5 mg/m³ can cause long term lung damage (pulmonary edema, tracheobronchitis, pneumonitis).

Minimal Risk Levels (MRL)

- Inhalation: 0.03 mcg/m³ acute
- Inhalation >1 year: 0.01 mcg/m³
- Oral: 0.5 mcg/kg/day (less than 1 year)
- Oral 0.1 mcg/kg/day (>1 year)
Symptoms of Cadmium Exposure

**Inhalation:**

**Short term:**
- Low to medium: irritation of nose and throat.
- High: delayed cough, chest pain, sweating, chills, weakness, difficulty breathing (9mg/m3/5h), death (40-50mg/m3/1h).

**Long term:** Loss of sense of smell, emphysema, kidney damage, anemia. Possible increase cancer.

**Ingestion:**

**Short term:**
- Nausea, vomiting, diarrhea, abdominal cramps

**Long Term:** Kidney damage, anemia, loss of bone density. Itai-Itai disease
Biomarker Monitoring

Blood: recent exposure

Urine: Total body burden, can be used to estimate dietary or airborne cadmium exposure.

Fecal: daily dietary intake
Why Medical Surveillance?

Identifies workers who may be at increased risk

Prevent kidney and lung disease

Detect and minimize existing cadmium induced disease
Currently exposed - The employer shall institute a medical surveillance program for all employees who are or may be exposed to cadmium at or above the action level unless the employer demonstrates that the employee is not, and will not be, exposed at or above the action level on 30 or more days per year (twelve consecutive months). Biological monitoring that includes the following tests: cadmium in urine (CdU), cadmium in blood (CdB), and beta-2 microglobulin in urine (B(2)-M)

1910.1027(l)

<table>
<thead>
<tr>
<th>Biological Measurement</th>
<th>Normal Levels</th>
<th>Elevated Levels, Non-Mandatory Removal</th>
<th>Highly Elevated Levels, Non-Mandatory Removal</th>
<th>Highly Elevated Levels, Mandatory Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium in urine (CdU)</td>
<td>≤ 3</td>
<td>&gt; 3 and ≤ 7</td>
<td>&gt; 7</td>
<td>&gt; 7</td>
</tr>
<tr>
<td>Cadmium in blood (CdB)</td>
<td>≤ 5</td>
<td>&gt; 5 and ≤ 10</td>
<td>&gt; 10</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>Beta-2 (B(2)-M)</td>
<td>≤ 300</td>
<td>&gt; 300 and ≤ 750</td>
<td>&gt; 750</td>
<td>&gt; 750</td>
</tr>
</tbody>
</table>

**Triggers:**
- All three measurements at normal levels.
- Any one measurement at an elevated level.
- Any one measurement at a highly elevated level.

**Risk at this level:**
- Negligible or relatively low risk of renal tubular proteinuria (i.e., above the background rate among the general population).
- Elevated risk of renal tubular proteinuria (i.e., above the background level experienced by the general population).
- Elevated, and perhaps highly elevated, risk of renal tubular proteinuria (i.e., above the background level experienced by the general population).

**Actions:**
- Provide annual biological monitoring and biannual medical examinations.
- Provide semi-annual biological monitoring and annual medical examinations until all measurements return to normal levels.
- If medically removed from job: Provide quarterly biological monitoring and semiannual medical examinations until physician decides to return employee to job or permanently remove employee from job.
- If not medically removed from job: Provide quarterly biological monitoring and semiannual medical examinations until all measurements return to normal levels.
- Mandatory medical removal required. Provide quarterly biological monitoring and semiannual medical examinations until physician decides to return employee to job or permanently remove employee from job.

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1 This table addresses only medical removal actions specified by the Cadmium standard; other requirements may apply based on the results of other medical examinations.

2 CdU = CdU μg per g Cr

3 CdB = CdB μg per g Cr

4 B(2)-M = β(2)-M μg per g Cr

5 In cases in which the β(2)-M is highly elevated and CdU and CdB are at normal levels, the physician should check to determine that the β(2)-M levels accurately reflect the true β(2)-M levels. If they do, then the physician must determine that the cause of the highly elevated levels of protein is in urine (e.g., presence of anti-antinephropathic disease or amino-aciduria disease).
OSHA Requirements for Periodic Medical Exam

- Detailed work and medical history
- Complete physical- BP, RESP, Urinary system focus
- Chest Xray (initial)
- Pulmonary Function Testing
What does the Doctor need?

1910.1027(l)(9): The employer shall provide the following information:

- A copy of OSHA Cd standard and appendices;
- A description of the affected employee's former, current, and anticipated duties and occupational exposure to cadmium;
- A description of any personal protective equipment, including respirators, used or to be used by the employee, including when and for how long the employee has used that equipment; and
- Relevant results of previous biological monitoring and medical examinations.

- The employer shall instruct the physician not to reveal orally or in the written medical opinion given to the employer specific findings or diagnoses unrelated to occupational exposure to cadmium.
The employer shall promptly obtain a written, medical opinion from the examining physician for each medical examination performed on each employee.

- **The diagnosis** (related to Cd exposure)
- The physician's **opinion** as to whether the employee has any detected medical condition(s) that would place the employee at **increased risk** of material impairment to health from further exposure to cadmium, including any indications of potential cadmium toxicity;
- The **results of testing** that directly assess the employee's absorption of cadmium;
- **Recommendations to remove or limit** employee’s activities, duties, or PPE use.
- A statement that the physician has clearly and carefully **explained to the employee** the results of the medical examination, including all biological monitoring results and any medical conditions related to cadmium exposure that require further evaluation or treatment, and any limitation on the employee's diet or use of medications.
What were the considerations for medical monitoring in this case?

Monitoring was for a single exposure “new” procedure.

Performed in July, Results in September, Medical surv. Initiated >3 months later.

Concerns about “unmonitored” unknown
Medical Monitoring Plan:

1) Medical monitoring, physician written opinion, bio-monitoring, risk communication.
2) Repeat personal monitoring
3) Offer repeat testing, and annual testing.
4) Enrolled in Respiratory protection program.
Medical Monitoring for Intermittent exposures in Conservation

Wide variety of hazards, many unknown/untested

Wide variety of procedures

Short or intermittent exposures

Donor fund limitations

“...the science and art devoted to the anticipation, recognition, evaluation, prevention, and control of those environmental factors or stressors arising in or from the workplace which may cause sickness, impaired health and well being, or significant discomfort among workers or among citizens of the community.”
Options?

Screen in/ Screen Out

Engineering controls

Prevent the worst…
Button Treatment Conclusions

Conducted treatment by hand

With assistance!

Example buttons before and after treatment
Questions?

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