The History of Beryllium as a Work Place Hazard

Paul Wambach

Phone: 240-644-7081

Email: PFWambach@verizon.net

Acute Beryllium Disease

- Chemical pneumonia in workers extracting beryllium oxide. Van Ordstrand HS, Hughes R, Carmody MG. Cleve Clin Quart 1943;10:10
- The toxicology of beryllium. Hyslop F, et al. NIH Bulletin No. 181, 1943
- Acute inhalation toxicity of beryllium; four definitive studies of beryllium sulfate at exposure concentrations of 100, 50, 10, and 1 mg. per cubic meter. Stokinger HE, et al. Arch Ind Hyg Occup Med. 1950 Apr;1(4):379-97.
- A reconsideration of acute Beryllium disease. Cummings KJ, Stefaniak AB, Virji MA, Kreiss K. Environ Health Perspect. 2009 Aug;117(8):1250-6.

Chronic Beryllium Disease

- Delayed chemical pneumonitis occurring in workers exposed to beryllium compounds. Hardy HL, Tabershaw IR. J Ind Hyg Toxicol. 1946 Sep;28:197-211.

- Epidemiology of beryllium intoxication. Sterner JH, Eisenbud M. AMA Arch Ind Hyg Occup Med. 1951 Aug;4(2):123-51

Beryllium Exposure Limits

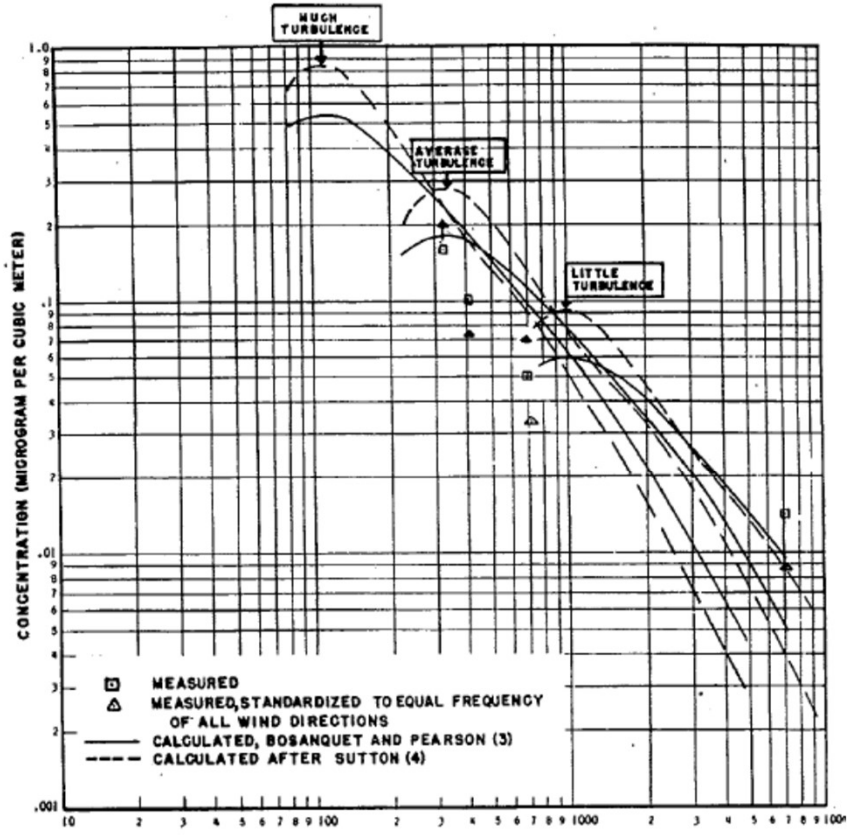


FIG. 5
COMPARISON OF AVERAGE TEN WEEK TEST POINTS AGAINST THEORETICAL DATA

- Current Exposure Limits
  - 15-minute STEL
    - OSHA: 2 µg/m^3
  - 8-hour TWA OELs
    - NIOSH REL: 0.5 µg/m^3
    - OSHA PEL: 0.2 µg/m^3
    - DOE AL: 0.2 µg/m^3
    - OSHA AL 0.1 µg/m^3
    - ACGIH TLV 0.05 µg/m^3
  - EPA Ambient Air
    - 24-hour: 0.02 µg/m^3
    - 30-day: 0.01 µg/m^3

How did CBD disappear in 1950?

The Beryllium Case Registry

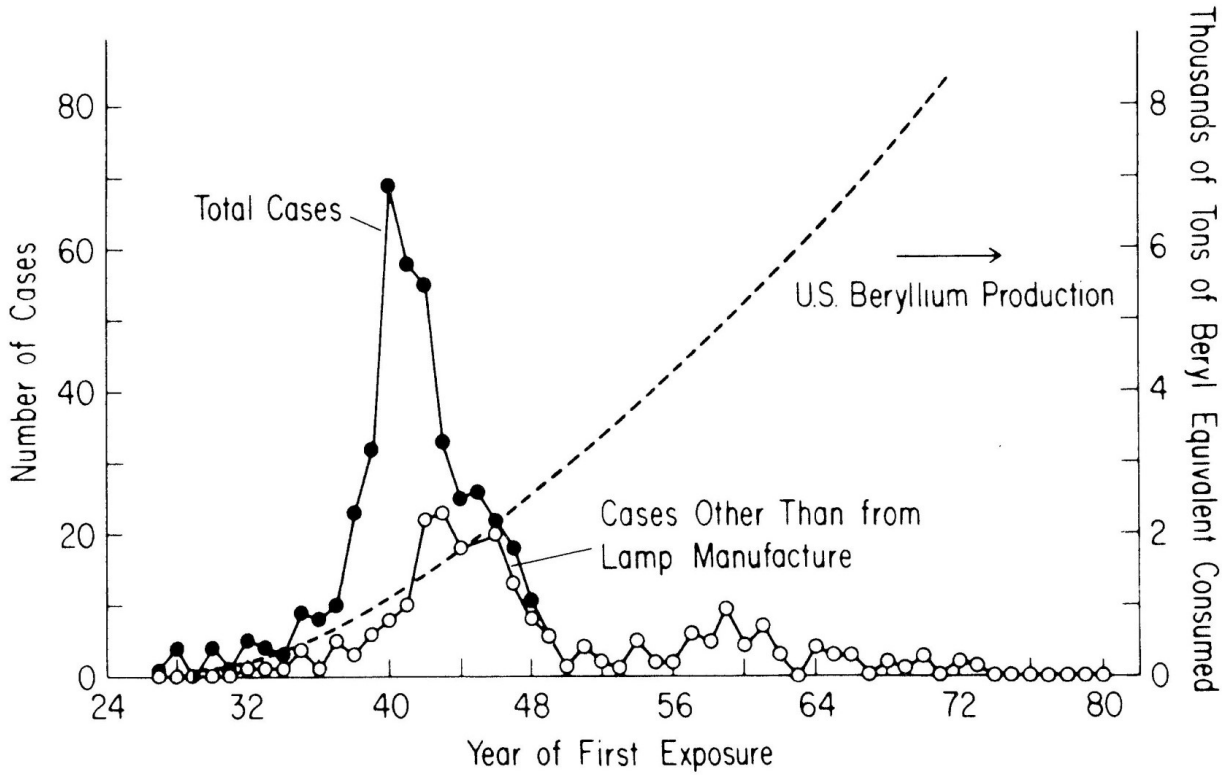


Fig. 1. Number of cases of chronic beryllium disease in the U.S. by year of first exposure, 1924–1980. Also shown is the great increase in beryllium production. The workplace standard was established in 1950.

Estimating historical exposures of workers in a beryllium manufacturing plant. Sanderson WT, Petersen MR, Ward EM. Am J Ind Med. 2001 Feb;39(2):145-57

	DWAs by time period			
Job	**1935–1960**	**1961–1970**	**1971–1980[a]**	**1981–1992[a]**
Ore mill	70.5	8.5[b]	—	—
Sinter mixer	21.6	12.5[b]	—	—
Sinter furnace	88.4	15.0[b]	—	—
Leacher	89.6	22.0[b]	—	—
Calcine furnace	82.1	43.9	1.9	1.1
Arc furnace	131.0	69.9	3.1	1.4
Dross reclaim	29.2	16.1	1.6	0.12
Melt and cast furnace	65.4	34.8	1.1	0.78
Heat weigher	23.6	12.5	0.24	0.17
Ajax furnace	767/49[c]	38.4	1.2[d]	—
Foundry molder	55.9	24.1	0.63[d]	—
Machinist	23.0	12.2	0.26	0.11
Hot mill roller	25.2	10.9	0.37	0.27
Scarfer lathe	25.2	11.0	0.51	0.29
Cold roller	14.8	7.8	0.08	0.03
Extrusion press	17.0	9.1	0.32	0.12

Daily Weighted Average

Operator: Arc Furnace Helper

OPERATIONS OR OPERATING AREA	TIME PER OPER. [MIN.]	OPER. PER SHIFT	TIME PER SHIFT (MIN.)	NO. OF SAMPLES	CONCENTRATION µg/m³			AVER. CONC. TIMES TOTAL TIME (T x C)
					LOW	HIGH	AVER.	
Operator's Control Stations #4 Fce GA			21	12	0.22	1.63	0.48	10
Charge Storage Area #4 Fce GA			81	3	0.46	1.97	1.02	83
Charging #4 FCE GA*			32	4	2.00	13.7	6.50	208
Tapping #4 Fce BZ*			43	3	1.01	5.00	2.42	104
Adds Fce Dust & Stirs & Skims Dross BZ*			64	5	2.14	4.29	3.31	212
Drum Dross at Dross Table BZ*			21	3	5.90	9.90	7.19	151
Transfer Metal BZ*			22	2	2.14	8.90	5.52	121
Pouring to Pigs BZ*			43	3	1.33	5.31	3.87	166
Cleans Floor Sweeping BZ*			37	1	4.05	4.05	4.05	150
Bags Charge Mix BZ*			70	2	1.0	4.05	2.52	176
Prepare & Weigh Cu Scrap GA			16	1	0.25	0.25	0.25	4
Lunch			15	3	0.17	2.10	0.84	13
Washup Locker Room			15	7	0.54	8.60	2.25	34

* Respirator Operation

$\Sigma T = 480$ $\Sigma(T \times C) = 1432$

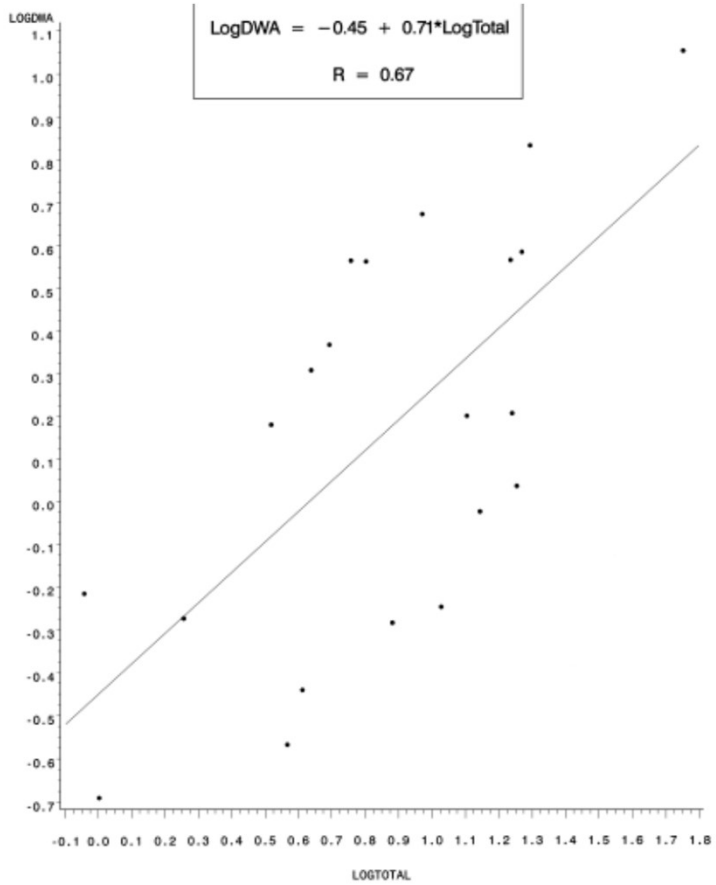
$$\frac{\Sigma(T \times C)}{\Sigma(T)} = \frac{1432}{480} = 2.98 \ \mu g/m^3$$

Beryllium Sampling Methods, Donaldson HM and Stringer WT, Report # NIOSH-76-201, July 1976

Arithmetic Mean of 357 Samples		
DWA	Total	Respirable
2.68 µg/m^3	4.18 µg/m^3	1.36 µg/m^3

Least Squares Linear Regression		
	Total	Respirable
Equation y =	0.33 + 0.48 * DWA	0.14 + 3.6 * DWA
Correlation - R	0.49	0.33
If DWA = 2 Then	2.99 µg/m^3	0.92 µg/m^3
97.5% LCL	2.75 µg/m^3	0.83 µg/m^3
97.5% UCL	3.25 µg/m^3	1.02 µg/m^3

Comparing DWA Results Collected by Reading Plant Industrial Hygienists to Personal Breathing Zone Samples Collected by State of Pennsylvania Industrial Hygienists



- Line fit plot based on 177 personal breathing zone samples collected in 1972 and 1975 and matching DWA estimates
- Ln(DWA) = -0.45 + 0.71 * Ln(Total)
- Ln(Total) = (Ln(DWA) + 0.45)/0.71
- Total = Exp((Ln(DWA) + 0.45)/0.71)
- If DWA = 2 Then Total = 5

Rocky Flats Plant Be Machine Shop

	Fixed Air Head		Personal BZ	
Year	1984	1985	1984	1985
Data Points	423	396	37	62
Mean ($\mu g/m^3$)	0.23	0.19	1.29	1.12
% Exceeding 2 $\mu g/m^3$	1.2	1.8	17.2	14.1
Maximum ($\mu g/m^3$)	5.42	6.56	11.50	6.39

CBD Reappears

The Beryllium Lymphocyte Proliferation Test

- Reversible beryllium sensitization in a prospective study of beryllium workers. Rom WN, Lockey JE, Bang KM, Dewitt C, Johns RE Jr. Arch Environ Health. 1983 Sep-Oct;38(5):302-7
- Long term follow up of workers exposed to beryllium. Preuss OP. Br J Ind Med. 1985 Jan;42(1):69
- Chronic beryllium disease in a precious metal refinery. Clinical epidemiologic and immunologic evidence for continuing risk from exposure to low level beryllium fume. Cullen MR, Kominsky JR, Rossman MD, Cherniack MG, Rankin JA, Balmes JR, Kern JA, Daniele RP, Palmer L, Naegel GP, et al. Am Rev Respir Dis. 1987 Jan;135(1):201-8.
- Proliferative response of bronchoalveolar lymphocytes to beryllium. A test for chronic beryllium disease. Rossman MD, Kern JA, Elias JA, Cullen MR, Epstein PE, Preuss OP, Markham TN, Daniele RP. Ann Intern Med. 1988 May;108(5):687-93.
- HLA-DPB1 glutamate 69: a genetic marker of beryllium disease. Richeldi L, Sorrentino R, Saltini C. Science. 1993 Oct 8;262(5131):242-4.

Beryllium Disease Screening in the Ceramics Industry.

Blood lymphocyte test performance and exposure-disease relations. Kreiss K, Wasserman S, Mroz MM, Newman LS. J Occup Med. 1993 Mar;35(3):267-74.

- Number Screened: 505
- Number confirmed sensitized: 7 (1.4%)
- Number diagnosed CBD: 9 (1.8%)
  - 2 cases identified from abnormal chest x-ray)
- Total population of current and former employees: 1,666
- CBD cases diagnosed prior to the study: 11

Epidemiology of Beryllium Sensitization and Disease in Nuclear Workers

Kreiss K, Mroz MM, Zhen B, Martyny JW, Newman LS. Am Rev Respir Dis. 1993 Oct;148(4 Pt 1):985-91

- Number Screened - 895
- Number confirmed sensitized – 18 (2.0%)
- Number diagnosed CBD – 15 (1.7%)
  - No exposure: 68 Screened -> 1 CBD (1.5%)
  - Minimal exposure: 369 Screened -> 4 CBD (1.1%)
  - Intermittent exposure: 303 Screened -> 8 CBD (2.6%)
  - Consistent exposure: 148 Screened –> 5 CBD (3.4%)

Identification of an Abnormal Beryllium Lymphocyte Proliferation Test

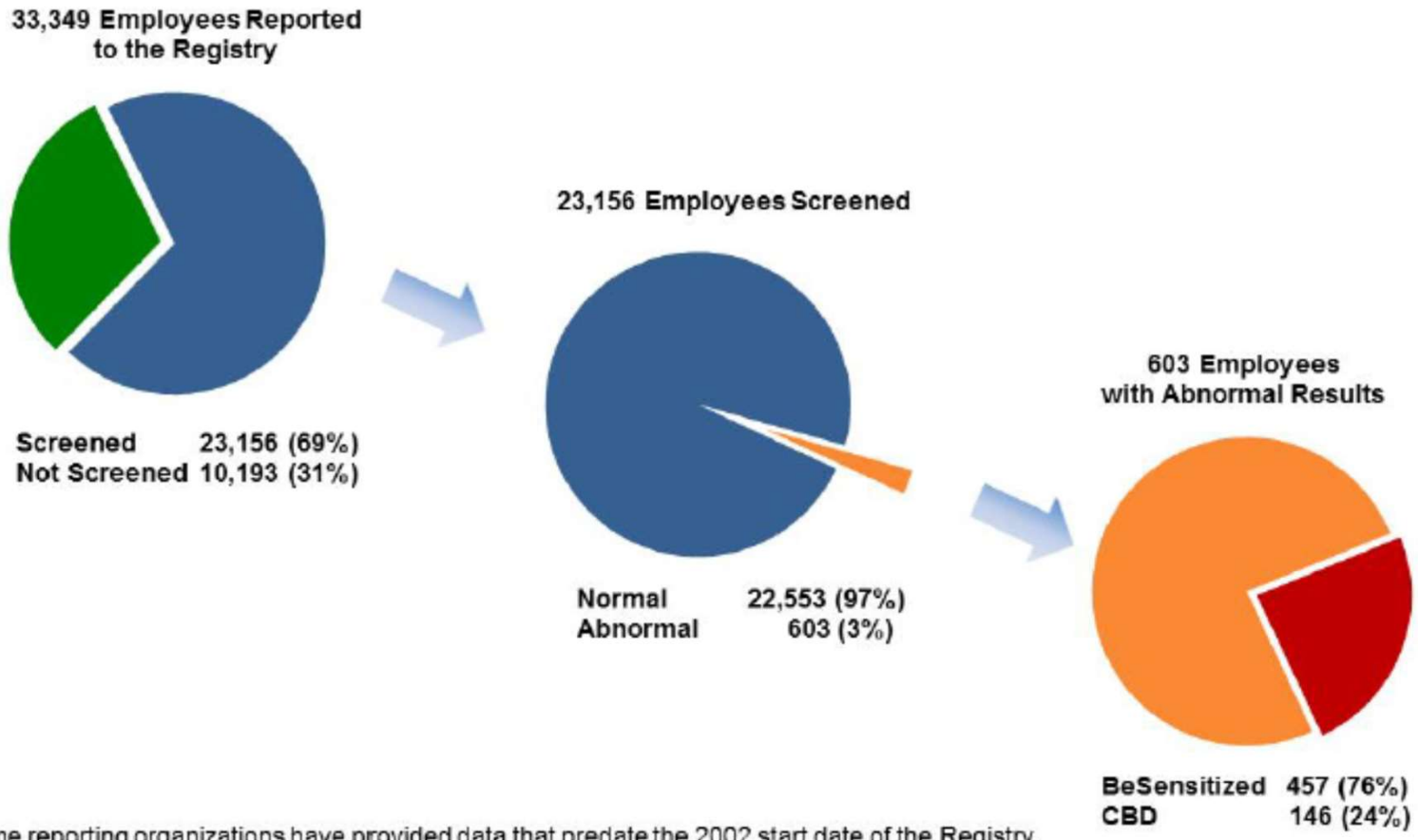
Frome EL, Newman LS, Cragle DL, Colyer SP, Wambach PF. Toxicology. 2003 Feb 1;183(1-3):39-56.

	Summary Follow-up Data for Y-12 Group					
		Follow-up Results				
Group	Initial Results	Borderline	Normal	Unknown	Abnormal	CBD
Abnormal	80	7	21	4	27	21
Borderline	52	6	32	10	3	1
Normal	948	6	629	309	3	1
Total	1080	19	682	323	33	23

- 33 of 1080 confirmed sensitized: 3.1%
- 23 of 1080 diagnosed with CBD: 2.1%
- Exposure Monitoring Results in 1990
  - Number of Samples: 679
  - Number of Detected Results: 73 (10%)
  - Percent of Results Exceeding 2 $\mu g/m^3$: 1.4%
  - 95% Upper Confidence Limit for Percent Exceeding: 2.4%

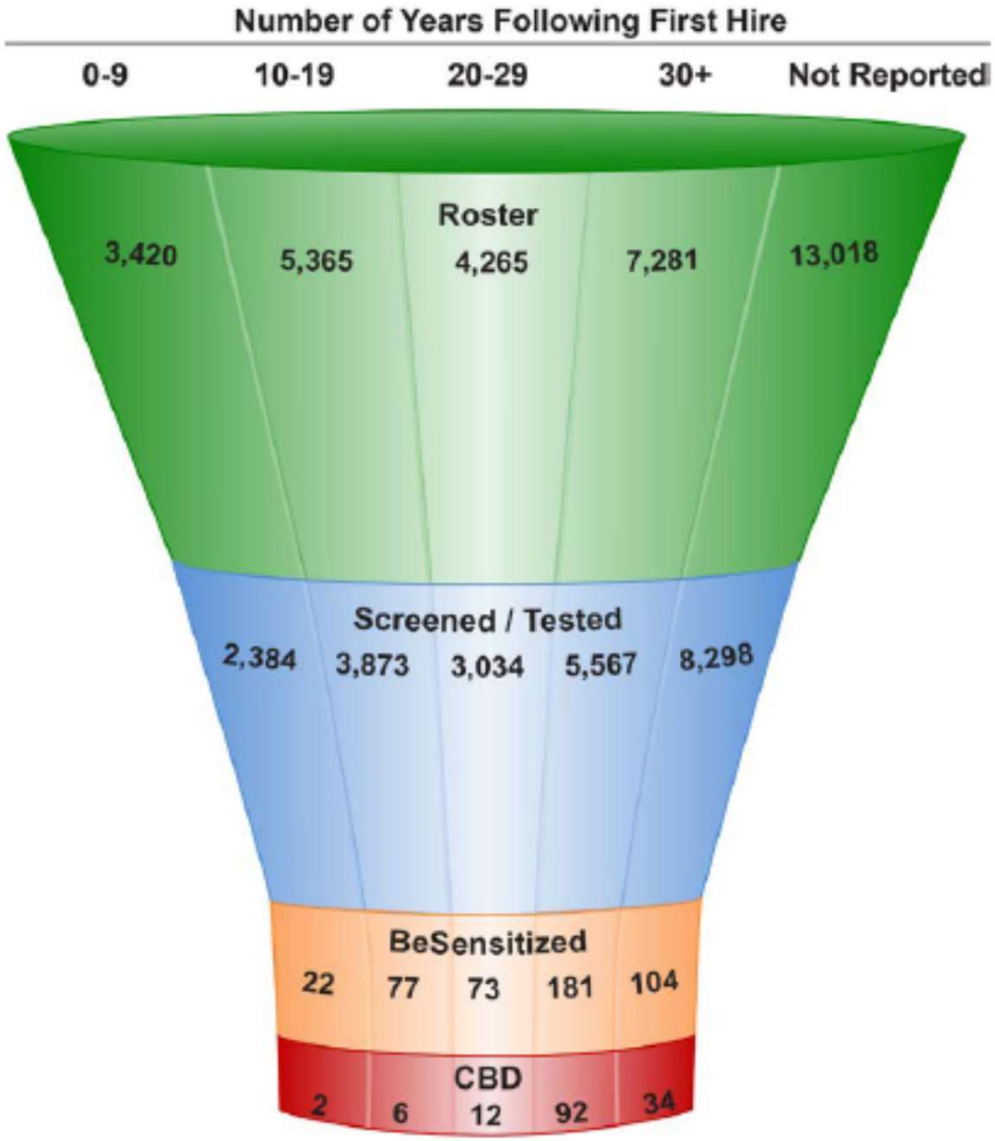
Beryllium Associated Worker Registry

Screening Status and Progression from BeLPT Testing to "Sensitized" to CBD Through 2015*



*Some reporting organizations have provided data that predate the 2002 start date of the Registry.

New Hires versus Long Term Workers



Beryllium Carcinogenesis

Risk = Hazard + Outrage

NTP 14th Report on Carcinogens

Beryllium and beryllium compounds are known to be human carcinogens based on sufficient evidence of carcinogenicity from studies in humans. Beryllium and beryllium compounds were first listed in the Second Annual Report on Carcinogens as reasonably anticipated to be human carcinogens based on sufficient evidence of carcinogenicity from studies in experimental animals. The listing was revised to known to be human carcinogens in the Tenth Report on Carcinogens in 2002

Lung Cancer Cases and Controls by Beryllium DWA Exposure Estimates

Cumulative Exposure, (μg/m^3 days)	≤ 25	26 – 2444	2445–15,490	> 15,490
Odds Ratio (20 year lag)	1.00	2.10	2.47	1.63
Average Exposure (μg/m^3)	≤ 4	4.1 – 23	23.1 – 31	> 31
Odds Ratio (20 year lag)	1.00	2.77	3.39	1.76

Sanderson WT, Ward EM, Steenland K, Petersen MR. "Lung cancer case-control study of beryllium workers." Am J Ind Med. 2001 Feb;39(2):133-44.

Cohort mortality study of workers at seven beryllium processing plants: update and associations with cumulative and maximum exposure.

Schubauer-Berigan MK, Couch JR, Petersen MR, Carreón T, Jin Y, Deddens JA. Occup Environ Med. 2011 May;68(5):345-53

Maximum Daily Weighted Average Exposure	< 10 µg/m^3				> 10 µg/m^3		
	Cases	SMR	95% CI		Cases	SMR	95% CI
All Workers	95	0.83	0.67 to 1.02		198	1.4	1.21 to 1.61
Excluding							
Short term workers	70	0.85	0.66 to 1.07		76	1.32	1.04 to 1.65
Workers exposed for > 1 year to another occupational carcinogen	73	0.82	0.65 to 1.04		160	1.46	1.24 to 1.71
Professional workers	72	0.87	0.68 to 1.09		195	1.39	1.2 to 1.6

Compensation Paid Since 2001

Energy Employees Occupational Illness Program

Data as of 11/05/2017

Statistical data updated weekly on Mondays

Combined Part B and E Summary

		CLAIMS	CASES
Applications Filed		295,575	197,107*
Total Compensation Paid	Payments	112,435	81,856
	Total Dollars		$10,575,648,088
Total Medical Bills Paid	Total Dollars		$3,721,423,679
Total Compensation + Medical Bills Paid			$14,297,071,767

* The above numbers of applications filed represent 117,497 unique individual workers.

Global estimates of the burden of injury and illness at work in 2012.

Takala J, et al. J Occup Environ Hyg. 2014;11(5):326-37

- Work-related cancer: Attributable Fraction (AF) = 8.4% of all cancer deaths
  - (13.8% male, 2.2% female)
- Circulatory system diseases: AF=12.4%
  - (14.4% male, 6.7% female)
- Respiratory system diseases: AF = 4.1%
  - (6.8% male, 1.1% female)
- Communicable diseases: AF=8.8%
  - (4.8%male, 32.5% female) the latter being high due to occupational infections in the health sector.