



ACCURACY OF PERSONAL MONITORING BADGES

.... DOES IT MATTER?

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GOALS OF PRESENTATION

Accuracy of Personal Monitoring Badges: Does It Matter?

Broadened understanding of accuracy of exposure assessments.

Simplified understanding of studies on the uncertainty of sampling events, lab analysis, and exposure risk judgments.

Acknowledgements & References

"A Strategy for Assessing and Managing Occupational Exposures"
Ed. S. D. Jahn, W.H. Bullock, and J.S. Ignacio (AIHA University)

"Making Accurate Exposure Risk Decisions", A. D. Perkins, Jerome Lavoué, Paul Hewett, & John Mulhausen (AIHA University)

ACCURACY OF PERSONAL MONITORS

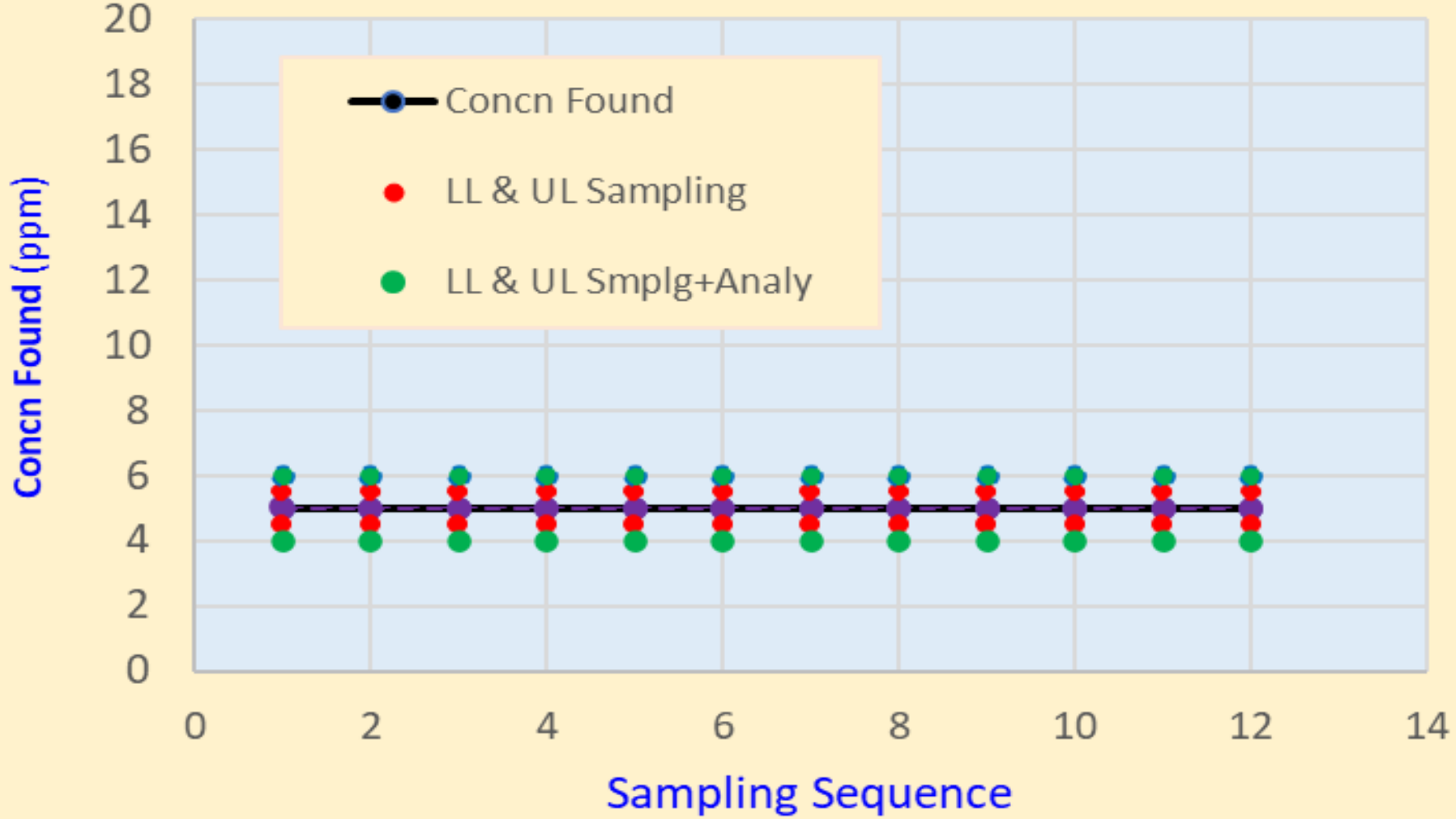
...REQUIREMENTS

- NIOSH Guidelines
 - Sampling & Analytical Methods
 - Uncertainty $\leq 25\%$ @95% Confidence
- OSHA Guidelines
 - Sampling & Analytical Methods
 - No General Guidelines
 - Special Substance Regulations
 - Uncertainty $\leq 25\%$ @95% Confidence
 - $\leq 35\%$ in some cases

WHAT IS THE ACCURACY OF SAMPLING & ANALYSIS?

- Sampling & Analysis
 - Sampling Rate Uncertainty
 - $\leq \pm 5-10\%$
 - Recovery/Analysis of Sampler
 - $\leq \pm 5-10\%$
 - Overall Uncertainty
 - $\leq \pm 10-25\%$
- Variation Among
 - Samplers
 - Labs
 - Analysts
 - Overall Variation $\leq \pm 10-25\%$

Uncertainty in Sampling/Analysis



To decide whether this accuracy matters ,we must consider ...

WHY WE MONITOR

- Is TWA Concentration in each worker's breathing zone $<$ OEL?
- Occupational Exposure Limit (PEL, STEL, TLV, other OEL)
 - An Occupational Exposure Limit is meant to be a “safe level”
 - I.e., **No Effect & No Harm** *if exposure* $<$ **OEL**

TWA = Time-Weighted-Average OEL = Occupational Exposure Limit (PEL, STEL, TLD, etc.)

WHY WE MONITOR

- Is TWA Conc'n in a worker's breathing zone < OEL?
 - Real-World Answer...neither YES nor NO ... but, a statistic
 - *We should ask ...*
 - What is the likelihood of exceeding the OEL?
 - Different workers, different days
 - SEG any day of the year
 - When an OSHA inspector is in the plant
-
- SEG = Similar Exposure Group (cohort of workers with similar exposures)

“OLD SCHOOL” – EXPOSURE RISK DECISIONS

- OSHA Inspector samples workers on a single day
 - A random audit ... but not “representative”
- OSHA’s PEL Calculation
 - (TWA Conc’n Found) – (estimated Sampling Uncertainty)
 - Adjusted Exposure Value
 - If Adjusted Exposure Value > PEL, you get a citation.

CONFLICTING VIEWS OF OSHA COMPLIANCE

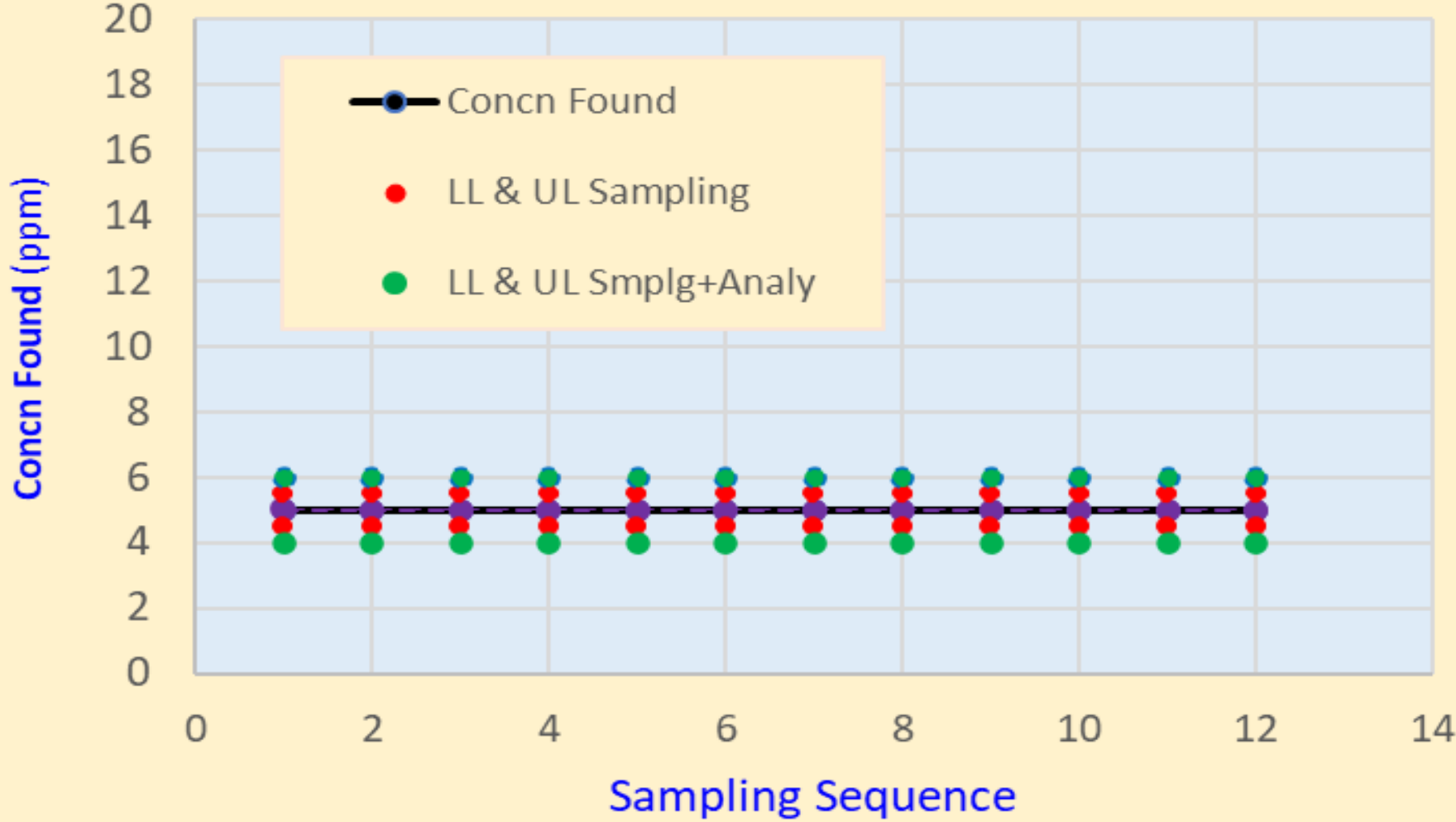
- The average of a worker's TWA exposures < PEL
 - 50% of exposures < PEL
- The 95th percentile of workers' TWA exposures < PEL
 - 95% of exposures < PEL
- The 100th percentile of a worker's TWA exposures < PEL
 - 100% of exposures < PEL

Nicas, M., Simmons, B. P., & Spear, R. C. (1991). ENVIRONMENTAL VERSUS ANALYTICAL VARIABILITY IN EXPOSURE MEASUREMENTS. *American Industrial Hygiene Association Journal*, 52(12), 553–557.
<https://doi.org/10.1080/15298669191365199>

WORKPLACE VARIATION

- Early (1980s) IH Models assumed uniform & constant exposures
- OSHA's compliance model assumed uniform & constant exposures
- Many IH's liked to believe exposures are uniform & constant

Uncertainty in Sampling/Analysis



WORKPLACE VARIATION... *ACTUALLY FOUND TO BE HIGH!!*

survey of 183 exposure groups with 15,295 measurements ...

- “The results indicate that, contrary to popular belief, only about one fifth of the HEGs were uniformly exposed (< 2-fold difference among 95% of individual mean exposures) while an equal number showed a high degree of variation between workers (> 15-fold difference among 95% of individuals).”

S. M. RAPPAPORT, H. KROMHOUTA & E. SYMANSKI (1993) VARIATION OF EXPOSURE BETWEEN WORKERS IN HOMOGENEOUS EXPOSURE GROUPS, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION JOURNAL, 54:11, 654-662, DOI: [10.1080/15298669391355198](https://doi.org/10.1080/15298669391355198)

MORE ON WORKPLACE VARIATION

- “...an analysis of exposure data from nine types of industrial processes for 31 different worker groups found that workers in 87% of the groups had a GSD ≥ 1.5 .”

Selection of the Measures of Exposure for
Epidemiology Studies S. M. Rappaport Pages 448-457;
<https://doi.org/10.1080/1047322X.1991.10387912>

- “Typical workplaces have a GSD between 1.5-4.0” – AIHA’s IHDA

“For typical values of the GSD and CV, environmental variability is far more important than analytical variability in determining the variance of the measured 8-hr TWAs.”

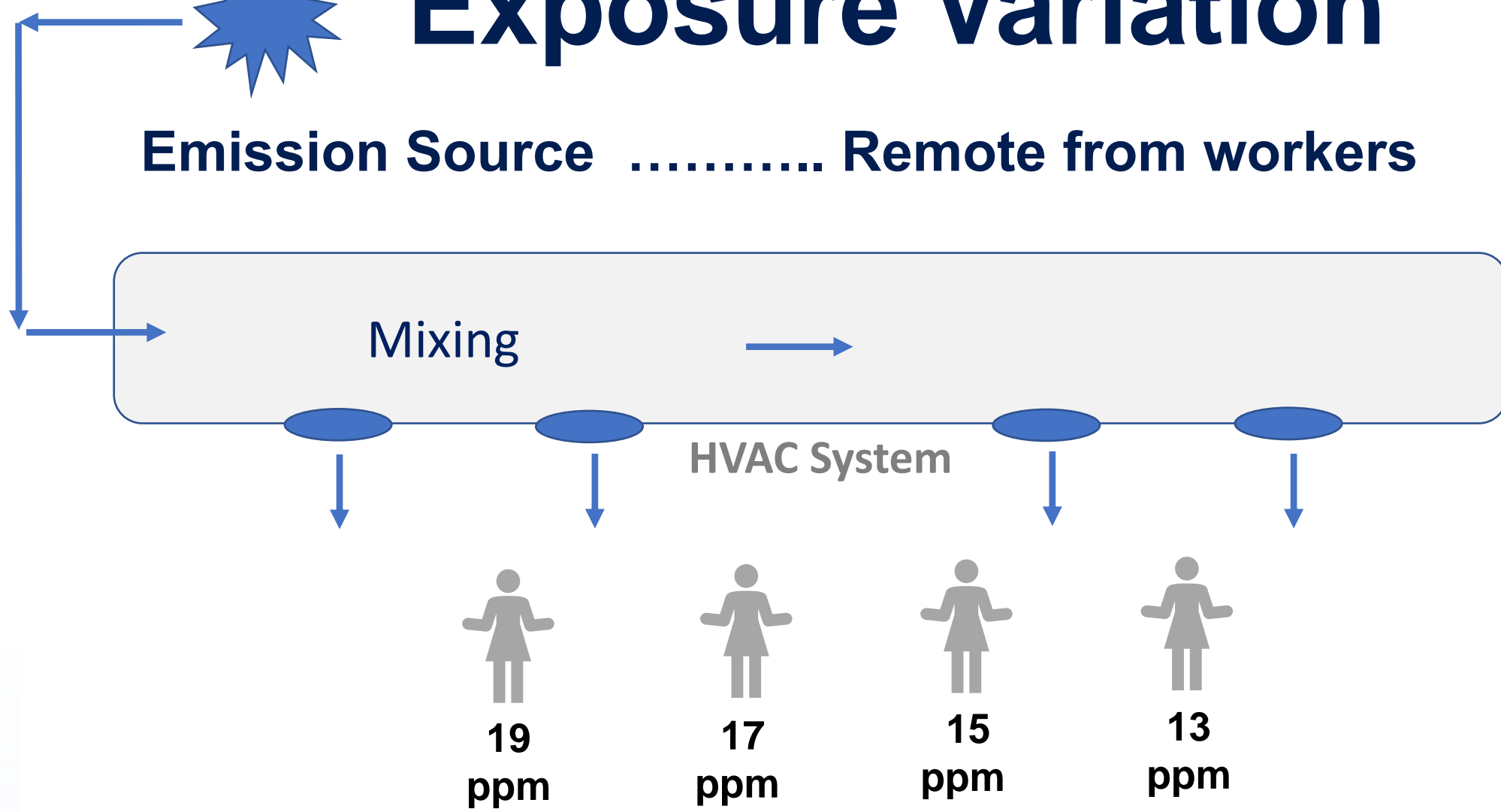
“A resulting policy implication is that the OSHA inappropriately focuses on analytical variability when determining compliance with its permissible exposure limits.”

Nicas, M., Simmons, B. P., & Spear, R. C. (1991). ENVIRONMENTAL VERSUS ANALYTICAL VARIABILITY IN EXPOSURE MEASUREMENTS. American Industrial Hygiene Association Journal, 52(12), 553–557.
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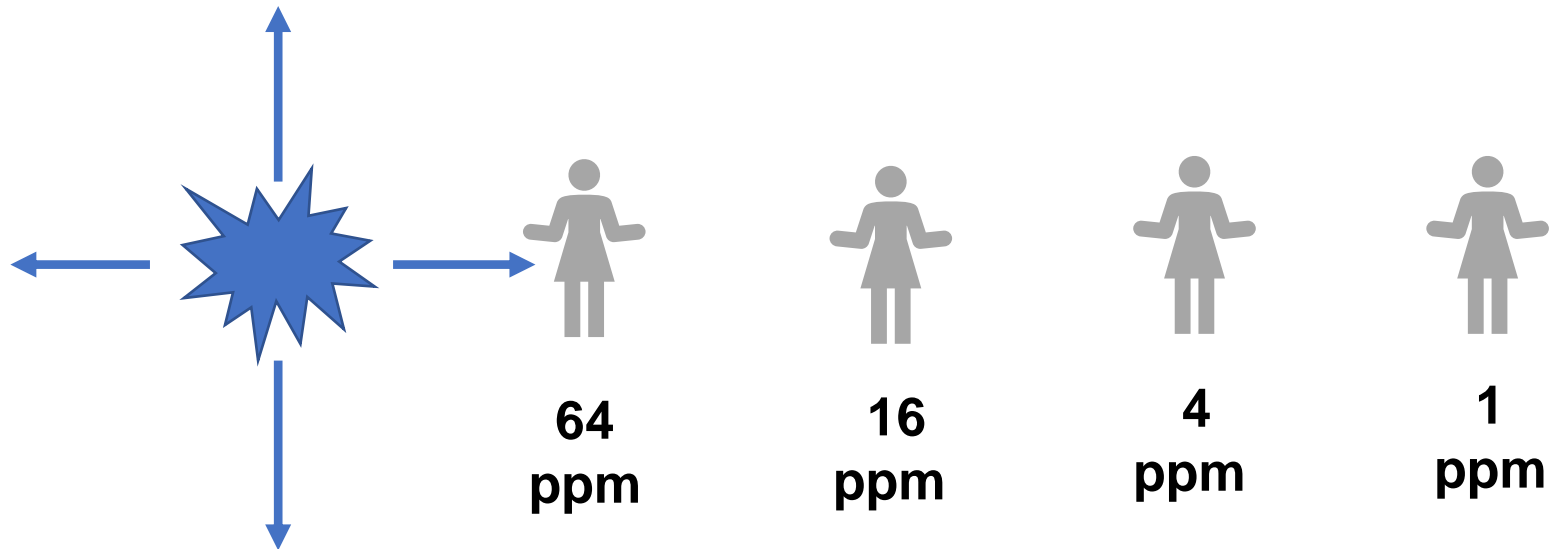
Exposure Variation

Emission Source Remote from workers

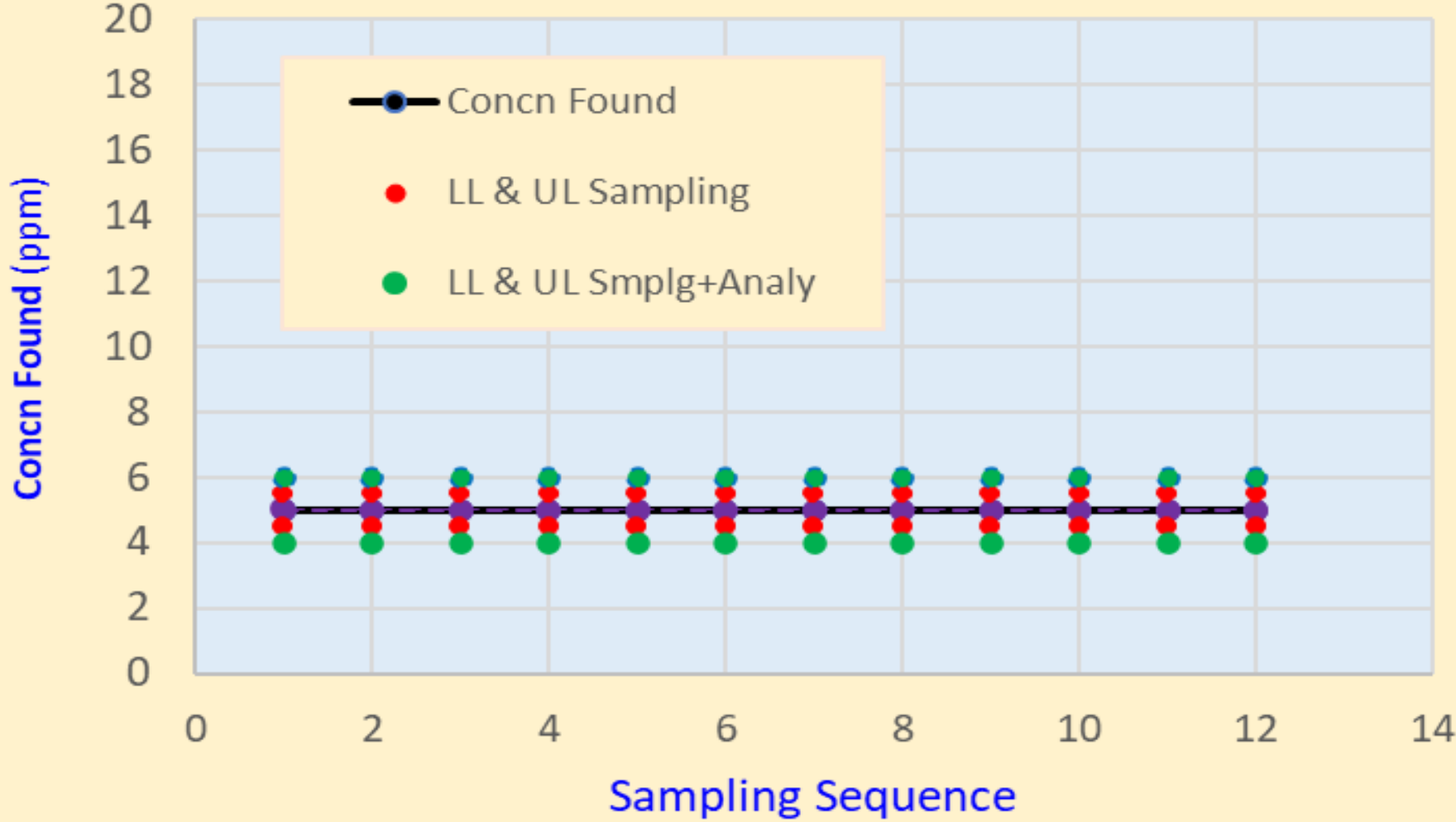


Exposure Variation

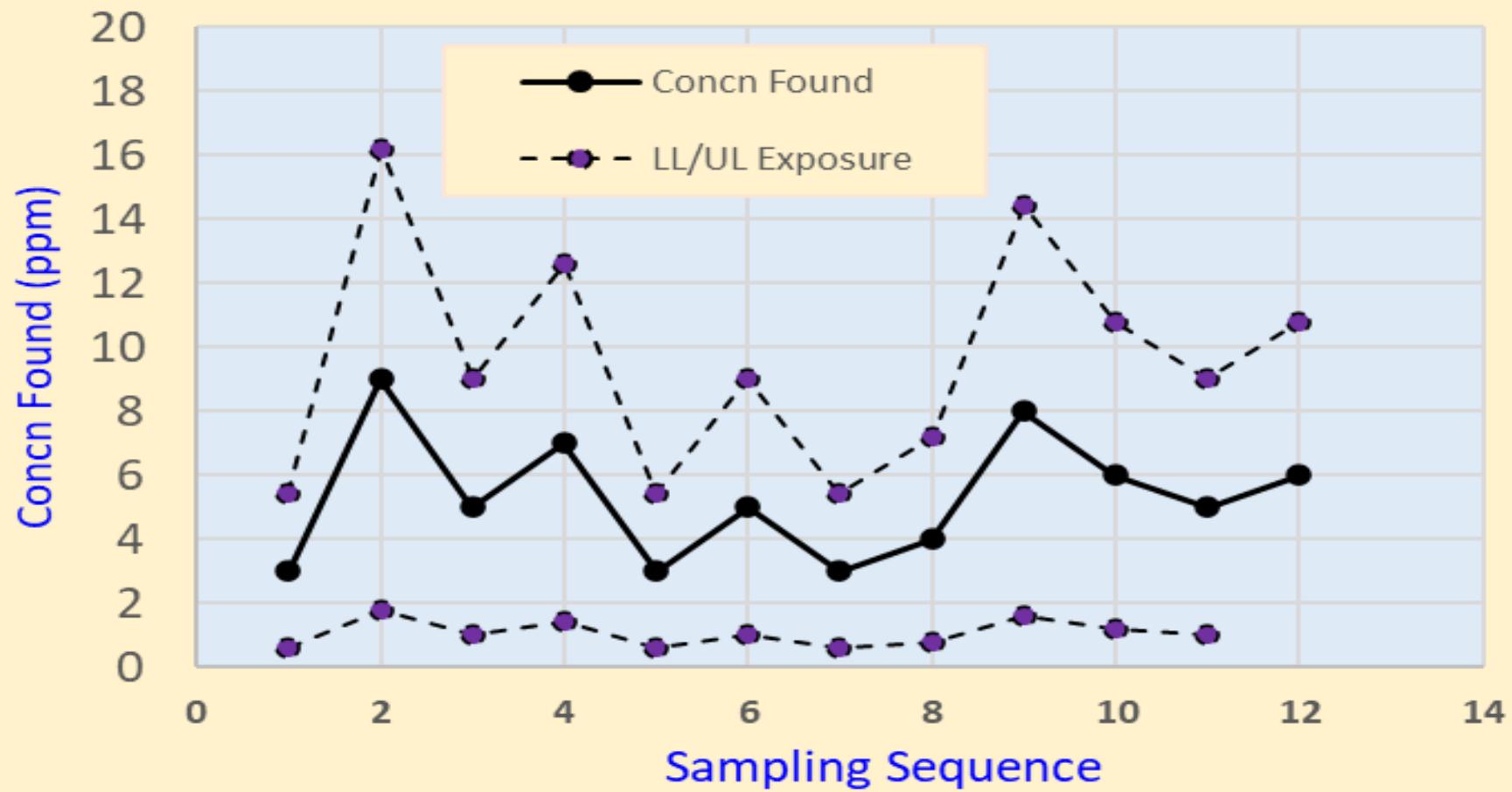
Emission Source close to workers



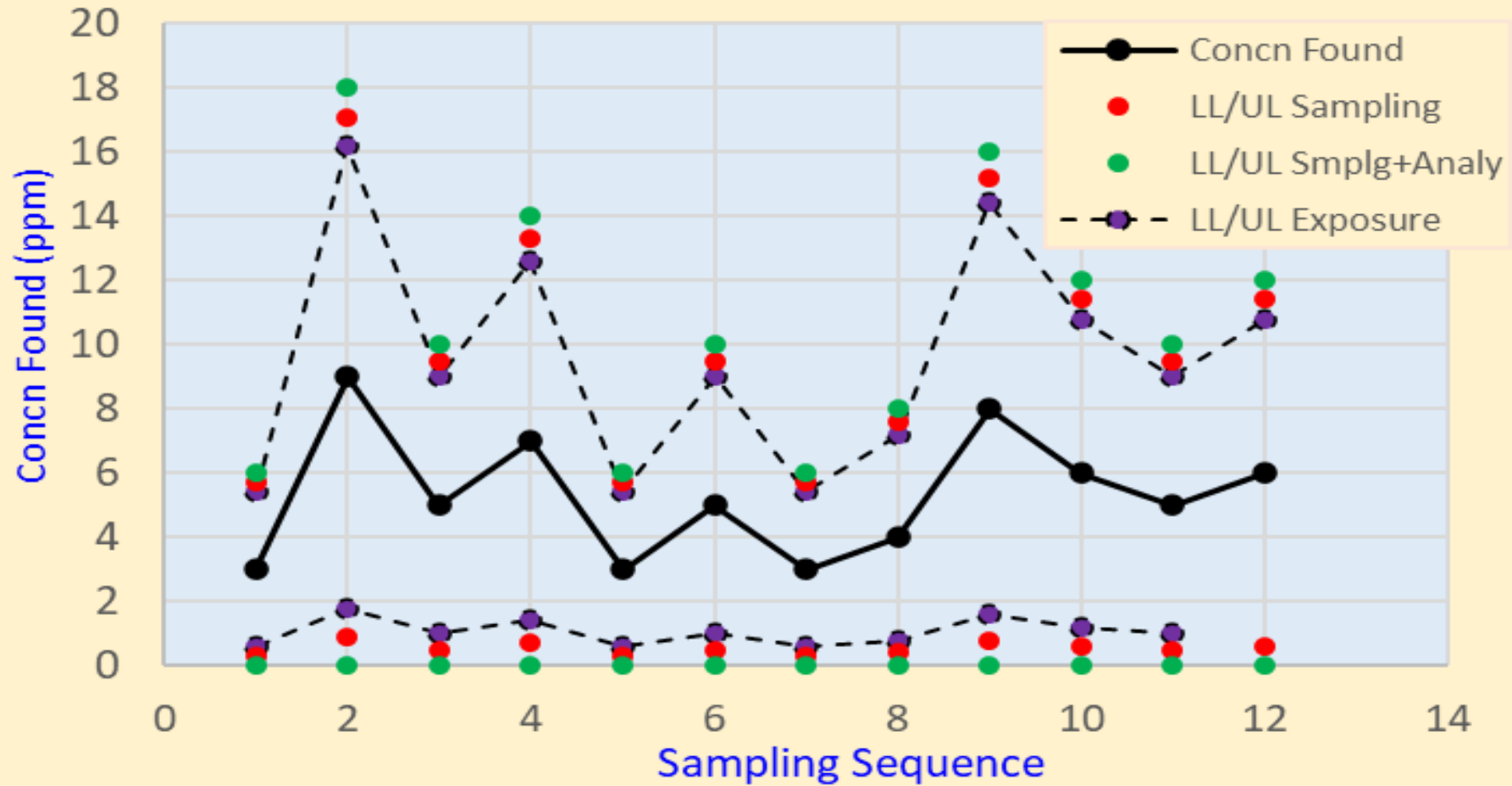
Uncertainty in Sampling/Analysis



Uncertainty in Exposures



Uncertainty in Exposures + Sampling/Analysis



EXPOSURE ASSESSMENT - OLD & NEW SCHOOL

1980s

- Within a HEG (Homogeneous Exposure Group), *Workplace Concentrations are uniform.*
- The main issue was to accurately measure exposure of the HEG.

2000's

- A HEG is now known as a SEG (Similar Exposure Group)
- *The main issue is to estimate the distribution of exposure values among workers in each SEG.*

AIHA EXPOSURE ASSESSMENT & MGMT MODEL

Higher Standard of Care

- Since Exposures Have Been Shown to be Highly Variable
- Use the Most Protective OEL
 - PEL, ACGIH TLV, In-House OEL, NIOSH REL
- Assess & Control Exposures on a Statistical Basis
 - 95th Percentile of SEG Exposures is controlled below OEL

AIHA EXPOSURE ASSESSMENT & MANAGEMENT MODEL

Exposure Category	Exposure Level (95 th Percentile)	Level	Employer Response
0	<0.01 of OEL	Unexposed	No Action
1	0.01-0.10 of OEL	Low	General Haz Com & Training
2	0.1-0.5 of OEL	Med	Specific Haz Com & Personal Monitoring
3	0.5-1.0 of OEL	Borderline	Surveillance & Regular Monitoring
4	> 1.0 OEL	Over Exposed	Implement Respirators & Controls

AIHA INITIATIVES

- Improve Exposure Judgment Accuracy
 - A shift in practice to improve exposure judgment
 - Use AIHA's suite of tools for improving exposure decisions
 - Checklist Tool
 - IHSTAT (Bayesian Decision Analysis for monitoring data)
 - IHDA-AIHA (simplified IH Decision Analysis for interpreting monitoring data)

Need to understand ...

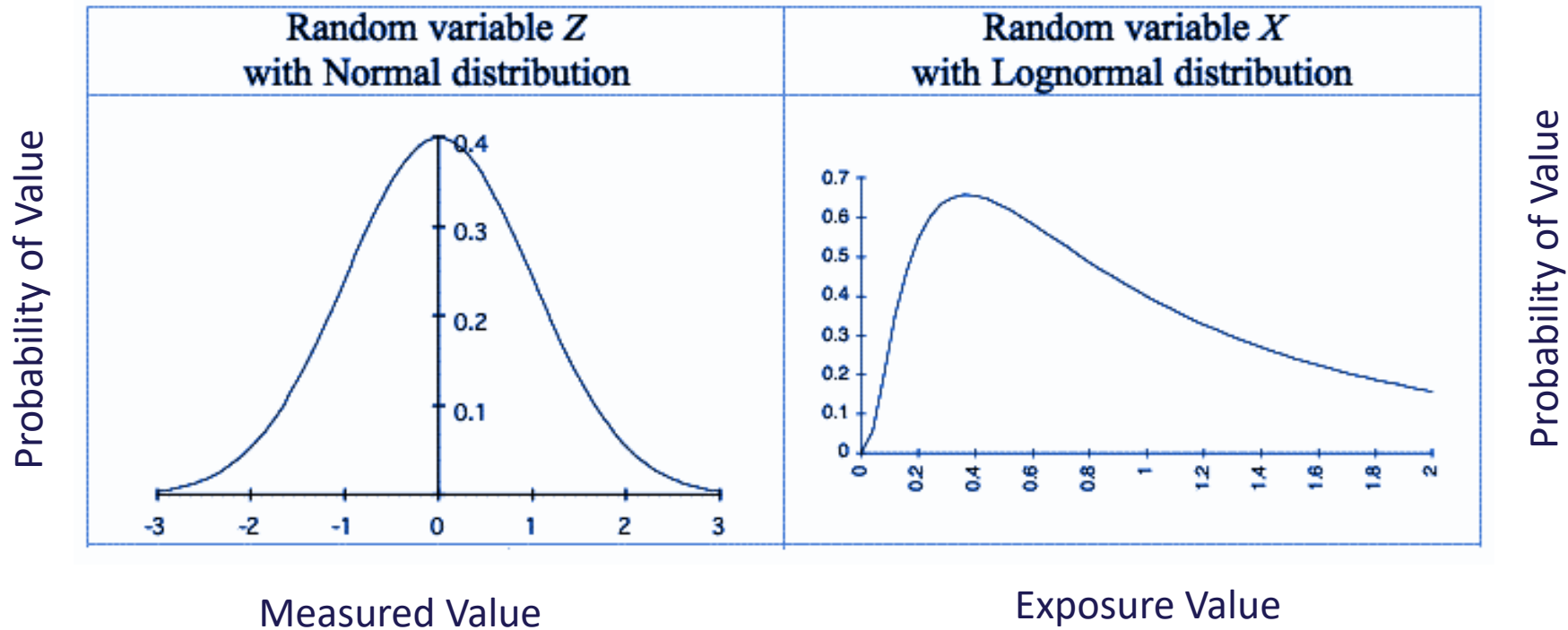
LOGNORMAL EXPOSURE MODEL

- Distribution of Worker Exposures is not “normal”
- Exposure Distributions tend to be skewed or Log Normal
 - Skewed toward higher levels
 - Leaks & Spills result in higher values
 - Few random events that lead to lower values
 - There are no exposures less than zero

LOGNORMAL DISTRIBUTION OF EXPOSURES

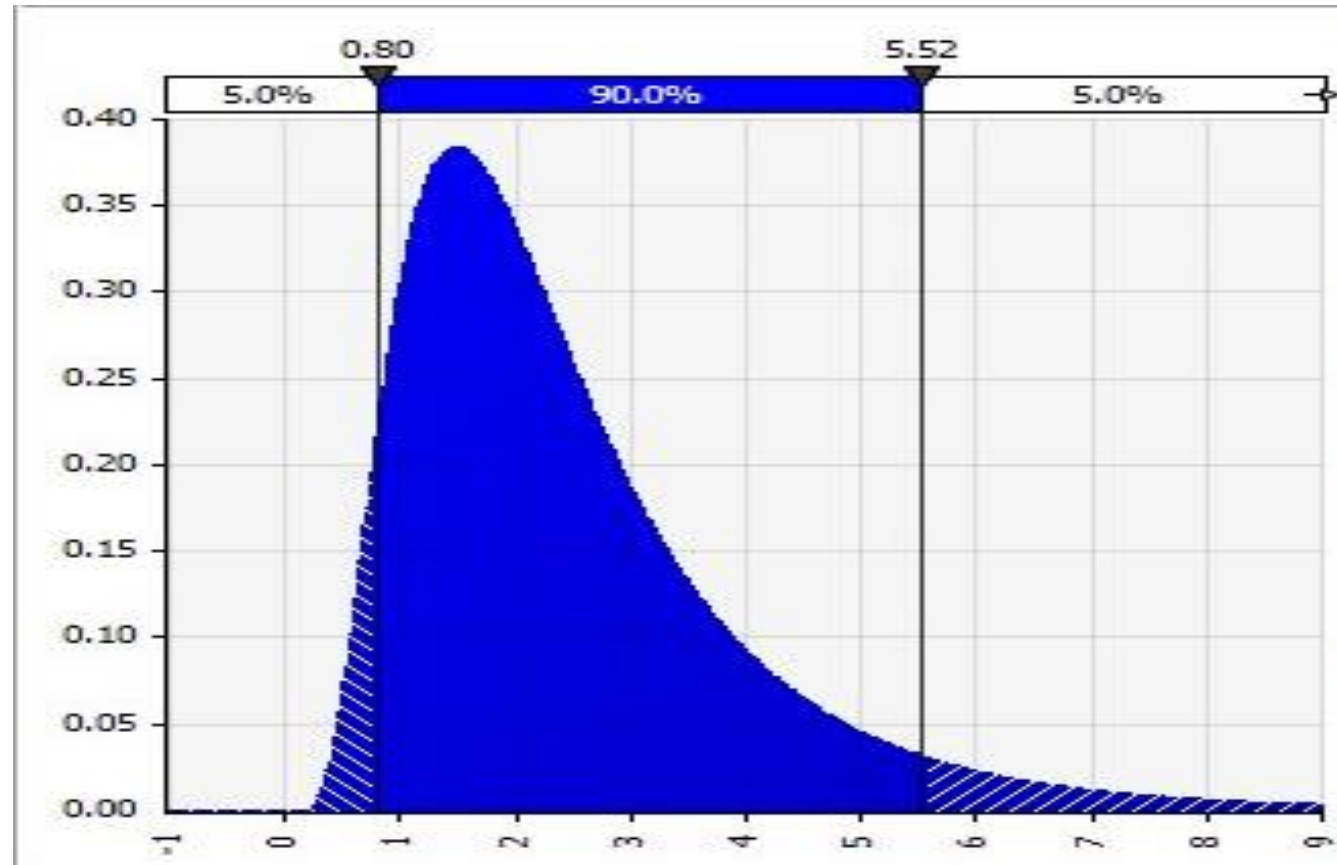
Sampler Uncertainty

Exposure Uncertainty



LOGNORMAL EXPOSURE VARIATION

It's not nice, but that's how it is.



POSITIVE SKEW IN LOGNORMAL DATA

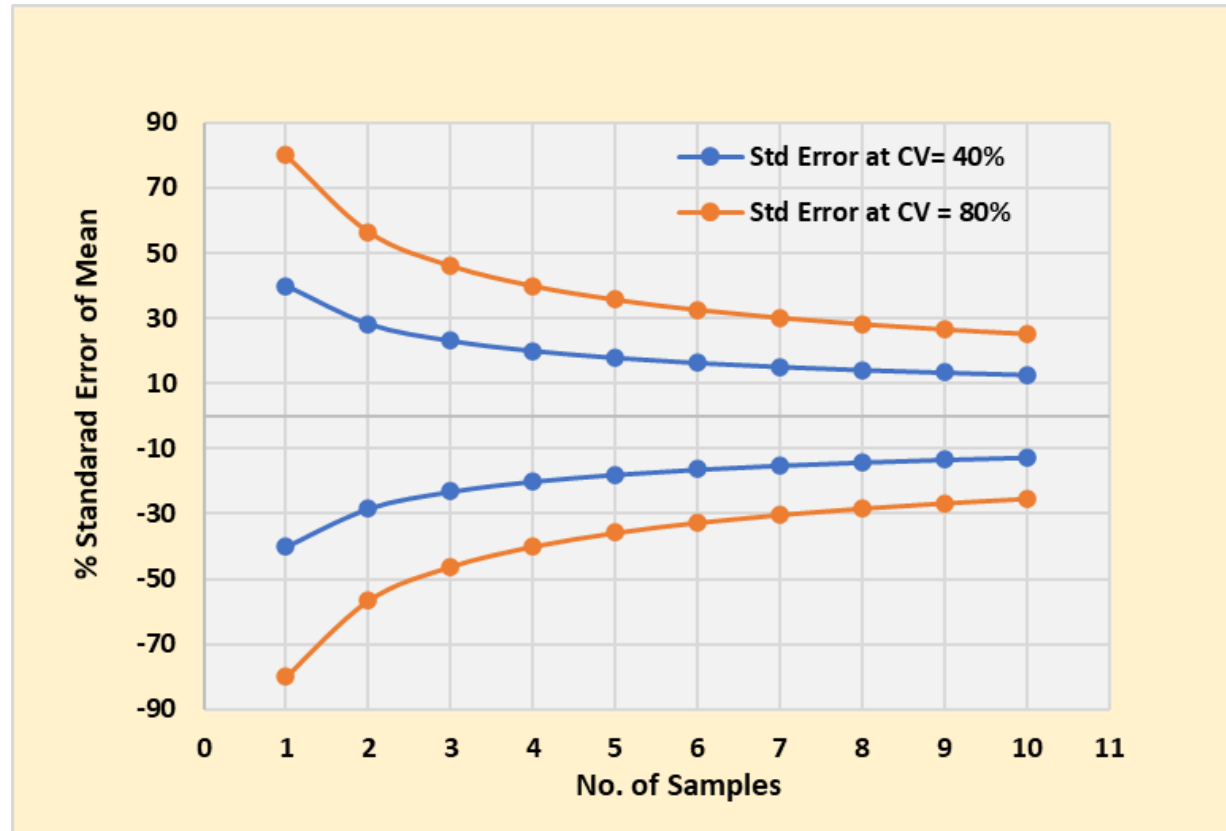
- Normal Statistics

- Mean (Median) = 10 10
- Std Dev = 1 2
- X (95%) = 12 14

- LogNormal Statistics

- Median = 10 10
- GSD = 1.5 3.0
- X(95%) = 20 60

SAMPLES INCREASE ... UNCERTAINTY DECREASES

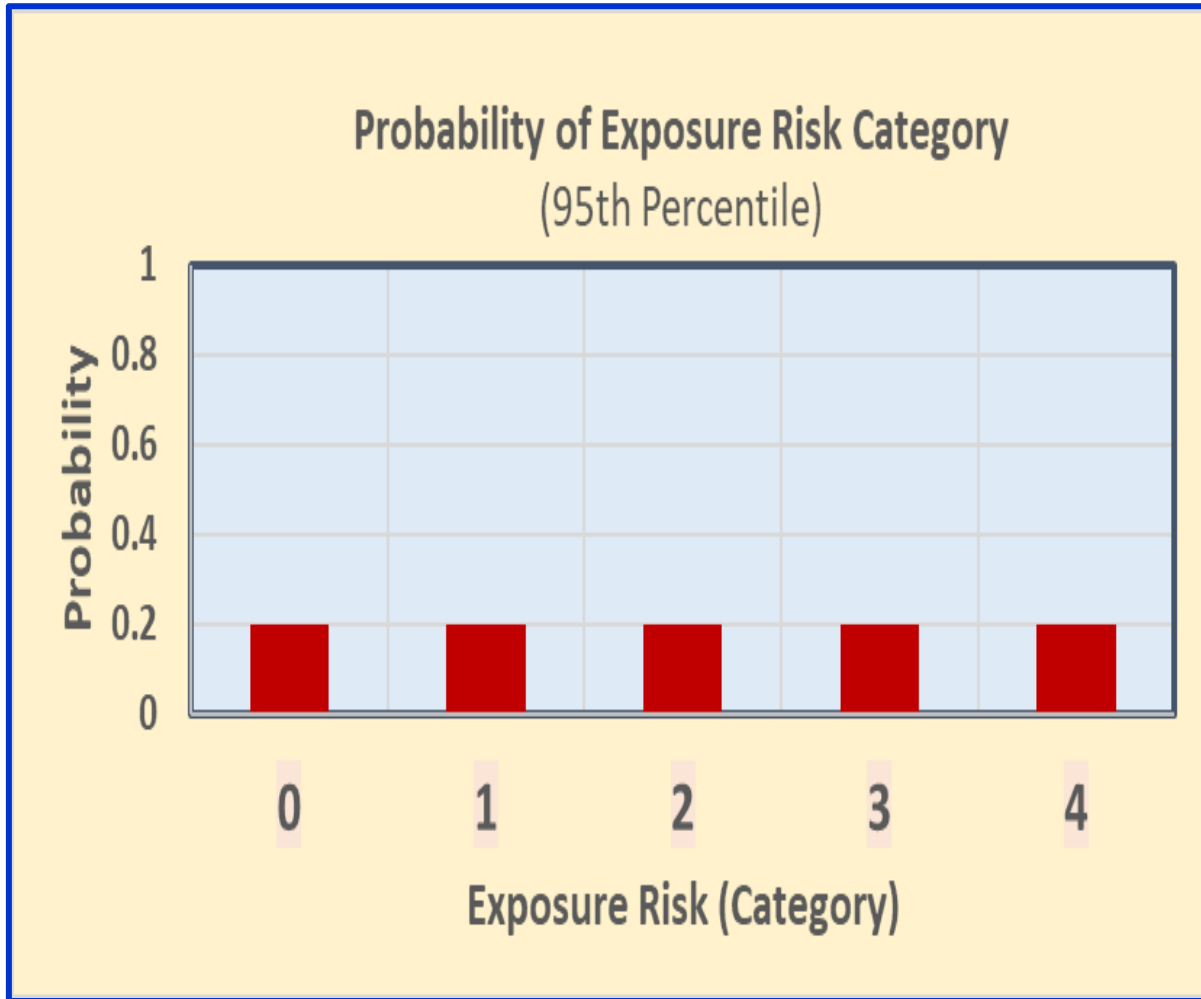


AIHA - IH DATA ANALYST

- Uses Bayesian Decision Analysis (BDA)
- Suppose we monitor once & result is 50% of the PEL
 - Are we likely in compliance with OSHA?
 - Do we likely have a “safe workplace”?
- IH Data Analyst using BDA will tell you “NO”
 - One result at 50% of the PEL
 - IHDA says “60% probability the 95th percentile exceeds the PEL”
 - 95th percentile means that 5% (1/20) tests would exceed the PEL

IH DATA ANALYST (AIHA)

[OEL = 25 ppm; 0 samples]



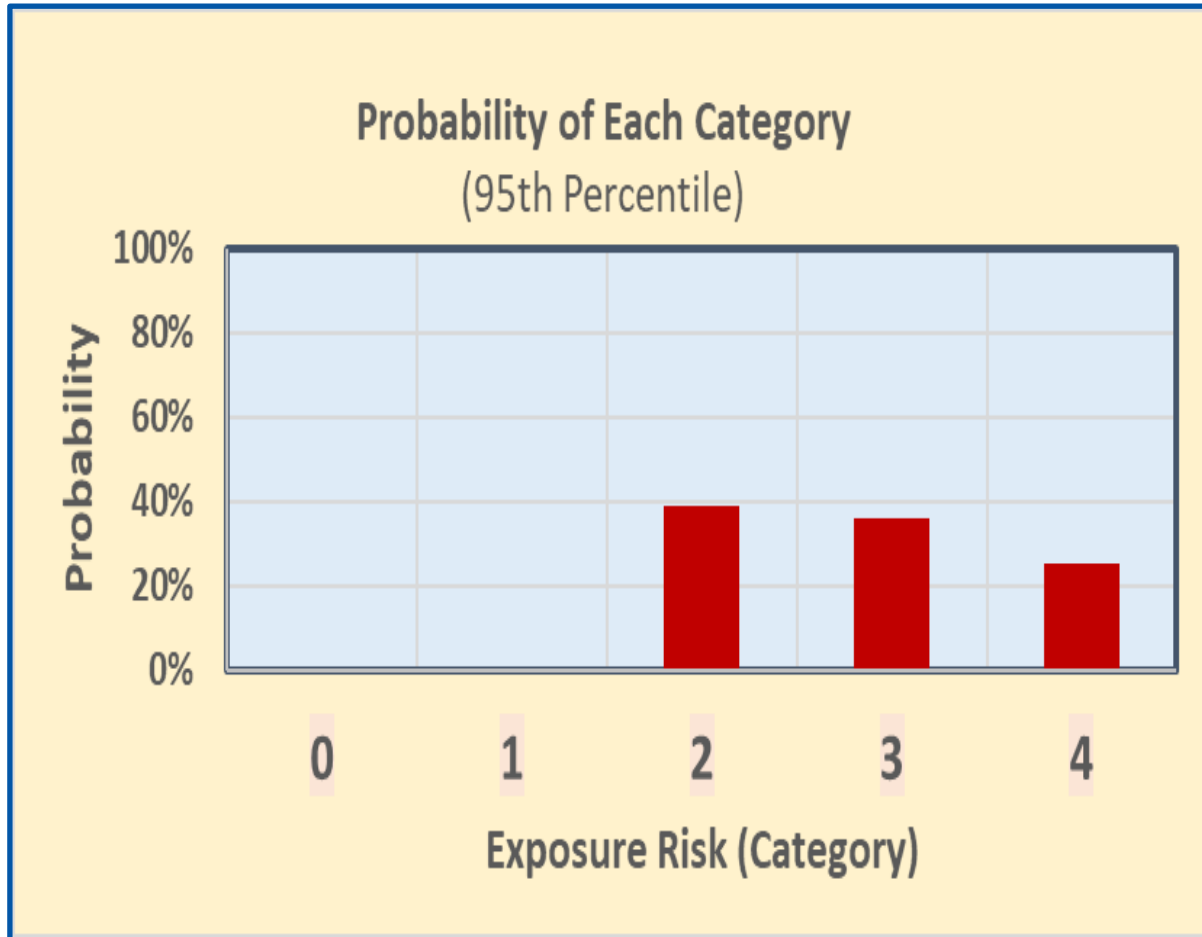
Category	Response
0	<0.01* OEL No Action
1	<0.1* OEL Haz Com/Training
2	<0.5* OEL Haz Com/Monitor
3	<1.0* OEL Surveillance/Monitor
4	>1.0* OEL Respirators/Controls

(*) 95th percentile of SEG exposures

IH DATA ANALYST (AIHA)

[OEL = 25 ppm; 1 sample]

[3 ppm]



Category

Response

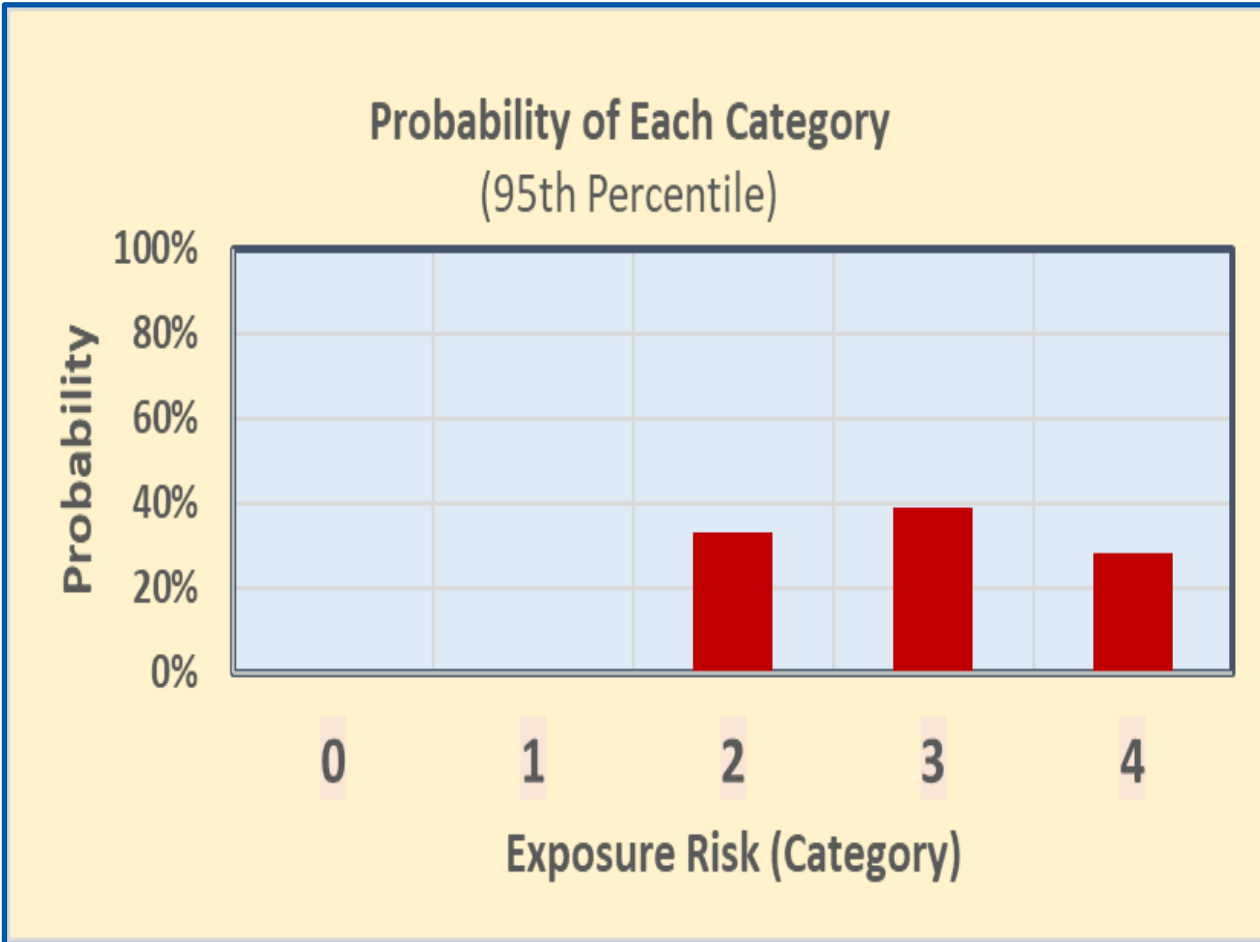
0	<0.01* OEL	No Action
1	<0.1* OEL	Haz Com/Training
2	<0.5* OEL	Haz Com/Monitor
3	<1.0* OEL	Surveillance/Monitor
4	>1.0* OEL	Respirators/Controls

(*) 95th percentile of SEG exposures

IH DATA ANALYST (AIHA)

[OEL = 25 ppm; 3 samples]

[3, 9, 5 ppm]



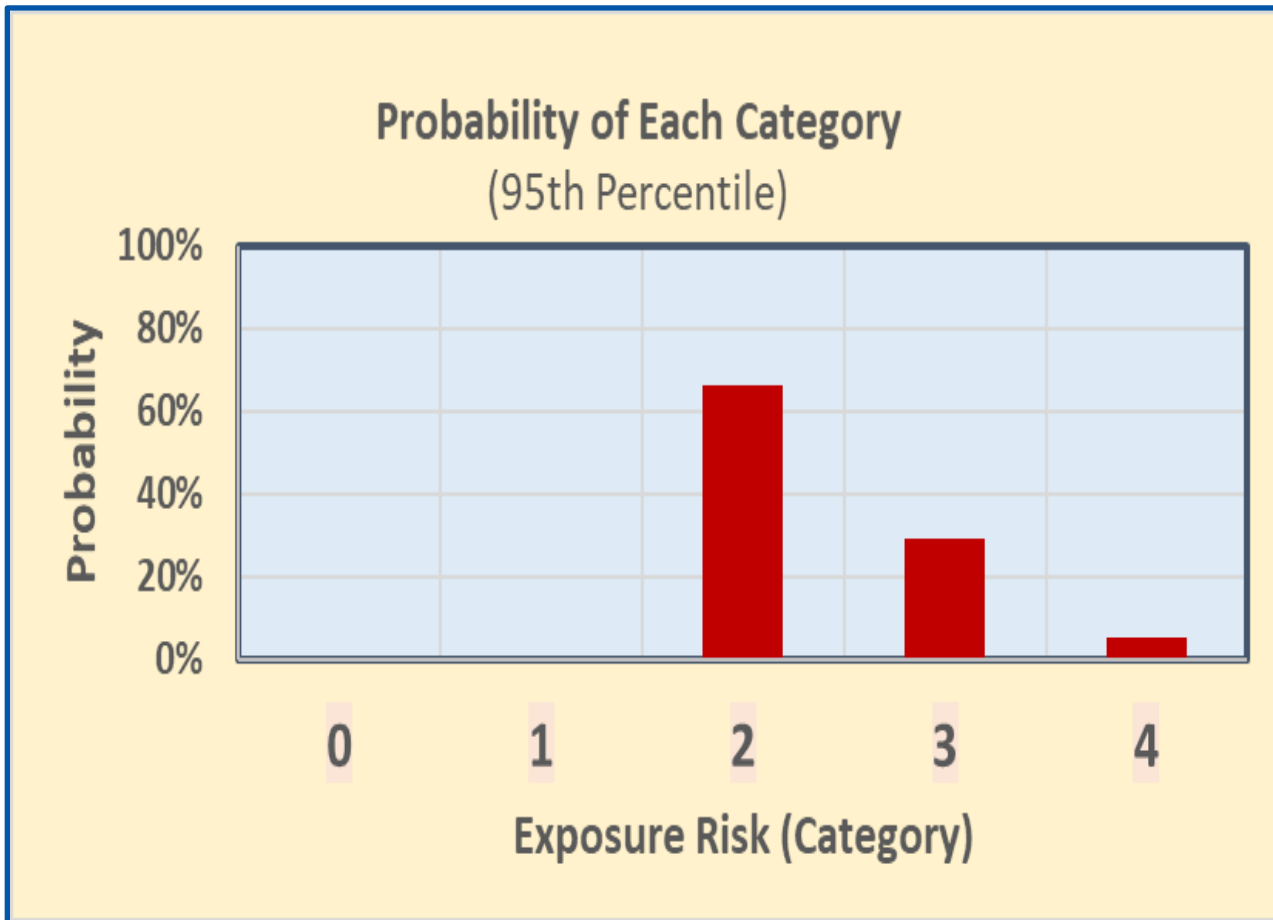
Category	Response
0	No Action
1	Haz Com/Training
2	Haz Com/Monitor
3	Surveillance/Monitor
4	Respirators/Controls

(*) 95th percentile of SEG exposures

IH DATA ANALYST (AIHA)

[OEL = 25 ppm; 7 samples]

[3, 9, 5, 7, 3, 5, 3 ppm]



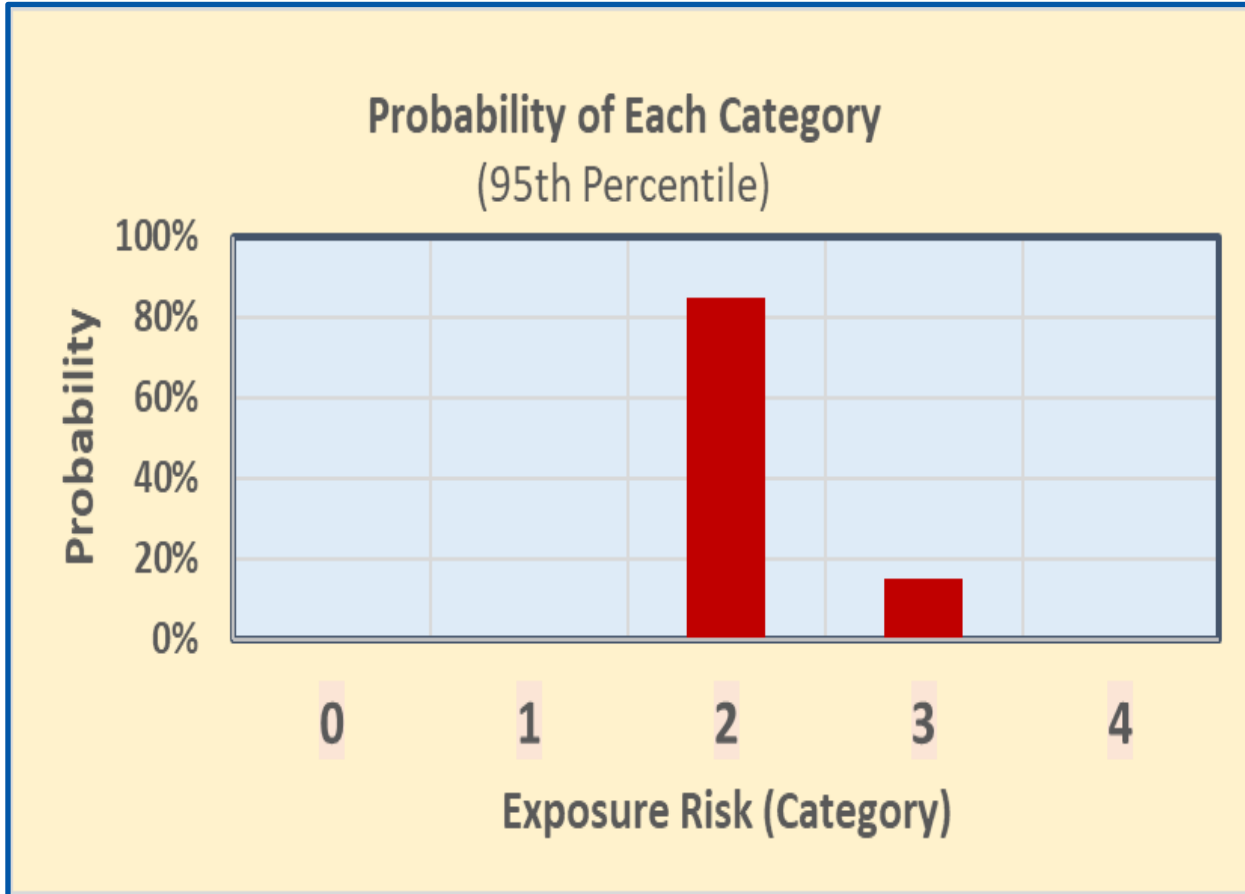
Category	Response
0	<0.01* OEL No Action
1	<0.1* OEL Haz Com/Training
2	<0.5* OEL Haz Com/Monitor
3	<1.0* OEL Surveillance/Monitor
4	>1.0* OEL Respirators/Controls

(*) 95th percentile of SEG exposures

IH DATA ANALYST (AIHA)

[OEL = 25 ppm; 12 samples]

[3 , 9 , 5 , 7 , 3 , 5 , 3 , 4 , 8 , 6 , 5 , 6 ppm]



Category	Response
0	<0.01* OEL No Action
1	<0.1* OEL Haz Com/Training
2	<0.5* OEL Haz Com/Monitor
3	<1.0* OEL Surveillance/Monitor
4	>1.0* OEL Respirators/Controls

(*) 95th percentile of SEG exposures

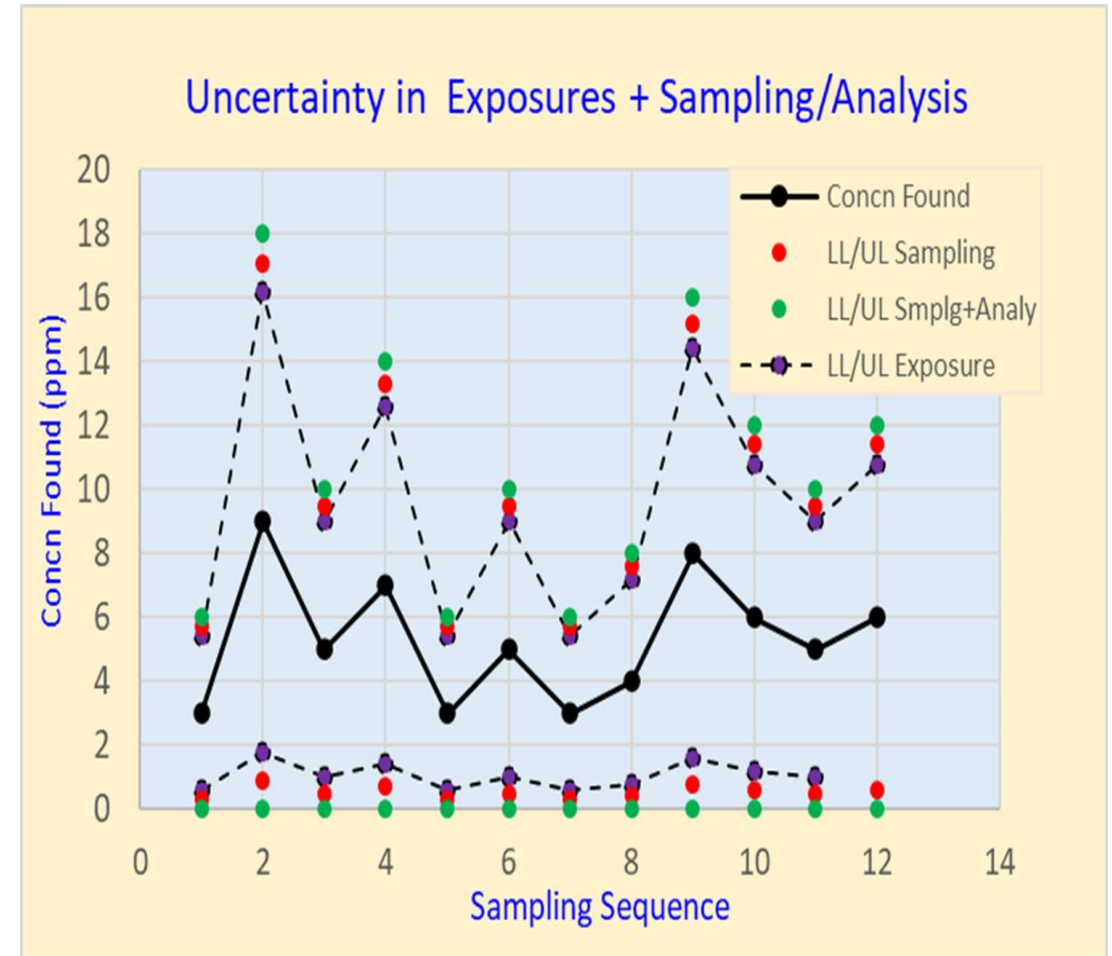
HOW MUCH DOES SAMPLING ACCURACY MATTER?

Because the normally-distributed sample and analytical variability for the vast majority of monitoring methods is so much smaller than typical lognormally-distributed environmental variability, it is usually ignored when conducting the statistical analysis.

John Mulhausen/Paul Hewett - creators of AIHA's IHDA system
associated course "[Making Accurate Exposure Risk Decisions](#)"

DOES ACCURACY OF MONITORS MATTER ?

- Yes
 - Sampling & Lab Analysis should be accurate within guidelines
- BUT
 - Workplace Variation is so great compared to Sampling & Analytical that difference between methods do not change exposure assessment decisions



CONCLUSIONS

- Variations in Sampling/Analysis are important in Personal Monitoring
 - Uncertainty $\leq + 25\%$
- Variations in Actual Exposures are ***much more*** important
 - typ. Workplace Variations ... 200%-600% of Median (GSD = 1.5-3.0)
- Statistical Analysis of Exposure Data using AIHA IHDA
 - Accurate exposure risk decisions
 - Higher “Standard of Care”

SUGGESTIONS

- Use AIHA Exposure Assessment Tool Kit & Management Model
- Use AIHA IHDA (Bayesian Decision Analysis)
 - Will Tell You How Much to Sample
- Use Cost-Effective & Convenient Sampling Methods
 - Higher Standard of Care
 - Best Use of Limited Resources



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Finis ... Thank You!