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

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Background

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 through 1950 and purified thorium from 1950 to 1960, for use in experiments and weaponry. Large amounts of beryllium were used in the process of isolating and casting these metals. Castings frequently "blew out" and needed machining, 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.

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 Proliferation Test (BeLPT)
- General blood work (CBC, comprehensive metabolic panel, TSH, cholesterol, A1c), urine analysis & Hemoccult blood test.

Methods

As of July 1, 2010, 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 Hankinson et al., 1999[1]. 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 pneumoconioses. The highest ILO profusion score was used to reconcile multiple readings. Parenchymal abnormalities were defined as an ILO profusion score $\geq$ 1/0.

Results

Table 1. Beryllium Sensitized vs. Not Sensitized ALFW

	Sensitized n=19	Not Sensitized n=1,052	p-value	Statistical Test
Age (mean)	71	61.96	0.000454	t-test
Years at Ames Lab (mean)	4.11	5.33	0.527	t-test
Years since first hired at Ames Lab (mean)	47.42	37.93	0.00029	t-test
Smoking Status				
Never smoker	10	681	0.27	Fisher's test
Ex-smoker	8	309		
Current smoker	1	33		
Missing	0	29		
Gender				
Male	15	731	0.46	Fisher's test
Female	4	321		
PFT* (mean)	(n=19)	(n=1,044)		
FVC% predicted	99.1	93.7	0.16	W|KW test
FEV1% predicted	95.6	94.1	0.41	W|KW test
FEV1/FVC	71.2	76.5	0.0158	W|KW test
Parenchymal Abnormalities	(n=17)	(n=974)		
Yes	2	57	0.0775	Fisher's test
No	15	917		

* PFT data are adjusted for smoking by never, ex- or current smoker.

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

Decade of Hire	Beryllium Sensitization, n(%) Fisher's exact p= 0.037			Parenchymal Abnormalities, n(%) Fisher's exact p= 0.20			PFT Measures (mean)			
	BeS	Non-BeS	Total	Positive	Negative	Total	FVC% predicted W|KW p=0.0766	FEV1% predicted W|KW p=0.0946	FEV1/FVC W|KW p=0.0000	Total
1940 Uranium Era	1 (4.6)	21 (95.4)	**22**	2 (10)	18 (90.0)	**20**	88.1	90.0	70.5	**22**
1950 Thorium Era	6 (3.3)	178 (96.7)	**184**	11 (6.2)	165 (93.8)	**176**	93.0	91.6	72.5	**182**
1960 R & D	9 (2.9)	302 (97.1)	**311**	25 (8.6)	267 (91.4)	**292**	94.3	95.0	75.1	**310**
1970 R & D	3 (1.2)	249 (98.8)	**252**	10 (4.3)	223 (95.7)	**233**	92.5	93.8	78.2	**249**
1980 R & D	0 (0.0)	182 (100.0)	**182**	5 (3.1)	158 (96.9)	**163**	95.3	96.1	79.1	**180**
1990 R & D	0 (0.0)	112 (100.0)	**112**	6 (6.1)	93 (93.9)	**99**	95.0	94.9	78.9	**112**
2000 R & D	0 (0.0)	8 (100.0)	**8**	0 (0.0)	8 (100.0)	**8**	89.5	83.5	75.6	**8**
Total	**19 (1.8)**	**1,052 (98.2)**	**1,071**	**59 (5.9)**	**932 (94.1)**	**991**				**1,063**

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

Jobs by Exposure Potential	Beryllium Sensitization, n(%) Fisher's exact p= 0.82			Parenchymal Abnormalities, n(%) Fisher's exact p= 0.0482			PFT Measures (mean)			
	BeS	Non-BeS	Total	Positive	Negative	Total	FVC% predicted F-P p=0.0899	FEV1% predicted W|KW p=0.0103	FEV1/FVC W|KW p=0.59	Total
No Exposure administrative, accounting, editor, graphic arts, draftsman, auditor	2 (1.2) (11.1)	165 (98.8) (15.9)	**167 (15.8)**	3 (2) (5.3)	150 (98.4) (16.4)	**153 (15.7)**	91.0	90.0	76.5	**164 (15.7)**
Low Exposure engineer, mathematician, geologist, bacteriology, computer science/programmer, medical, teaching assistant, imaging /scanner, reactor & press operator, glass blower, glass washer, media/photographer, driver	2 (1.2) (11.1)	164 (98.8) (15.9)	**166 (15.8)**	11 (7.4) (19.3)	137 (92.6) (14.9)	**148 (15.2)**	93.4	94.9	77.0	**165 (15.8)**
High Exposure physicist, chemical engineer, professor, postdoc, research asst., grad asst., lab tech, health & safety, guard, metallurgist, machinist, electrician, pipefitter, mechanic, mail, custodian, maintenance, construction	14 (1.9) (77.8)	706 (98.1) (68.2)	**720 (68.4)**	43 (6.4) (75.4)	629 (93.6) (68.7)	**672 (69.1)**	94.6	95.0	76.3	**716 (68.5)**
Total	**18 (1.7)**	**1,035 (98.3)**	**1,053**	**57 (5.9)**	**916 (94.1)**	**973**				**1,045**

* Exposures to airborne dusts of asbestos, beryllium or other metals based on job location (as advised by the Ames Laboratory).

Results

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

Ever Smoke	Exposure Potential, n(%) Male: Fisher's exact p= 0.0362 Female: Fisher's exact p= 0.0060			
	No	Low	High	Total
YES				
Male	15 (5.4) (45.4)	60 (21.4) (48.8)	205 (73.2) (36.7)	**280 (39.2)**
Female	38 (59.4) (29.5)	6 (9.4) (15.0)	20 (31.2) (14.1)	**64 (20.6)**
NO				
Male	18 (4.2) (54.6)	63 (14.5) (51.2)	353 (81.3) (63.3)	**434 (60.8)**
Female	91 (36.8) (70.5)	34 (13.8) (85.0)	122 (49.4) (85.9)	**247 (79.4)**
TOTAL				
Male	**33 (4.6)**	**123 (17.2)**	**558 (78.2)**	**714**
Female	**129 (41.5)**	**40 (12.9)**	**142 (45.6)**	**311**

Results

Correlations Between Independent Variables (Spearman Correlation Coefficient):

- FVC% predicted/Smoking= - 0.11730, p=0.0002
- FVC% predicted/Years since first hired at Ames Lab= -0.06805, p=0.0332
  - Controlling for smoking, FVC% predicted is not associated with Hire Date= -0.04111, p=0.20
- FVC% predicted/Employment Duration= 0.05723, p=0.0733 (borderline)
  - Controlling for smoking, FVC% predicted is not associated with employment duration= -0.03797, p=0.24
- Controlling for smoking, FEV1/FVC is associated with:
  - Employment Duration= -0.10434, p=0.0011
  - Years since first hired at Ames Lab = -0.22768, p<0.0001

Findings

❖BeS rate of 1.8% (n=19) is higher than the 1.3% rate in the study of DOE workers from the Nevada Test Site[2] and 1.4% rate in the study of DOE construction workers[3] (both studies used the same definition of confirmed abnormal BeLPT as the one used in this study).

❖All of the BeS ALFWs had normal FVC% predicted (p=0.16), FEV1% predicted (p=0.41) and FEV1/FVC (p=0.0158) and 2 (11.8%, n=17) were found with parenchymal abnormalities (p=0.0775).

❖The 5.9% rate of parenchymal abnormalities is comparable to 5.4% in former DOE nuclear weapons production workers from the Savannah River Site[4] and 5.6% from the Iowa Army Ammunition Plant (unpublished) but higher than the 2.2% rate in construction workers from three DOE sites[5].

❖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 first hired 9.5 years earlier than non-sensitized workers (p=0.00029).
- BeS individuals were on average 9 years older than non-sensitized individuals (p=0.00045).

❖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 pneumoconiotic dusts during production eras. The facility has been undergoing remediation since the 1960s.
- Beryllium dust has been detected in at the Ames Laboratory as recently as 2001.
- 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 6-8% per year[6]. CBD is often lethal and those 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=0.0011) were statistically significantly associated with obstructive physiology.

❖Among men and women, there is an association between smoking status (ever, never) and occupational exposure in both genders (male, p=0.0362; female, p=0.0060).
- The association between smoking and exposure is reversed in males versus females. Most of the men who smoked had jobs within the high exposure group (76.2%) whereas the most women who smoked had jobs in the no exposure group (59.4%).
- Gender roles may confound exposures and risks for occupational lung disease in this and other studies.

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