Risk Factors for Lung Disease in Former Atomic Energy Workers from the Ames Laboratory

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Since the Manhattan Project, atomic energy scientists have been a highly exposed workforce due to processing and experimenting with many toxic chemicals and radioactive agents. Occupational exposures to uranium, plutonium, thorium, beryllium, asbestos, and other toxins may increase the risk of lung disease.

In 1942, scientists at Iowa State University in Ames, Iowa joined a national effort to develop atomic energy and initiated a chemical research and development program to accompany the Manhattan Project's existing physics program.

The Ames Laboratory developed a highly efficient process for producing high-purity uranium metal in large quantities and furnished one-third of the uranium metal used in the first successful demonstration of a chain-reaction at the University of Chicago.

The Ames Laboratory produced 2 million pounds (1,000 tons) of uranium between 1950 and 1956 purified from thorium to 1990, for use in experiments and weapons. Large amounts of beryllium were used in the process isolating and casting these metals. Castings frequently "blew out" and needed molding, which created beryllium dust.

Beryllium is a light weight, spark and heat resistant metal ideal for the weapons industry. Exposure to beryllium can cause beryllium sensitization (BeS) and Chronic Beryllium Disease (CBD).

Post-1960, the Ames Laboratory participated in research and development and presently conducts a broad range of applied chemical and physical research.

### Methods

**Former Worker Medical Screening Program (FWP)**

The FWP was established following the 1993 Defense Authorization Act (PL 102-484, Section 3162), which called for the U.S. Department of Energy (DOE) to evaluate the long-range health effects of hazardous and radioactive exposures among its former employees.

In 2005, DOE contracted with The University of Iowa College of Public Health to provide medical screenings to Ames Laboratory former workers (ALFW).

Medical screening tests include:
- Chest X-ray (CXR)
- Pulmonary Function Test (PFT)
- Beryllium Lymphocyte Proiferation Test (BeLPT)
- General blood test (CBC, comprehensive metabolic panel, TSH, cholesterol, A1c), urine analysis & Hemoccult blood test.

As of July 1, 2011, 1,146 ALFW have been screened and 1,071 participants were included in this analysis based on those who had at least one valid BeLPT, PFT and CXR as well as date of birth, sex, race and date of hire information.

Beryllium sensitization (BeS) was determined by a confirmed abnormal BeLPT defined as a minimum of 1) two abnormal results; or 2) one abnormal and one borderline test result.

PFTs were performed according to the American Thoracic Society (ATS) guidelines with percent predicted values calculated using the National Health and Nutrition Examination Survey (NHANES III)-based algorithm recommended by Hawkins et al. 1999. For those with multiple screenings, the most recent PFT result was used.

CXRs were reviewed by 3 readers experienced in the International Labor Organization's (ILO) system for classification of radiographs for pneumoconiosis. The ILO pneumoconiosis score was used to reconcile multiple readings. Parenchymal abnormalities were defined as an ILO profusion score ≥1,0.

### Background

#### Table 1. Beryllium Sensitized vs. Not Sensed ALFW

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Sensitized</th>
<th>Not Sensitized</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>71.1</td>
<td>61.9</td>
<td>0.000046</td>
</tr>
<tr>
<td>SD</td>
<td>11.3</td>
<td>10.3</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 2. Beryllium Sensitization, Parenchymal Abnormalities & PFT Measures by Decade of Hire

<table>
<thead>
<tr>
<th>Decade of Hire</th>
<th>Beryllium Sensitized (%)</th>
<th>Parenchymal Abnormalities (%)</th>
<th>PFT Measures (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940-1949</td>
<td>54.8</td>
<td>95.3</td>
<td>FEV1% predicted 95.6 ± 15.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>166</td>
<td>FVC% predicted 95.9 ± 15.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.2</td>
<td>FEV1/FVC% predicted 96.5 ± 13.0</td>
</tr>
</tbody>
</table>

#### Table 3. Beryllium Sensitization, Parenchymal Abnormalities & PFT Measures by Potential for Occupational Exposures

<table>
<thead>
<tr>
<th>Jobs by Exposure Potential</th>
<th>Beryllium Sensitized (%)</th>
<th>Parenchymal Abnormalities (%)</th>
<th>PFT Measures (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fishcer's exact p=0.032</td>
<td>Fishcer's exact p=0.032</td>
<td>FEV1% predicted 92.9 ± 15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>154</td>
<td>FVC% predicted 95.4 ± 16.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.2</td>
<td>FEV1/FVC% predicted 96.4 ± 15.3</td>
</tr>
</tbody>
</table>

#### Table 4. Smoking Status by Potential for Occupational Exposure by Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Ever Smoker</th>
<th>Smoker</th>
<th>Never Smoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15 (5.4)</td>
<td>8 (2.7)</td>
<td>100 (3.3)</td>
</tr>
<tr>
<td>Female</td>
<td>35 (10.6)</td>
<td>12 (3.6)</td>
<td>100 (3.3)</td>
</tr>
</tbody>
</table>

Correlations Between Independent Variables (Spearman Correlation Coefficient): P=0.0002

Risk factors for lung disease in former DOE workers from the Savannah River Site and 1.4% rate in the study of DOE construction workers (both studies used the same definition of confirmed abnormal BeLPT as the one used in this study).

The 5.9% rate of parenchymal abnormalities is comparable to 5.4% in former DOE nuclear weapon production workers from the Savannah River Site and 5.6% from the Iowa Army Ammonium Plant (unpublished) but higher than the 2.2% rate in construction workers from three DOE sites.

### Findings

- BeS is most strongly associated with decade of hire (p=0.037).
- All of the BeS ALFWs started working at the Ames Laboratory before 1979 and on average were hired 9.5 years earlier than non-sensitized workers (p=0.0002).
- BeS individuals were on average 9 years older than non-sensitized individuals (p=0.0004).
- BeS and parenchymal abnormalities occurred in all exposure strata which may be due to widespread dissemination of dusts exposing all workers.
- Many of those sensitized and/or with parenchymal abnormalities were exposed to multiple pneumoconiotics during production era. The facility has been undergoing remediation since the 1960s.
- Beryllium dust has been detected in at the Ames Laboratory as recently as 2004.
- BeLPT results for ALFWs working in specific buildings has led to the Ames Laboratory Health & Safety staff identifying beryllium residues in interstitial building spaces and initiating remediation.
- Surveillance for beryllium sensitization is needed as BeS progresses to CBD at an estimated 6% per year. CBD is often underreported with BeS were exposed on average 30 years ago, leaving ample time for CBD to develop.
- The strongest association that showed a decrease in pulmonary function was smoking (p=0.0002) compared to years since first hired at the Ames Laboratory (p=0.0332) and duration of employment (p=0.0733).
- Controlling for smoking, the latency since the first hire on-site (p=0.0001) and cumulative duration of employment (p=0.002) were statistically significantly associated with obstructive physiology.
- Among men and women, there is an association between smoking status (ever, never) and occupational exposures in both genders (male: p=0.032; female: p=0.006).
- The association between smoking and exposure is reversed in males and females. Most of the men who smoked had jobs within the high exposure group (76%) and all the women who smoked had jobs in the no exposure group (59%).
- Gender roles may confound exposures and risks for occupational lung disease in this and other studies.