



# BERYLLIUM EXPOSURE LIMITS

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# Beryllium Exposure Limits

- 25  $\mu\text{g}/\text{m}^3$  30-min. TWA OSHA PEL
- 10  $\mu\text{g}/\text{m}^3$  15-min. TWA ACGIH TLV-STEL
- 5  $\mu\text{g}/\text{m}^3$  8-Hr TWA OSHA "Ceiling"
- 2  $\mu\text{g}/\text{m}^3$  8-Hr TWA PEL and TLV
- 0.2  $\mu\text{g}/\text{m}^3$  8-Hour TWA ACGIH Notice of Intended Change for trial use
- 0.02  $\mu\text{g}/\text{m}^3$  Lifetime TWA EPA RfC
- 0.01  $\mu\text{g}/\text{m}^3$  30-Day TWA EPA NESHAP

# TLV-STEL Compliance



- 15-minute TWA should not be exceeded at any time during the workday
- Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day
- There should be at least 60 minutes between successive exposures in this range

# TLV-STEEL Compliance cont.

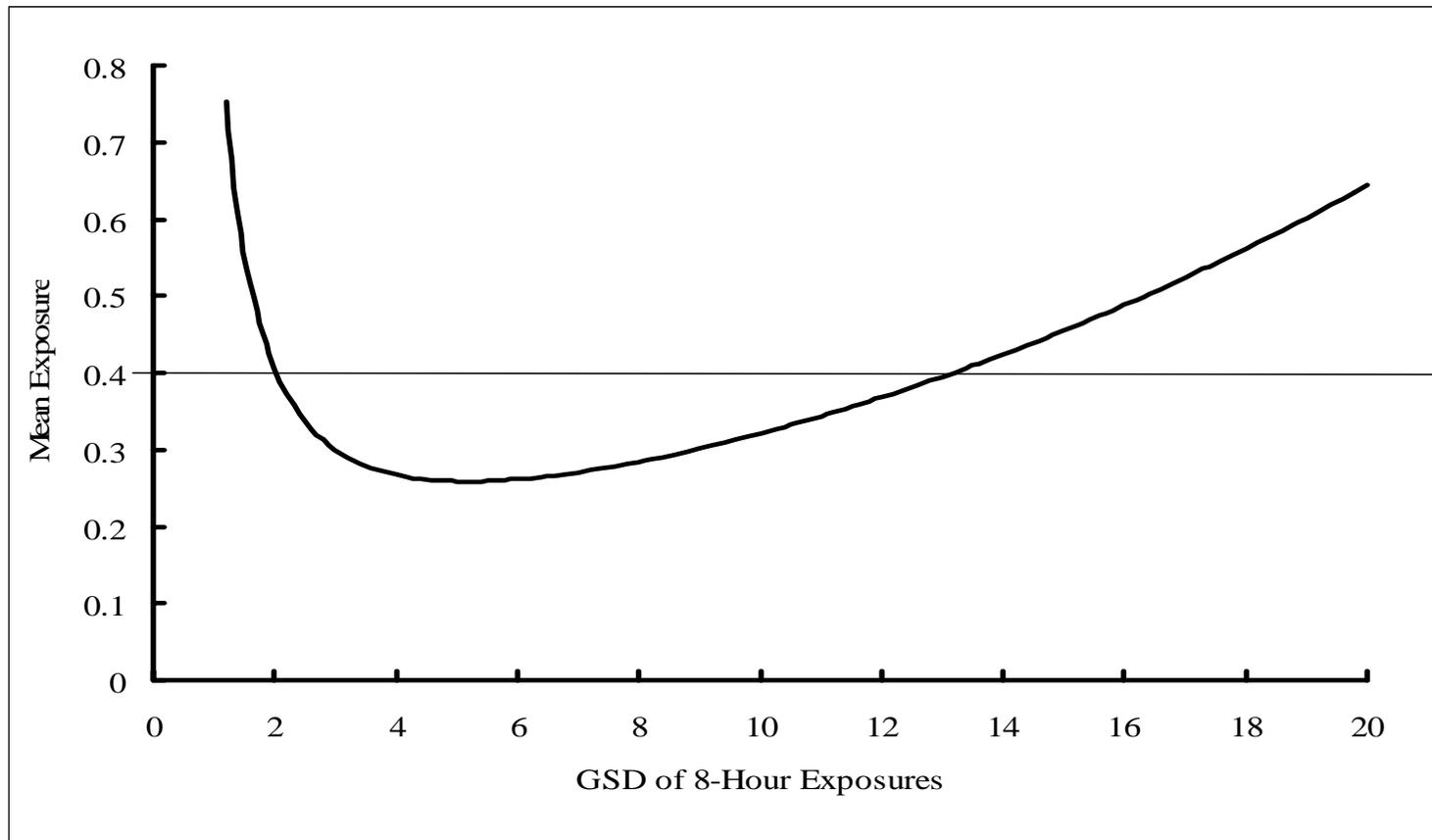
- 95% probability of compliance with  $2 \mu\text{g}/\text{m}^3$  TLV-TWA results in 35% probability of compliances with the  $10 \mu\text{g}/\text{m}^3$  TLV-STEEL
  - Tuggle, RM "The Relationship Between TLV-TWA Compliance and TLV-STEEL Compliance," AOEHL VOL. 15(4) 380-386 (2000)
- 95% compliance with an 8-Hr TWA level of  $10/32 \approx 0.3 \mu\text{g}/\text{m}^3$  assures compliance with TLV-STEEL

# Long Term Mean Compliance

- 95<sup>th</sup> Percentile  $< 4 \times$  Mean in any distribution
  - Rappaport SM. “Assessment of long-term exposures to toxic substances in air.” Ann Occup Hyg. 1991 Feb;35(1):61-121.
- Mean  $< 95^{\text{th}}$  Percentile/2.5 when the GSD is between 2 and 14
  - Wambach PF, Tuggle RM, “Development of an eight-hour occupational exposure limit for beryllium.” Appl Occup Environ Hyg. 2000 Jul;15(7):581-7

# Mean vs GSD

When 5% of 8-hour TWAs Exceed the OEL



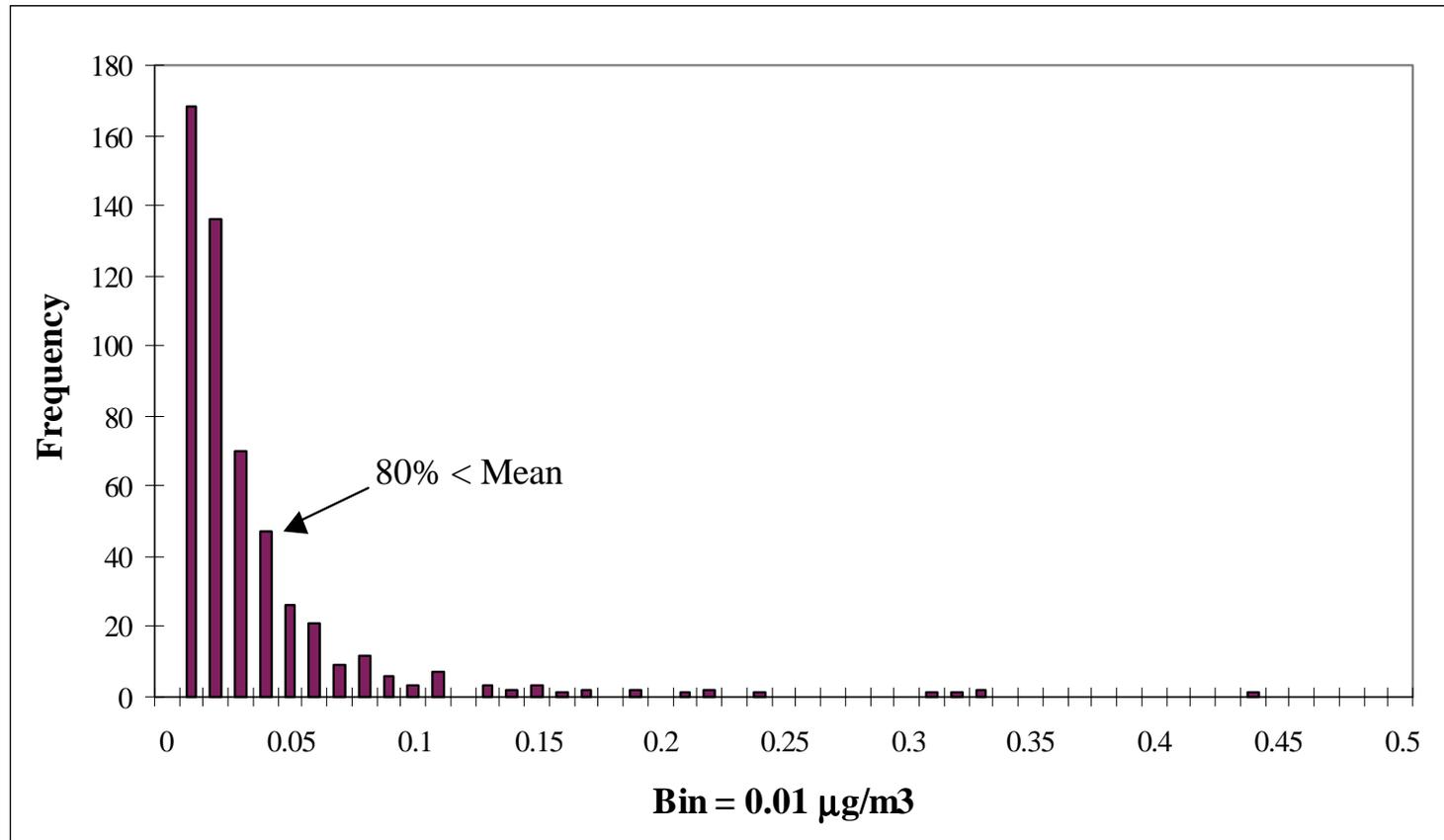
# Rocky Flats Beryllium Machining

## October 1986



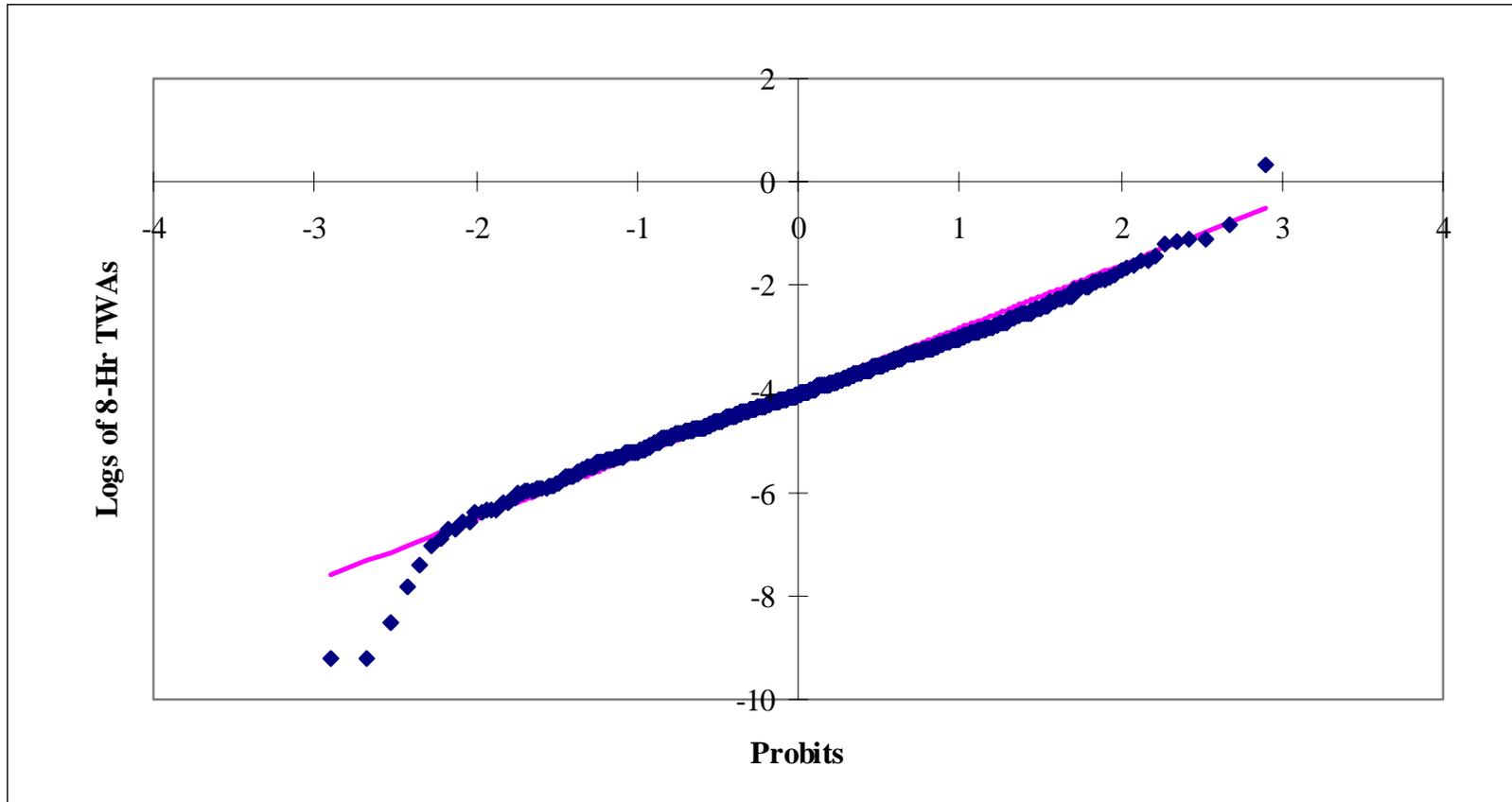
■ Geometric Mean	0.016 $\mu\text{g}/\text{m}^3$
■ Geometric Standard Deviation	3.20
■ Arithmetic Mean	0.044 $\mu\text{g}/\text{m}^3$
■ Actual 95%	0.107 $\mu\text{g}/\text{m}^3$
■ Range of 8-Hour TWAs	
— 1	0.0001 $\mu\text{g}/\text{m}^3$
— . . .	. . .
— 265	0.016 $\mu\text{g}/\text{m}^3$
— . . .	. . .
— 529	5.58 $\mu\text{g}/\text{m}^3$

# Histogram



# Log Probability Plot

## Beryllium Machining



# Analysis of Variance

## ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	172.4	22	7.84	7.08	6.9E-19	1.56
Within Groups	564.6	510	1.107067			
GSD Within	2.86					
GSD Between	1.71					

# Skewed Distribution

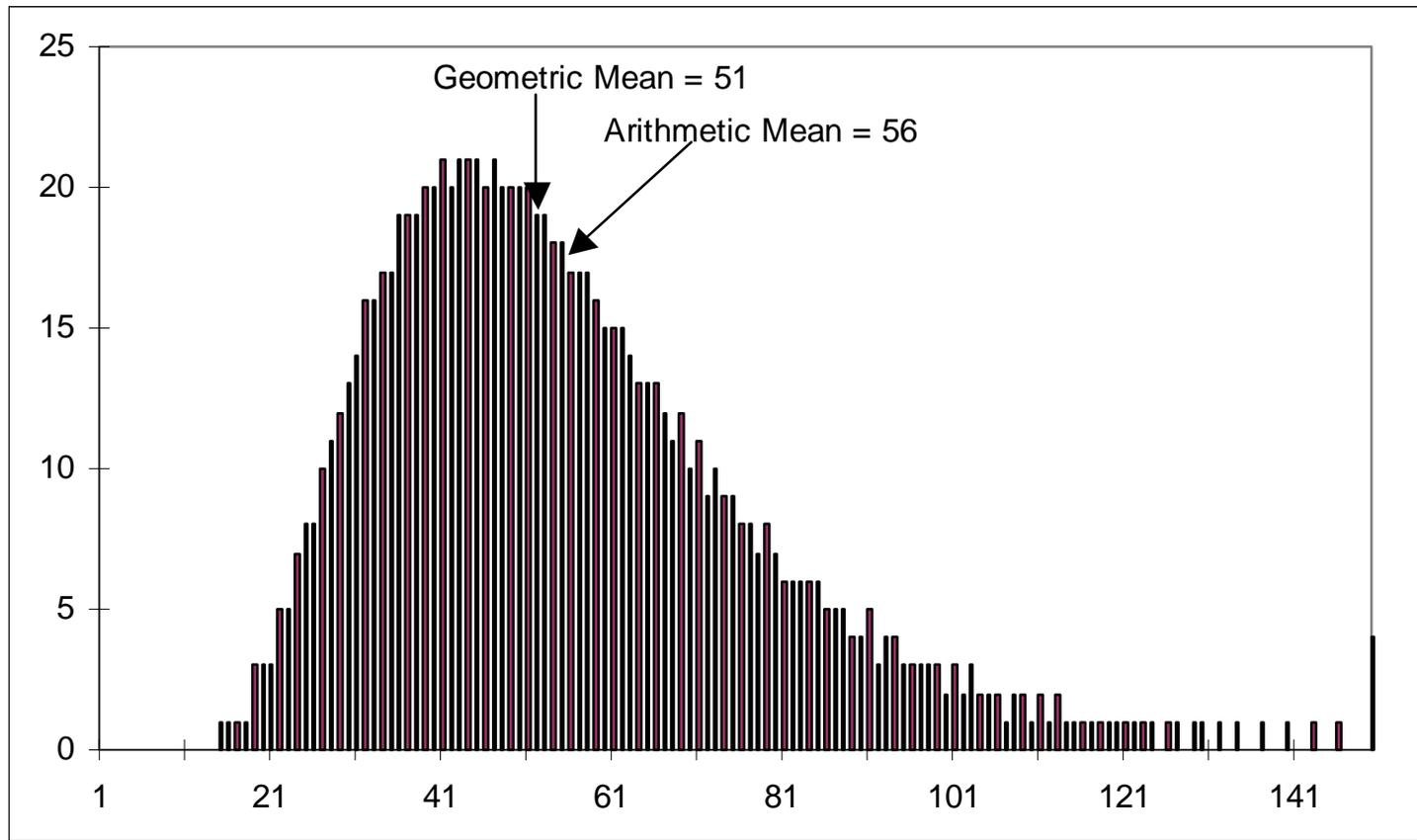
- Mean level highly affected by a few high levels
- Single outlier raises mean from  $0.033 \mu\text{g}/\text{m}^3$  to  $0.044 \mu\text{g}/\text{m}^3$  or 33%
- When  $\text{GSD} = 3.2$  95% confidence interval around the mean is large
  - $\pm 43\%$  with sample size = 60

# Other Data

- Cardiff Machine Shop Est. GSDs 1.9 – 4.6
  - $GSD = \text{Exp}[\{\ln(95^{\text{th}}\%) - \ln(\text{Median})\}/1.645]$
- Speedring Est. GSD = 6.1
  - $GSD = \text{Exp}[\sqrt{\{2 * \ln(\text{Mean}) - \ln(\text{Median})\}}]$
- Elmore Pebbles Plant Personal Samples Est. GSD = 3.8
  - $GSD = \text{Exp}[\{\ln(2) - \ln(\text{median})\} / Z(2)]$
- Rocky Flats 1984 – 1985 GSD = 2.9

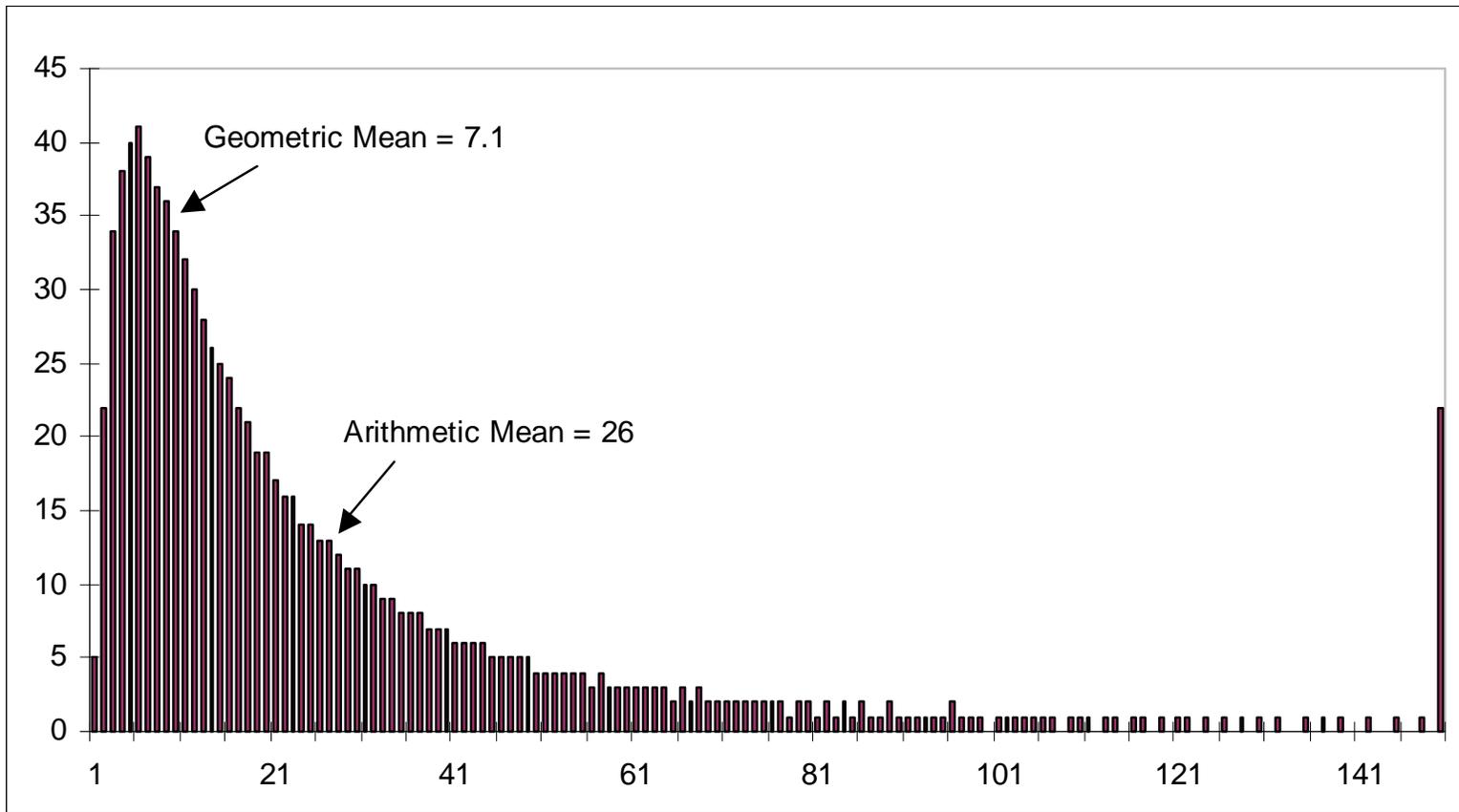
# Hypothetical Distribution

GSD = 1.5    95th% = 100



# Hypothetical Distribution

GSD = 5   95th% = 100



# Conclusions



- Investigations of dose rate vs total dose will be confounded by the large influence excursions have on mean exposure level
- Investigations of the influence of particle size on risk will be confounded by the uncertainty in determining mean levels
- Risk is driven by exposure excursions that are difficult to predict or detect without frequent monitoring