iH STATISTICS
THE NEXT GENERATION

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Occupational Hygiene 2016 – Glasgow, Scotland

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SafeBridge Consultants, Inc.

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Where We Are Today

- Despite advances, “professional judgment” still rules (i.e. one or more measurements “look fine”)
- Lognormal statistics are not intuitive
- Statistical tools are often misunderstood and misapplied

Table 1. Integrated Methylene Chloride Sampling Results at [redacted], August 2, 2010

Exposure Limits: PEL = 25 ppm (TWA), Action Level = 12.5 ppm (TWA)

Sample ID	Location and Duration	Sampling Result ppm	8 Hour Time Weighted Average Result*, ppm
XH5654	[redacted] (operator gluing plastic parts), 438 minutes	13.0	13.0 (10.6, 15.4)*
XH5650	Field Blank	LOD, < 5 µg	n/a

Table 1. Integrated Methylene Chloride Sampling Results at [redacted] January 20, 2011

Exposure Limits: PEL = 25 ppm (TWA), Action Level = 12.5 ppm (TWA)

Sample ID	Location and Duration	Sampling Result ppm	8 Hour Time Weighted Average Result, ppm
XU3851	[redacted] (operator gluing plastic parts), 489 minutes	12.0	12.0 (9.2, 14.8)*
XU3858	Field Blank	39 µg**	n/a

Statistical Tools

- Traditional (parametric) statistical calculations
- Bayesian statistics
- Rule based statistics such as EN689
- Others…

Parametric Statistics for a Small Data Set

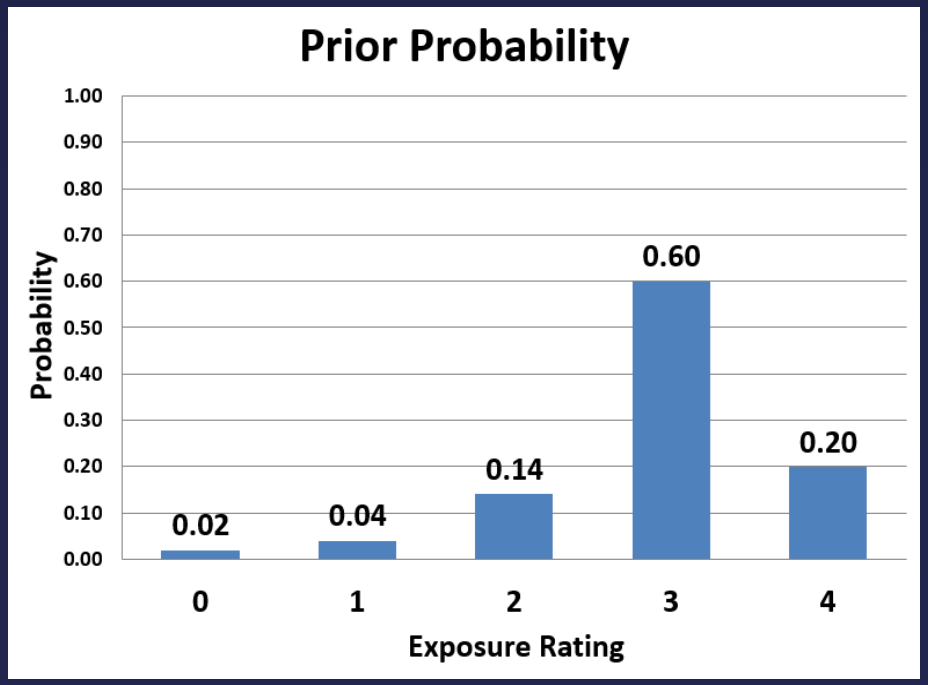
Data = 0.035, 0.17, 0.11; OEL = 1

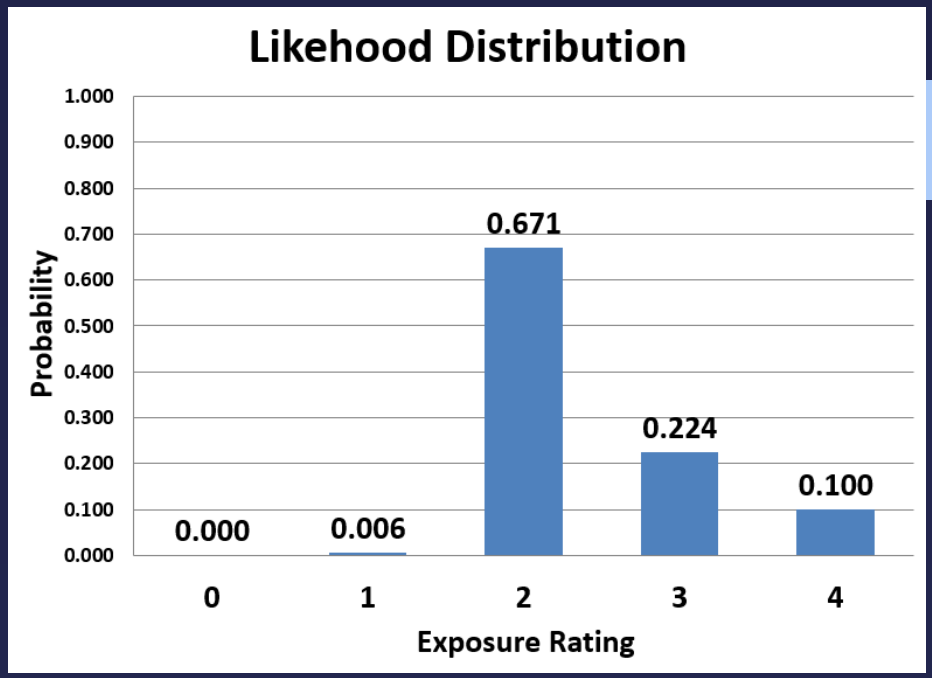
X95 = 0.33

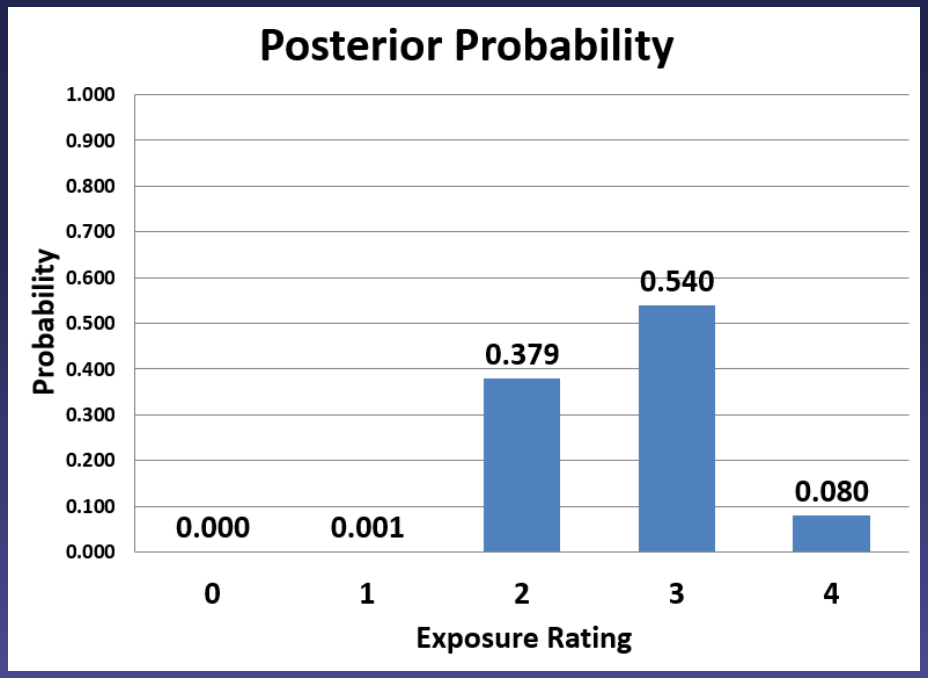
95% UCL X95 = 54

Actual: GM=0.2, GSD = 3, X95 = 1.2

No. samples	Frequency under-estimate GSD	Frequency under-estimate X95 by 2x
3	63%	30%
6	58%	15%
12	55%	<5%

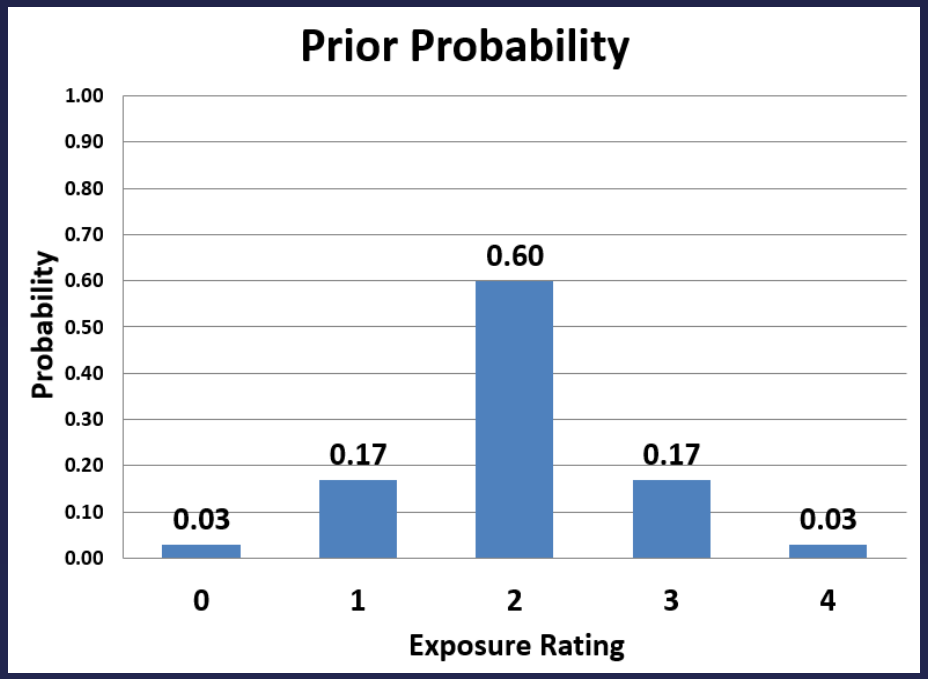


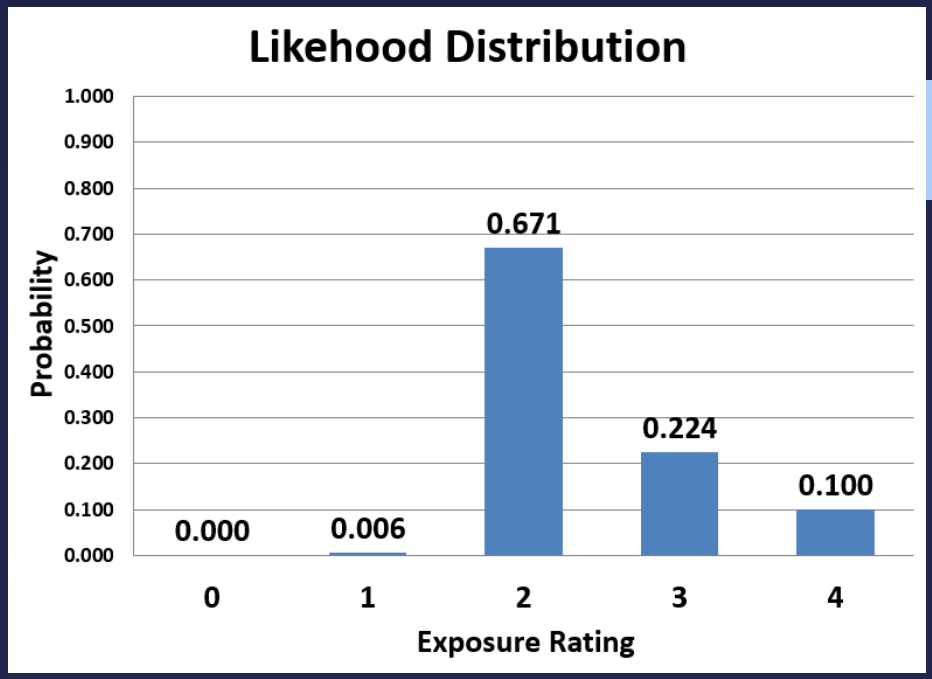


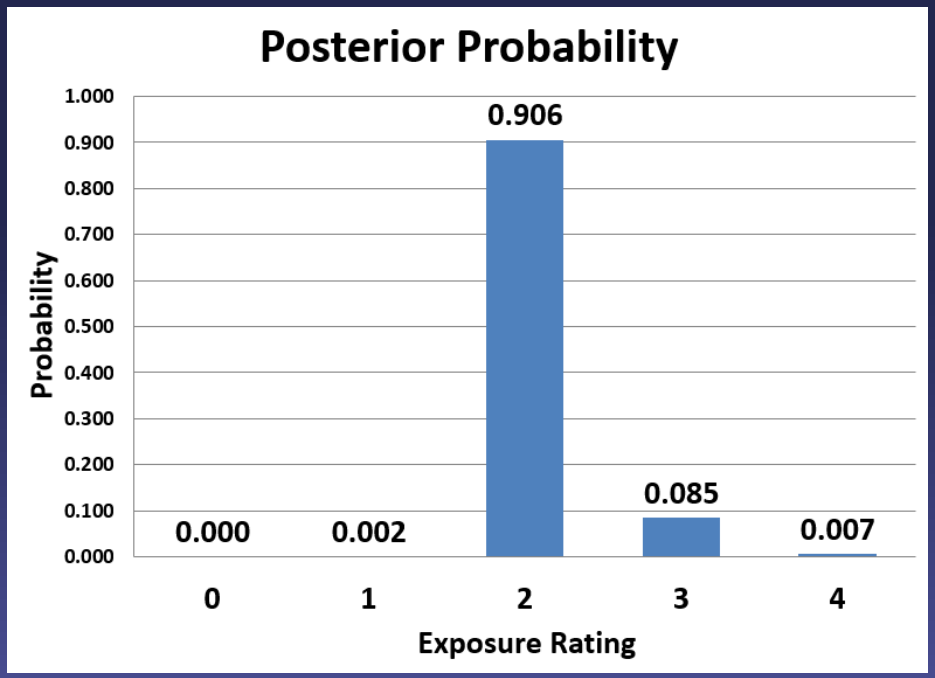


Data = 0.035, 0.17, 0.11

Actual: GM=0.2, GSD = 3, OEL =1, p>OEL = 0.07





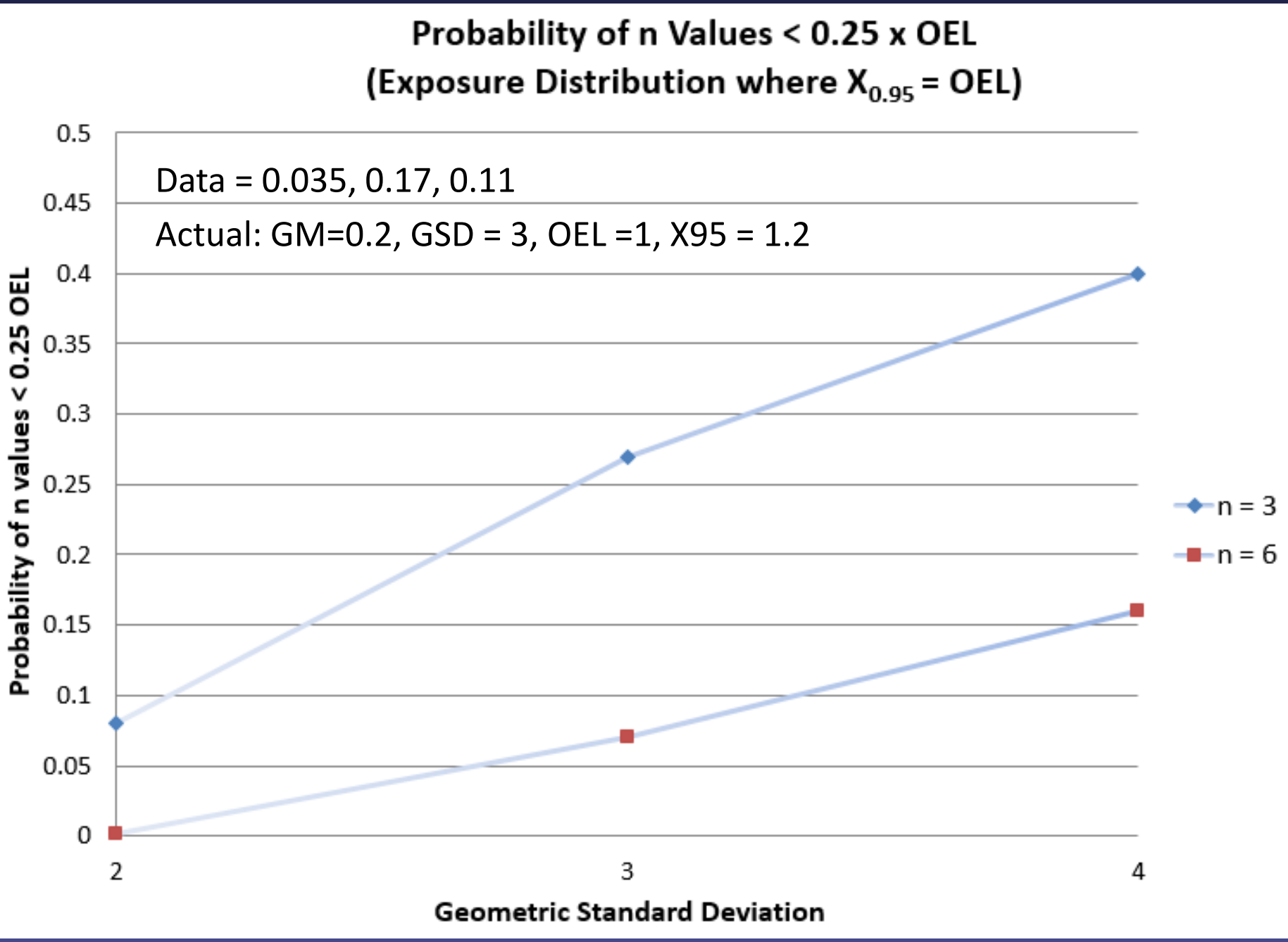


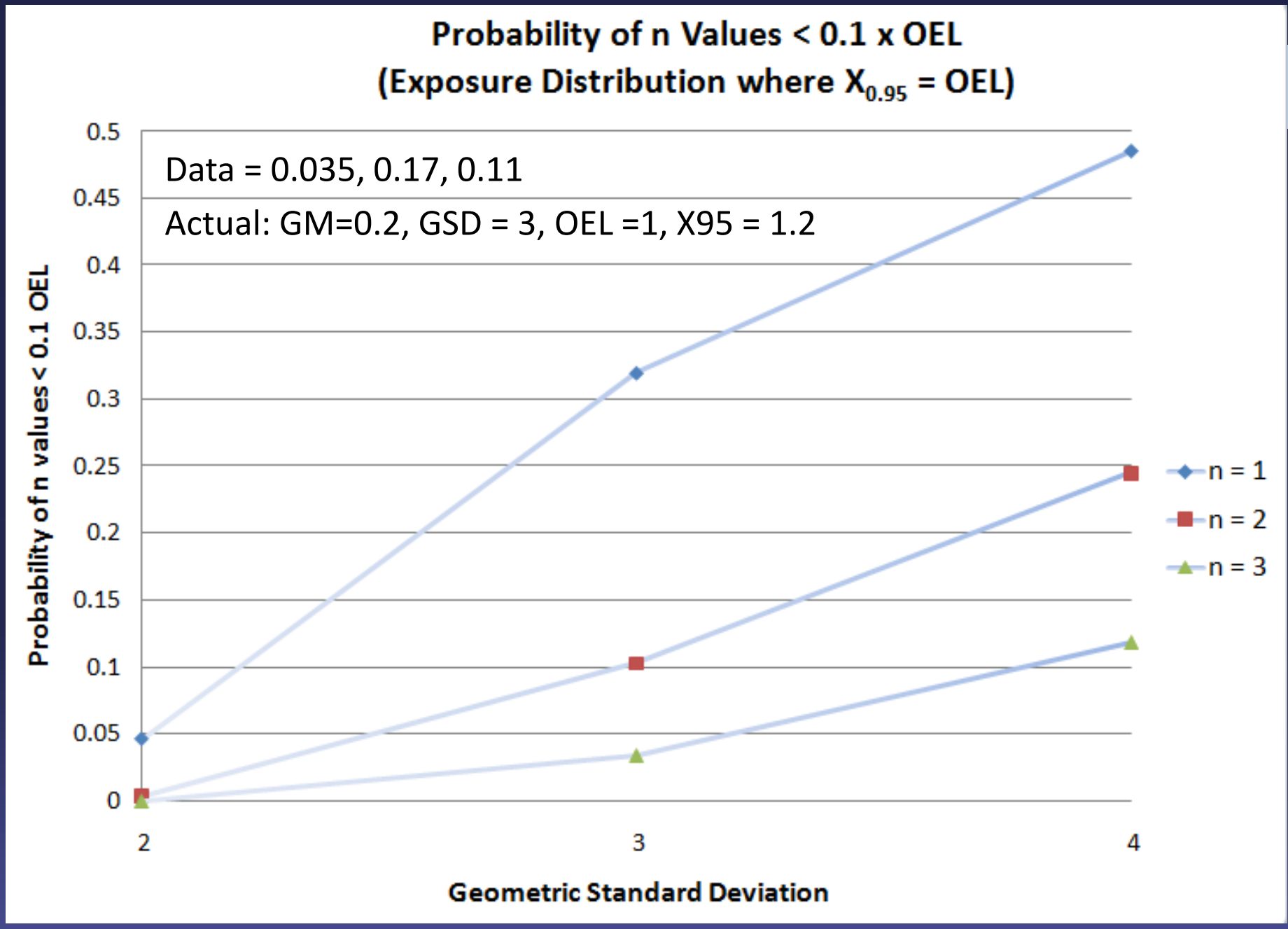
Data = 0.035, 0.17, 0.11

Actual: GM=0.2, GSD = 3, OEL =1, p>OEL = 0.07

Data = 0.035, 0.17, 0.11

Actual: GM=0.2, GSD = 3, OEL =1, X95 = 1.2


Probability of n Values < 0.25 x OEL
(Exposure Distribution where $X_{0.95}$ = OEL)
Data = 0.035, 0.17, 0.11
Actual: GM=0.2, GSD = 3, OEL =1, X95 = 1.2
Probability of n values < 0.25 OEL
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2
3
4
Geometric Standard Deviation
n = 3
n = 6


Probability of n Values < 0.1 x OEL
(Exposure Distribution where $X_{0.95}$ = OEL)
Data = 0.035, 0.17, 0.11
Actual: GM=0.2, GSD = 3, OEL =1, X95 = 1.2
Probability of n values < 0.1 OEL
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2
3
4
Geometric Standard Deviation
n = 1
n = 2
n = 3

“As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality.” - Albert Einstein

Mathematical accuracy ≠ pragmatism

Sensitivity and Specificity

	DISEASE (overexposed)	NO DISEASE (not overexposed)
TEST + (fails)	9 (true positives)	6 (false positives)
TEST – (passes)	1 (false negatives)	14 (true negatives)
Total	10	20

Sensitivity = TP / Disease = 9/10 = 90%

Specificity = TN / No disease = 14/20 = 70%

Sensitivity and Specificity

Example comparison of statistical tools for simulated data

- 10 sets of 3 random data points from 10 lognormal exposure distributions (i.e. 100 sets of 3 data points)
- Apply the following tools:
  - Parametric statistics - X95, 95% UCL X95
  - Rule based statistics - < 0.25 x OEL, < 0.1 x OEL

Sensitivity and Specificity

		True +	False +	False -	True -
Parametric statistics	X95	34	8	16	42
	95% UCL X95	50	46	0	4
Rule based statistics	3 < 0.25 x OEL	48	19	2	31
	3 < 0.1 x OEL	50	33	0	17

Sensitivity and Specificity

		Sensitivity	Specificity
Parametric statistics	X95	68%	84%
	95% UCL X95	100%	8%
Rule based statistics	3 < 0.25 x OEL	96%	62%
	3 < 0.1 x OEL	100%	34%

Risk Considerations

The choice of a statistical tool and the acceptance criteria, as well as the frequency of reassessment, may be affected by:

- Hazards
  - Severity of effects
  - Warning properties
  - Pharmacokinetics
- Reliability and robustness of engineering controls
- Professional judgment regarding exposure and how representative our measurements are

THE NEXT GENERATION

- Even more occupational hygienists – and others interpreting data – apply AND understand statistical tools
- The right statistical tool is chosen pragmatically – consider sensitivity and specificity
- Sampling plans and the choice of statistical tools and acceptance criteria incorporate risk assessment
- Better decisions are made more frequently – and with a higher probability of “success”

Thank You!

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