# Health Effects of Exposure to Beryllium in the Manufacture of Conventional Munitions

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# IAAAP MUNITIONS WORKERS STUDY

- **Aim I:** determine prevalence of beryllium sensitization (BeS) and chronic beryllium disease (CBD) in DoD conventional munitions workers

- **Aim II:** determine whether specific jobs/classifications in conventional munitions are associated with increased risk of beryllium sensitization

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# IOWA ARMY AMMUNITION PLANT (IAAAP)

- Built between 1941-1943 as a DoD conventional munitions Loading, Assembly and Packing (LAP) facility **still in operation today**
- Nuclear weapons assembled on site between 1949 and mid-1975 (AEC/DoE)
- Medical screenings for beryllium health effects of DoE workforce but no protocol for DoD workers

# BERYLLIUM (Be)


- Naturally occurring metal
  - Light weight (lighter than aluminum)
  - High stiffness (higher than steel)
  - High temperature stability
  - Transparency to x-rays
  - Neutron reflector
  - Non-sparking properties
- In use in aerospace, automotive, energy, defense, medical and electronics industries
- Over 18,000 current DoD contractor workers may be potentially exposed to Be (Henneberger et al., 2004) with no DoD protocol for routine screenings

# HEALTH EFFECTS OF EXPOSURE TO BERYLLIUM

- **Beryllium Sensitization (BeS)**
  - Asymptomatic, immune-mediated, genetic predilection suggested,
  - Affects up to 15% of exposed workers,
  - Carries a risk of progression to Chronic Beryllium Lung Disease (CBD)
  - Dose-response not well established although highest prevalence reported in direct long-term exposures to Be

- **Chronic Beryllium Lung Disease (CBD)**
  - Potentially progressive and fatal granulomatous lung disease with scarring of the lungs, no cure, treatment immunosuppression and supportive
  - Progression from BeS to CBD estimated at 6-8% year by one longitudinal study (Newman et al., 2005)
  - Non-specific symptoms: shortness of breath, weight loss, chest pain, persistent cough, night sweat and exhaustion

- Other: Lung Cancer (Sanderson et al., 2001, IARC vol. 58)

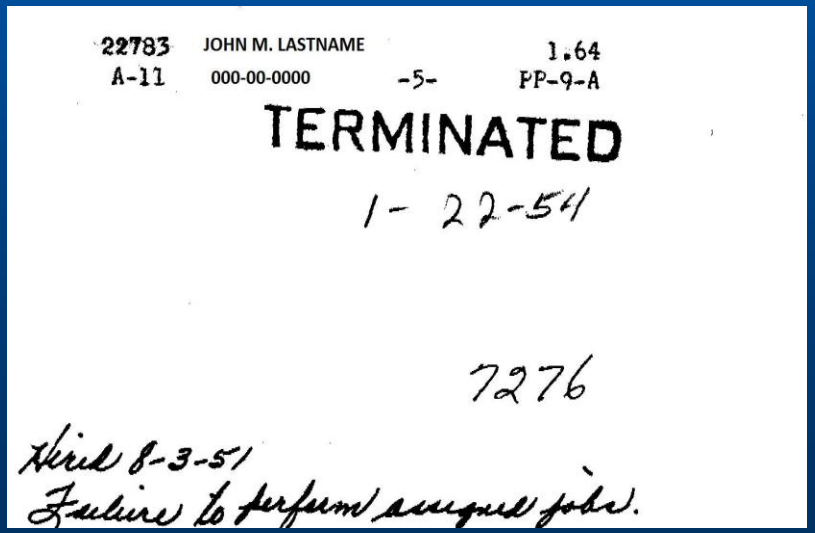
# METHODS - COHORT SELECTION

Estimated 33,500 workers - out of a total 38,000 working between 1948 and 2002 – were employed in conventional munitions operations only

Job codes and other plant records helped determine DoD vs. DoE employment

**Included** - DoD workers employed between 1948 and 2002 (the last year Cu-2%Be tools used on site)

**Excluded** - DoE (ever) workers confirmed by DoE specific job codes/titles or any other plant records, or self-reported


22783 JOHN M. LASTNAME 1.64
A-11 000-00-0000 -5- PP-9-A
TERMINATED
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Hired 8-3-51
Failure to perform assigned jobs.

# METHODS - BERYLLIUM EXPOSURE ASSESSMENT

- **No IH monitoring data for beryllium** - interviews with former production, trade and health safety workers to determine the exposure potential on-site (processes, jobs)
- **Millwrights, machinists, tool and die workers at direct occasional risk for exposure - machining of Cu-2%Be alloy tools**
- A 2007 survey of Be surface contamination (Sanderson et al., 2008); **2 samples site-wide > DoE surface contamination housekeeping level (3 µg/100 $cm^2$)** both in the area where millwrights used belt sanders to occasionally resurface alloy tools
- **Job Exposure Matrix (JEM)** developed by UI IH team – classified jobs into Be exposure rankings (category 0,1,2) based on frequency and proximity to known processes involving Be.

# METHODS - BERYLLIUM EXPOSURE ASSESSMENT

| Exposure category | Job category |
|---|---|
| **Category 0**<br>Virtually no exposure; lowest exposures at this facility | Administrative and office support, automotive and equipment mechanics, cameramen, carpenters, custodial, electricians, engineers, expeditors material handlers and checkers, equipment operators, fire-fighters, food service, firing site, ironworkers, inspectors, laborers, melt workers, healthcare, painters, plant utilities, rail and transportation, scale instrument repair, safety and health, security, sheet metal, storage, grounds workers, waste disposal, x-ray workers. |
| **Category 1**<br>Rare exposures; can include bystander or indirect exposure | Production operators and supervisors, explosive operators, component operators, scientists, plumbers/pipefitters |
| **Category 2**<br>Occasional exposures; can include bystander or indirect exposures | Machinists, tool and die workers, millwrights, mechanical division supervisors |
| **Category 3**<br>Frequent exposures; several times weekly; can include bystander or indirect exposure | Not assigned |

**Each worker assigned the highest ever worked in category of Be exposure based on the job codes in their personnel records**

# METHODS – SCREENINGS FOR BES AND CBD

- Participants predominantly self-selected through advertisements in the media with oversampling of those potentially highest exposed (exposure cat. 2) – small sample size
- BeS evaluated with a split Beryllium Lymphocyte Proliferation Test (BeLPT) with repeats of initial abnormal, borderline and uninterpretable results
- BeS defined as a confirmed abnormal BeLPT result i.e. double abnormal or one abnormal + one borderline
- BeS +ve offered clinical evaluation for CBD with lung function testing and high Resolution CT scan – clinical protocol based on clinical judgment with invasive testing (bronchoalveolar lavage (BAL) with transbronchial biopsy) dependent on the results of PFTs and HRCT

# RESULTS

- **Beryllium sensitization testing**
  - **8 (1.5%) with confirmed abnormal BeLPT out of 524 DoD workers tested**

| BeLPT result / Be Exposure | Confirmed abnormal BeLPT | | Total |
|---|---|---|---|
| | Y n (%) | N n (%) | |
| 0 | 1 (1.5) | 66 (98.5) | 67 |
| 1 | 5 (1.2) | 398 (98.8) | 403 |
| 2 | 2 (3.8) | 50 (96.2) | 52 |
| Total | 8 (1.5) | 514 (98.5) | 522 |
| N=2 missing exposure information (-ve BeLPT) | | | |

*p = 0.36 Cochran Armitage $\chi 2$*

*Odds of abnormal BeLPT in those exposed to highest exposure (cat 2) vs. rare and no exposure (cat 0+1)*

*OR = 3.10 (95% CI – 0.61 to 15.73)*

# RESULTS

| BeLPT result / Parameter | Confirmed abnormal BeLPT: Y | Confirmed abnormal BeLPT: N | p-value | OR (95% CI) |
|---|---|---|---|---|
| **Age,** mean (SD), range | 64(7); 54-74 | 63(10);28-88 | 0.85[3] | N/A |
| < 55 n, (%) | 1 (1.1) | 91 (98.9) | 0.97[2] | 1.0 |
| 55-59 n, (%) | 2 (2.1) | 93 (97.9) | | 1.96 (0.17-21.96) |
| 60-64 n, (%) | 2 (1.7) | 119 (98.3) | | 1.53 (0.14-17.13) |
| 65-69 n, (%) | 1 (1.0) | 96 (99.0) | | 0.95 (0.06-15.38) |
| 70+ n, (%) | 2 (1.7) | 117 (98.3) | | 1.56 (0.14-17.42) |
| **Sex**, n (%) | | | | |
| Male | 8 (2.9) | 273 (97.1) | 0.01[1] | N/A |
| Female | - | 243 (100.) | | |
| **Smoking,** n (%) | | | | |
| Ever smoker | 5 (1.5) | 330 (98.5) | 1.00[1] | 1.0 |
| Never smoker | 3 (1.6) | 186 (98.4) | | 1.07 (0.25-4.50) |
| **Immunosuppressant (systemic) use,** n (%) | | | | |
| Yes | - | 17 (100.0) | 1.00[1] | N/A |
| No | 8 (1.7) | 499 (98.3) | | |
| **Date of first hire,** n (%) | | | | |
| <7/1/1975 (during DoE operations on-site) | 7 (1.9) | 357 (98.1) | 0.45[1] | 1.0 |
| >7/1/1975 (no DoE operations on-site) | 1 (0.6) | 159 (99.4) | | 0.32 (0.04-2.63) |
| **Employment duration in months**, mean,SD, range | 48(67); 0.5-194.0 | 103(126);0.1-855.5 | 0.19[3] | N/A |
| <12 n, (%) | 3 (2.3) | 129 (97.7) | 0.19[2] | 1.0 |
| 12 – 40 n, (%) | 3 (2.3) | 131 (97.7) | | 0.99 (0.20-4.97) |
| 41 -169 n, (%) | 1 (0.8) | 133 (99.2) | | 0.32 (0.03-3.15) |
| 170+ n, (%) | 1 (0.8) | 131 (99.2) | | 0.32 (0.03-3.20) |

*[1] Fisher's exact test; [2] Cochran-Armitage test; [3] Wilcoxon rank-sum test*

# RESULTS

| ID | Age | Age at first hire | Smoking | FVC% | FEV1% | FEV1/ FVC% | $D_LCO$% | HRCT findings | BeLPT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 58 | 18 | Ex-smoker | 90 | 98 | 77 | 81 | No ILD, calcified granulomas, 2mm nodules | AB+AB |
| 2 | 59 | 18 | Ex-smoker | 96 | 100 | 73 | 102 | No ILD, calcified granulomas | AB+AB |
| 3 | 64 | 22 | Never | 100 | 103 | 77 | NA | Multiple non-pathologic <1cm mediastinal and hilar lymph nodes | AB+BD |
| 4 | 69 | 30 | Never | 94 | 114 | 83 | 89 | No ILD; 3mm pleural based nodule | AB+AB |
| 5 | 72 | 30 | Never | 128 | 120 | 68 | 83 | No ILD, minimal apical scarring and punctuate lymphadenopathy | AB+AB |
| 6 | 74 | 18 | Ex-smoker | 94 | 113 | 79 | 101 | No ILD; nodular intralobular septal thickening, 3mm nodule | AB+AB |
| 7 | 54 | 34 | Ex-smoker | Declined clinical follow up | | | | | AB+BD |
| 8 | 60 | 18 | Current | Declined clinical follow up | | | | | AB+BD |

# SUMMARY

- Low rate of BeS in DoD workers with low overall exposure to beryllium
- Increase in prevalence and risk of sensitization in workers with jobs associated with increased potential for exposure (consistent with statistically significant findings from DoE study from the same site (Mikulski et al., 2010 AJIM)
- No CBD found based on clinical evidence, pulmonary function testing and high resolution CT (protocol less sensitive than bronchoscopy/biopsy/lavage)

# OTHER BES STUDIES

- Taiwo OA, Slade MD, Cantley LF, Kirsche JC, Wesdock JC, Cullen MR. Prevalence of beryllium sensitization among aluminum smelter workers. Occup Med. 2010. published online on July 7, 2010
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