



iH
STATISTICS
THE NEXT GENERATION

Brent Altemose, Ph.D., CIH, CSP

Principal Hygienist

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SafeBridge Consultants, Inc.

A TRINITY CONSULTANTS COMPANY

Mountain View, CA ▪ New York, NY ▪ Liverpool, UK ▪ Easton, PA

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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

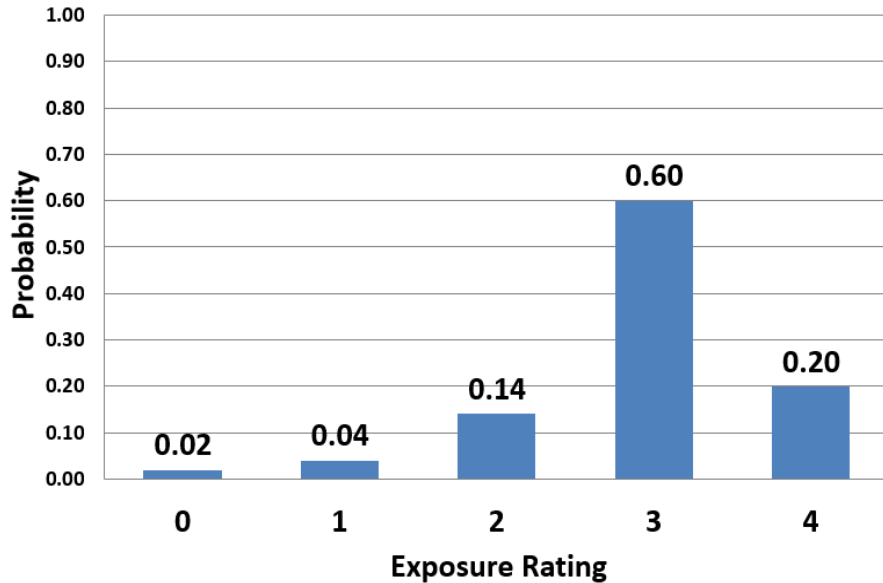
$X_{95} = 0.33$

95% UCL $X_{95} = 54$

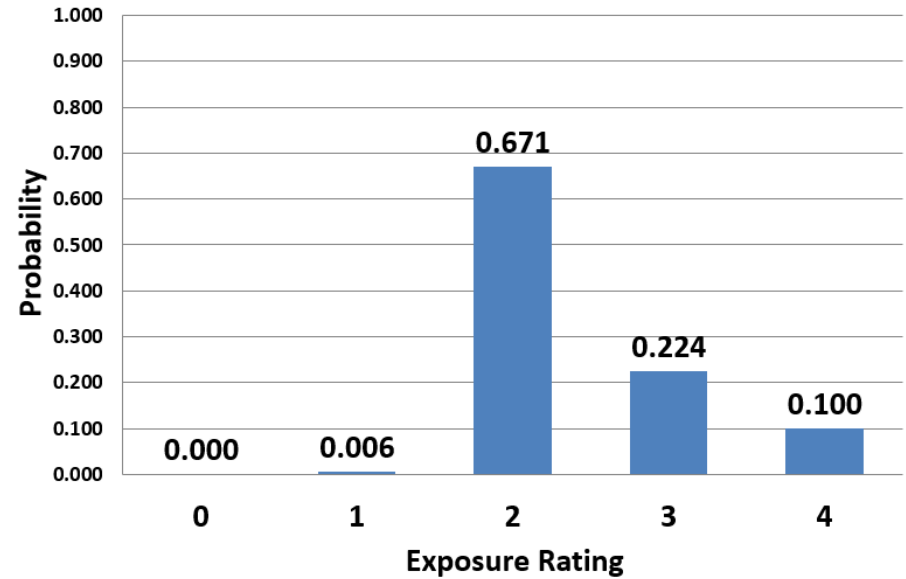
Actual: GM=0.2, GSD = 3, $X_{95} = 1.2$

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

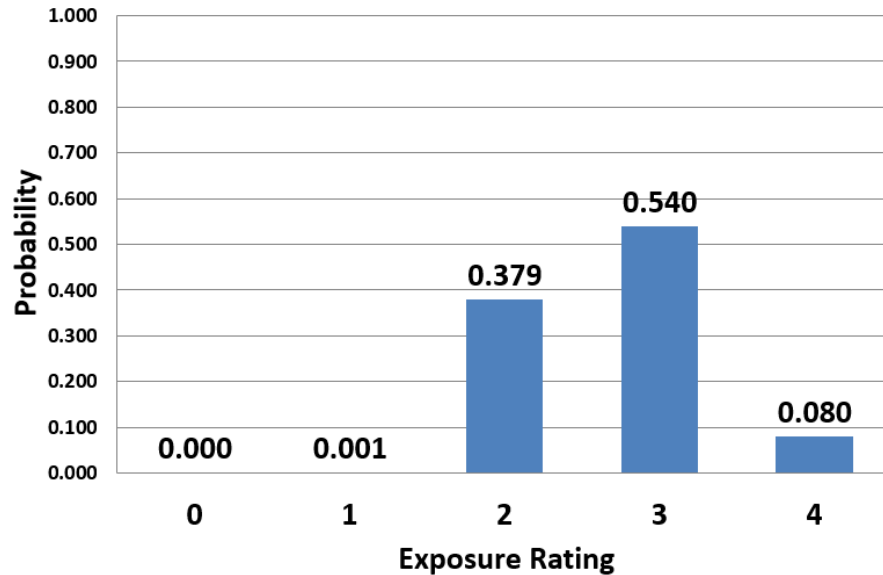
Prior Probability



Likelihood Distribution



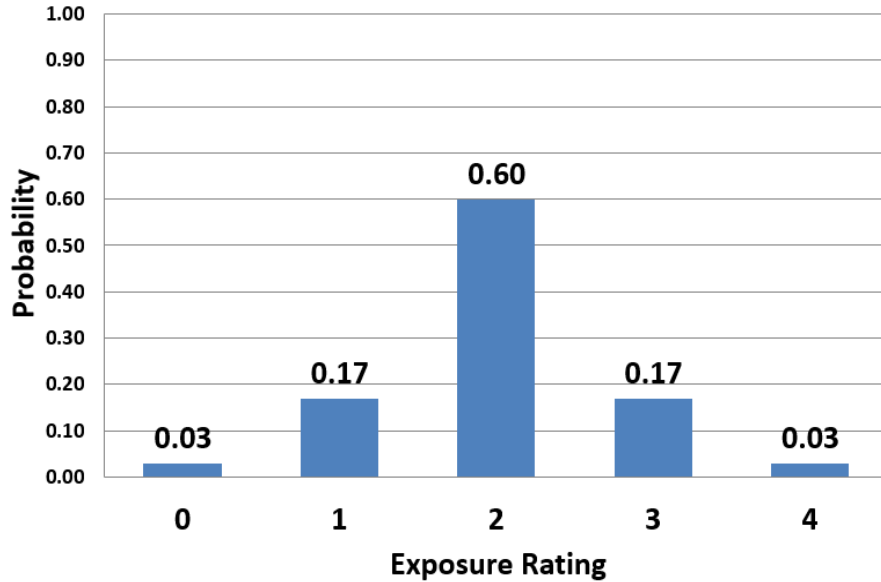
Posterior Probability



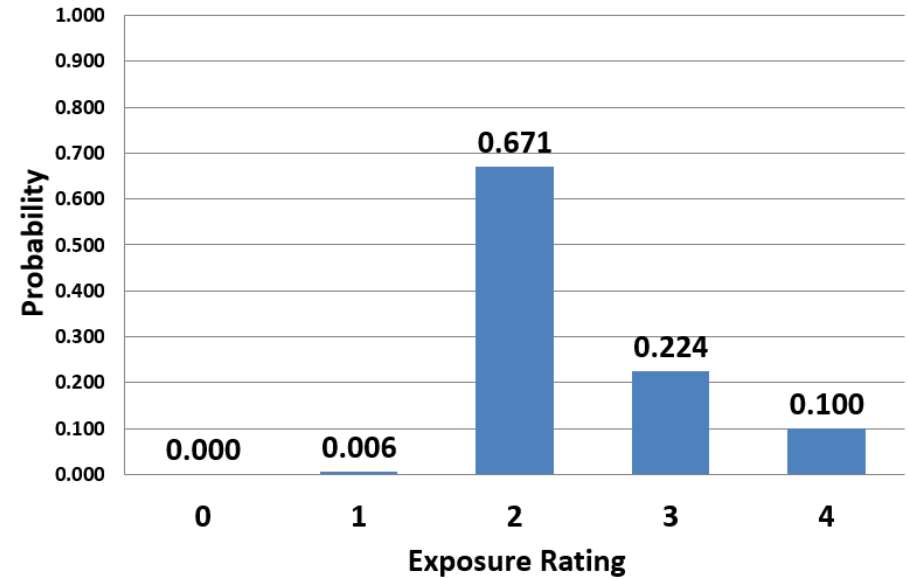
Data = 0.035, 0.17, 0.11

Actual: GM=0.2, GSD = 3,
OEL =1, $p > \text{OEL} = 0.07$

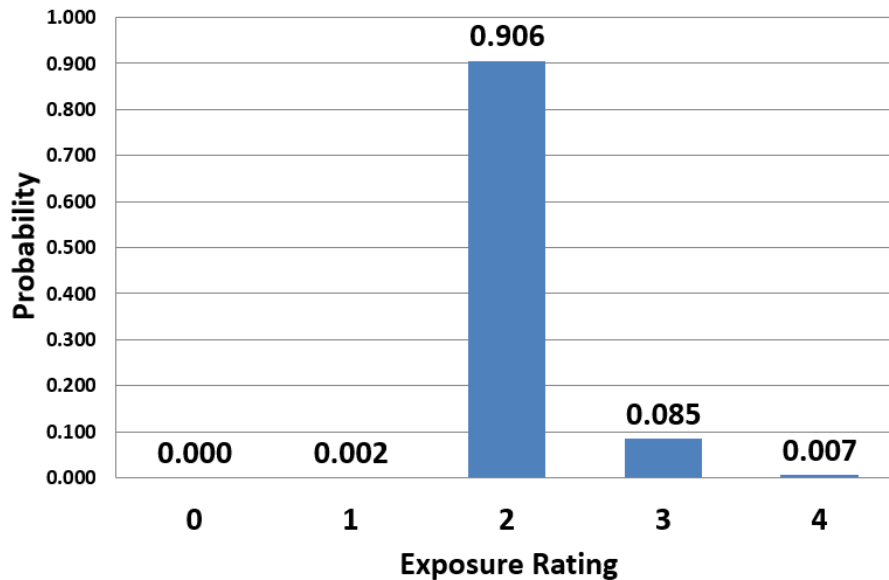
Prior Probability



Likelihood Distribution



Posterior Probability



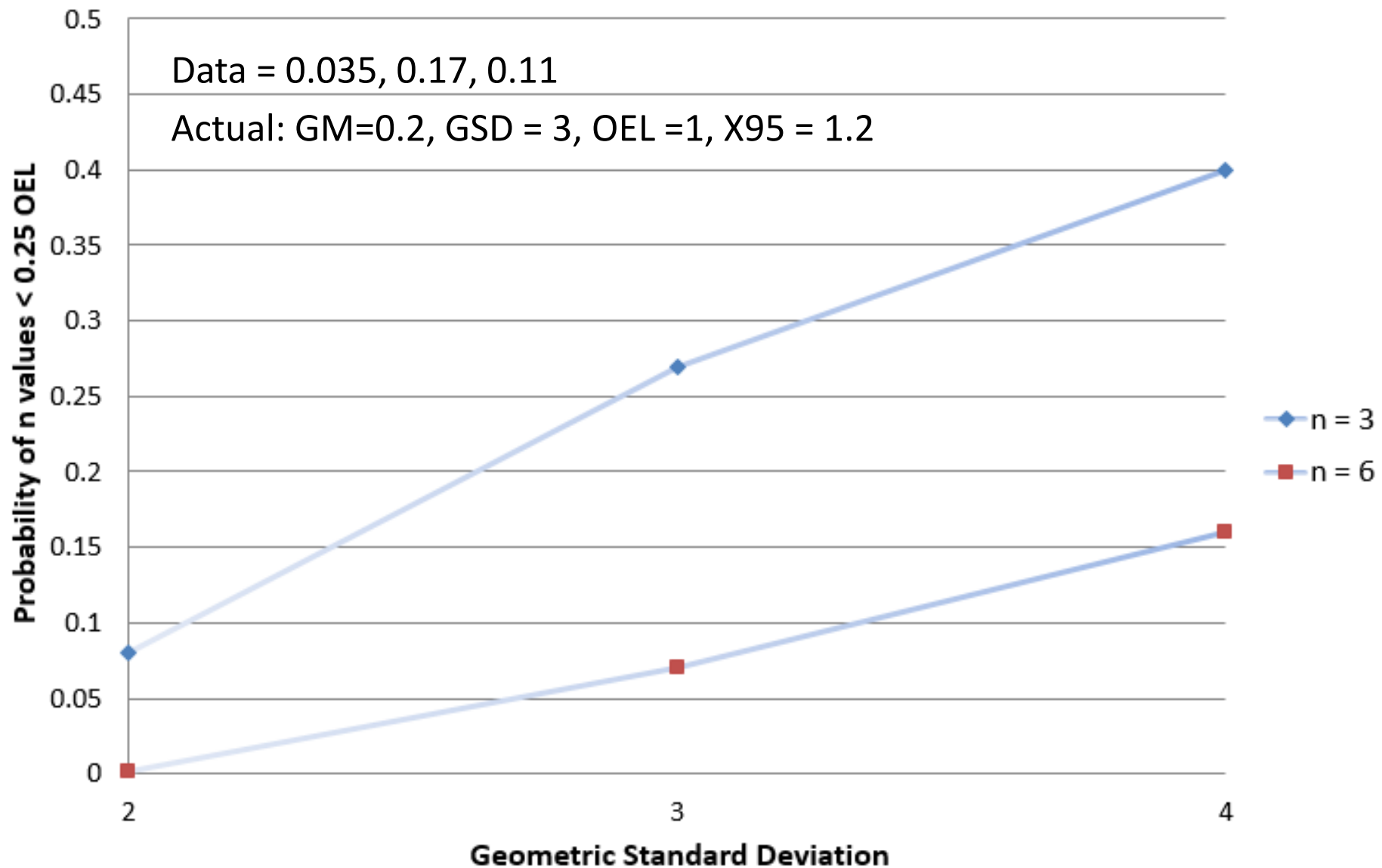
Data = 0.035, 0.17, 0.11

Actual: GM=0.2, GSD = 3,
OEL =1, $p > \text{OEL} = 0.07$

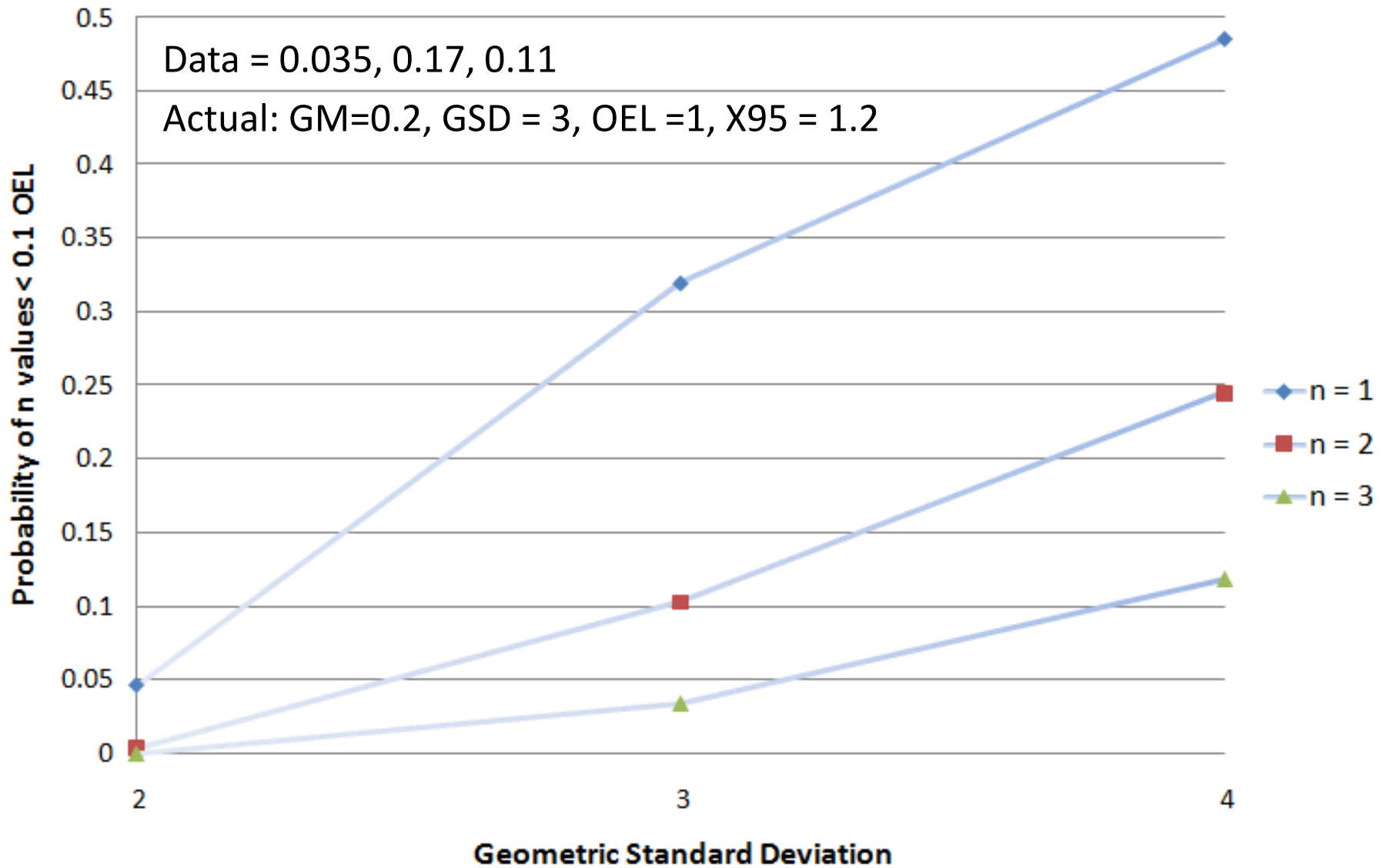
Data = 0.035, 0.17, 0.11


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

Probability of n Values < 0.25 x OEL (Exposure Distribution where $X_{0.95} = \text{OEL}$)



Probability of n Values < 0.1 x OEL (Exposure Distribution where $X_{0.95} = \text{OEL}$)





“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 \neq 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 - $< 0.25 \times \text{OEL}$, $< 0.1 \times \text{OEL}$

Sensitivity and Specificity

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

Sensitivity and Specificity

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