AIHA

CONNECT™

2025

TITLE

How Many Workplace Exposure Samples to Collect?

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PRESENTATION GOALS

- Provide info on the accuracy of exposure assessments
- Provide simplified understanding of uncertainty of sampling events and exposure risk judgments
- **Help an IH Figure Out How Many Samples to Collect!**

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)

WHY WE MONITOR

- Is TWA Conc'n in a worker's breathing zone < OEL?
- Answer … **neither YES nor NO!!**
  - *We should ask …*
  - **What is the likelihood of exceeding the OEL?**
    - Different Workers
    - Different Days
    - SEG throughout the year

  - SEG = Similar Exposure Group (workers with similar exposures)

WHAT QUESTION ARE WE REALLY ASKING?

- **What is the probability of an employee being overexposed?**

- Generates 2 Additional Questions
  - What is a safe Occupational Exposure Limit (OEL)?
  - **What is the probability of exceeding an OEL?**

“SAFE” OCCUPATIONAL EXPOSURE LIMIT (OEL)

- A “safe” OEL is a chemical exposure level that presents minimal risk of harm to a worker during a normal working life
  - ACGIH Threshold Limit Value (TLV)
  - NIOSH Recommended Exposure Limit (REL)
  - OSHA Permissible Exposure Limit (PEL)
  - Organization In-House OEL
- All of the above … intended to be “safe” OELs.
- Which OEL you choose is up to your organization.
  - Obviously, choosing a lower OEL reduces risk.

COMPLIANCE WITH OEL - HISTORY

- 3 Interpretations …
  - **The Average** of a worker's TWA exposures < OEL
    - 50% of exposures < OEL **(Least Protective!)**
  - **The 100th Percentile** of workers' TWA exposures < OEL
    - 100% of exposures < OEL (Theory of OSHA Rule)
  - **The 95th Percentile** of a worker's TWA exposures < OEL
    - 95% of exposures < OEL **(AIHA Standard of Care = Reasonable)**

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

AIHA - HIGHER STANDARD OF CARE

- Consistent with Definitive Studies
  - (Nicas 1991) (Rappaport 1991)

- **Exposure Assessment with High Confidence**
  - 95% of employee exposures below the OEL
  - AIHA's Higher Standard of Care

OSHA THEORY – HIGHER THAN AIHA STD?

- OSHA can …
  - Randomly Sampling Employees' Exposures
  - If 1 sample exceeds [PEL + Estimate of Analytical Uncertainty]
    - OSHA may cite the employer
      - Violation of the OSH Act of 1970
- OSHA legal theory = **100th percentile must be < PEL**

OSHA PRACTICE – LOWER THAN AIHA STD

- Since OSHA can cite an employer on 1 sample > PEL,
- the employer must be perfect or ... **“Lucky”**
- The Chances of being **“Lucky”** are excellent, because OSHA rarely visits your plant.
  - If they do, they usually collect a small number of samples.

ASPECTS OF OSHA COMPLIANCE

- There is a difference between being “In Compliance” and “Not Getting Caught”

- These outcomes look similar in a Mgmt Report, but very different for employees’ health

- OSHA Rules create a situation where you may be ***Not in Compliance*** but ***Unlikely to Be Caught***

WORKPLACE EXPOSURE VARIATION

Usually Under-Estimated!!

- OSHA compliance model assumes uniform & constant exposures

- **IH's like to believe exposures are uniform & constant**
  - **actual exposures**
    - **Highly Variable**
    - **Lognormal (skewed)**

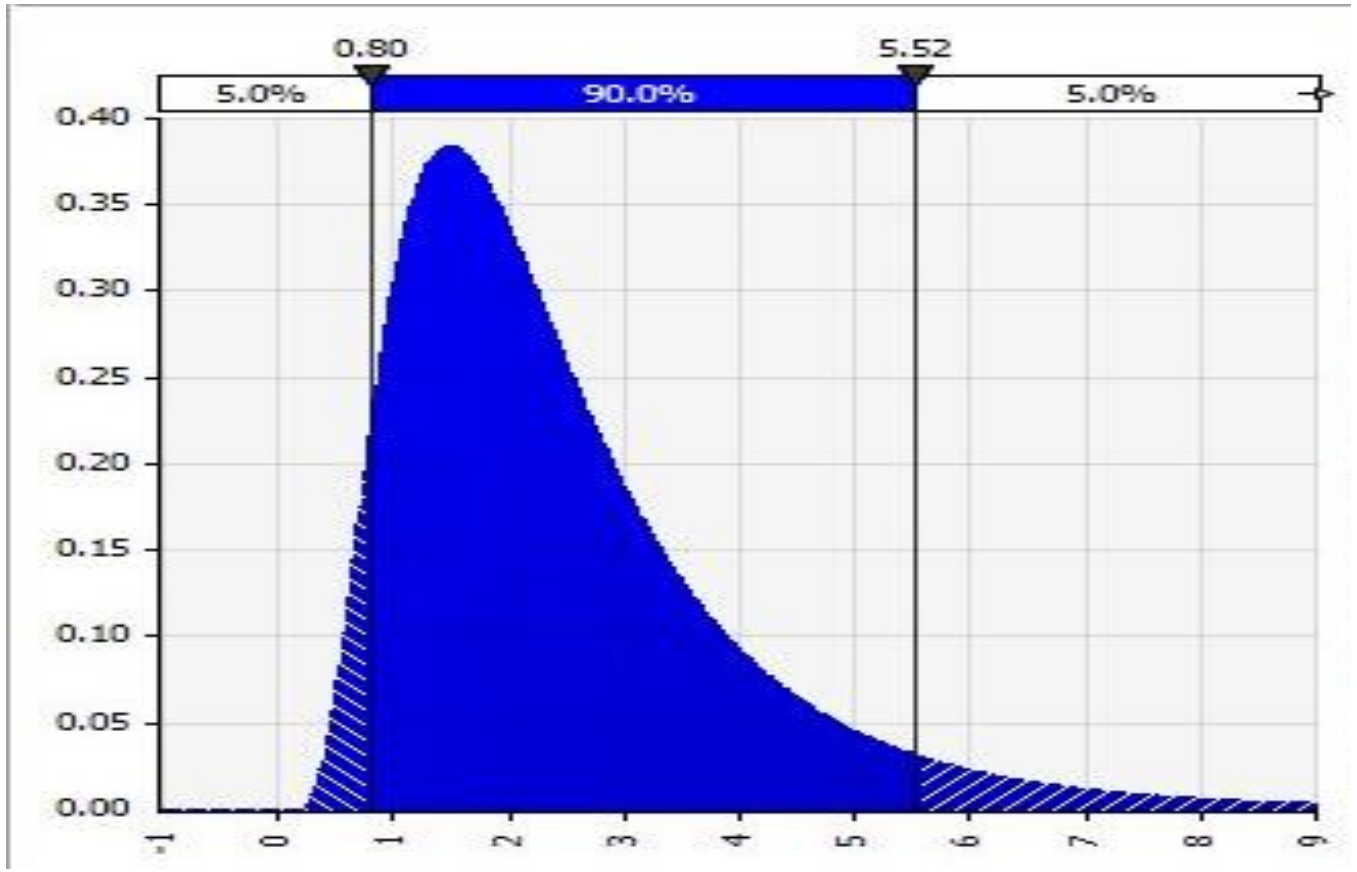
LOGNORMAL EXPOSURE MODEL

- Distribution of Workplace Exposures is not “normal”

- **Exposure Distributions tend to be skewed or “LogNormal”**
  - Skewed toward higher levels
  - Leaks & Spills result in higher levels
  - Few random events lead to lower values
  - There are no exposures less than zero

LOGNORMAL EXPOSURE VARIATION

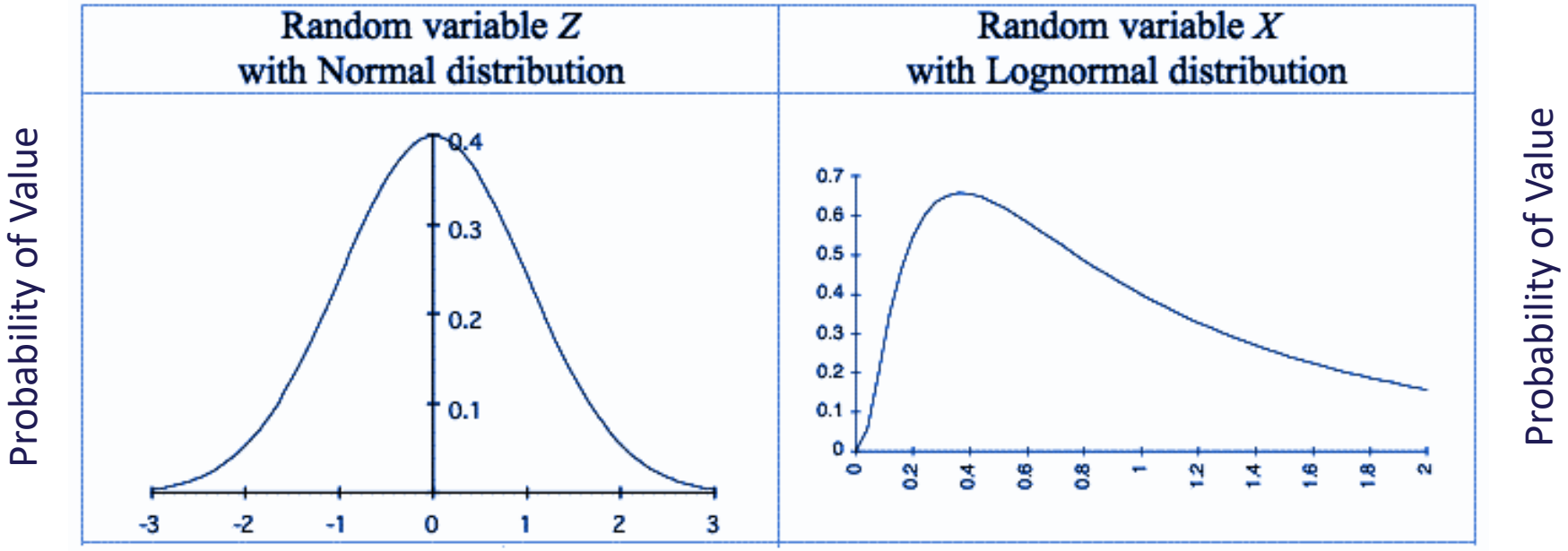
It’s not nice, but that’s how it is.



LOGNORMAL DISTRIBUTION OF EXPOSURES

Sampler Uncertainty

Exposure Uncertainty



POSITIVE SKEW IN LOGNORMAL DATA

- *Normal Statistics*

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

- *LogNormal Statistics*

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

MORE ON WORKPLACE VARIATION

- "Typical workplaces have a GSD between 1.5-4.0" – AIHA's IHDA

- "…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 $\geq$ 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

FLAWED OSHA COMPLIANCE STRATEGY

typ. ranges of GSD = 1.5 – 4.0.
"Environmental variability is far more important than analytical variability in determining the variance of the measured 8-hr TWAs."

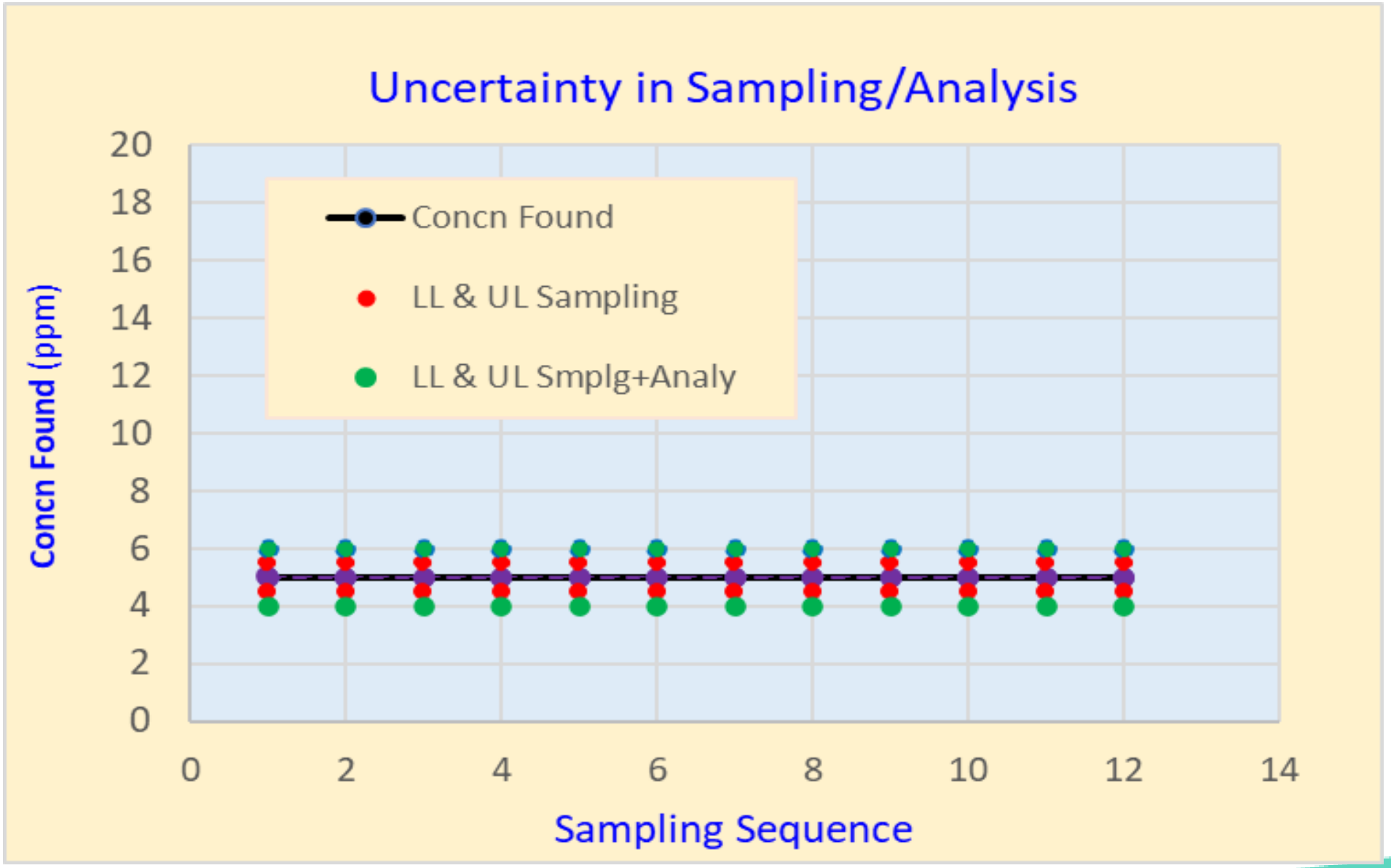
"OSHA inappropriately focuses on analytical variability when determining compliance with its permissible exposure limits."

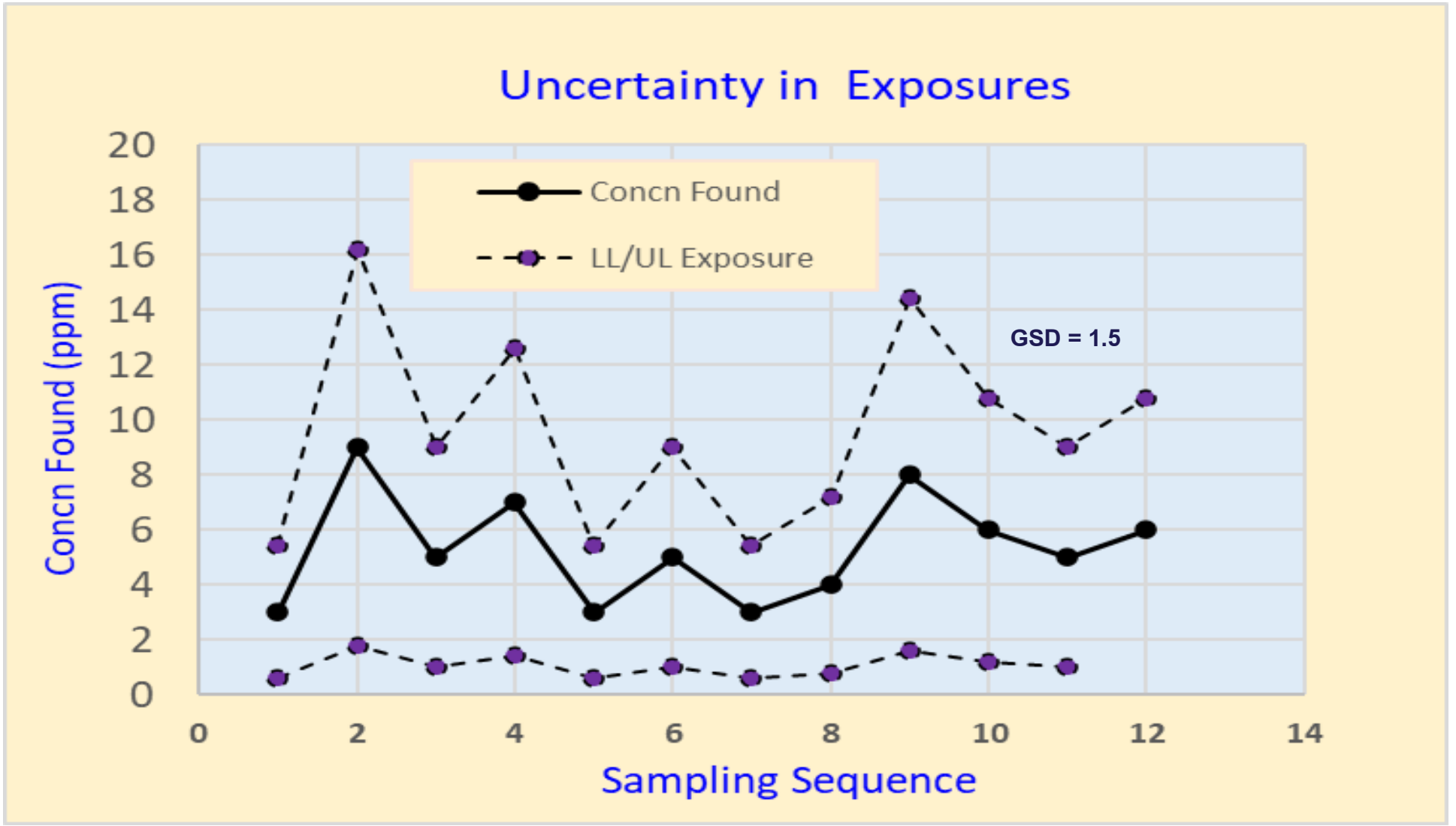
Nicas, M., Simmons, B. P., & Spear, R. C. (1991). ENVIRONMENTAL VERSUS ANALYTICAL VARIABILITY IN EXPOSURE MEASUREMENTS. American Industrial Hygiene Association Journal, 52(12), 553–557. https://doi.org/10.1080/15298669191365199

WORKPLACE VARIATION >> THAN SAMPLING ERROR

Because the normally-distributed sample and analytical variability for the vast majority of sampling 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"**


Uncertainty in Sampling/Analysis
Concn Found (ppm)
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Sampling Sequence
Concn Found
LL & UL Sampling
LL & UL Smplg+Analy


Uncertainty in Exposures
Concn Found
LL/UL Exposure
GSD = 1.5
Concn Found (ppm)
Sampling Sequence
0
2
4
6
8
10
12
14
16
18
20

AIHA – HIGHER STANDARD OF CARE

- Since Exposures Have Been Shown to be Highly Variable
- **Go Beyond OSHA Compliance**
- **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 controlled below OEL**

AIHA EXPOSURE MGMT MODEL

Exposure Category	Exposure Level (95th Percentile)	Employer Response	Level
0	<1% of OEL	No Action	Unexposed
1	1-10% of OEL	General Haz Com & Training	Low
2	10-50% of OEL	Specific Haz Com & Personal Monitoring	Med
3	50-100% of OEL	Surveillance & Regular Monitoring	Borderline
4	>100% of OEL	Implement Respirators & Implement Controls	Over Exposed

AIHA CONNECT 2025

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

AIHA – IMPROVING EXPOSURE JUDGMENT ACCURACY

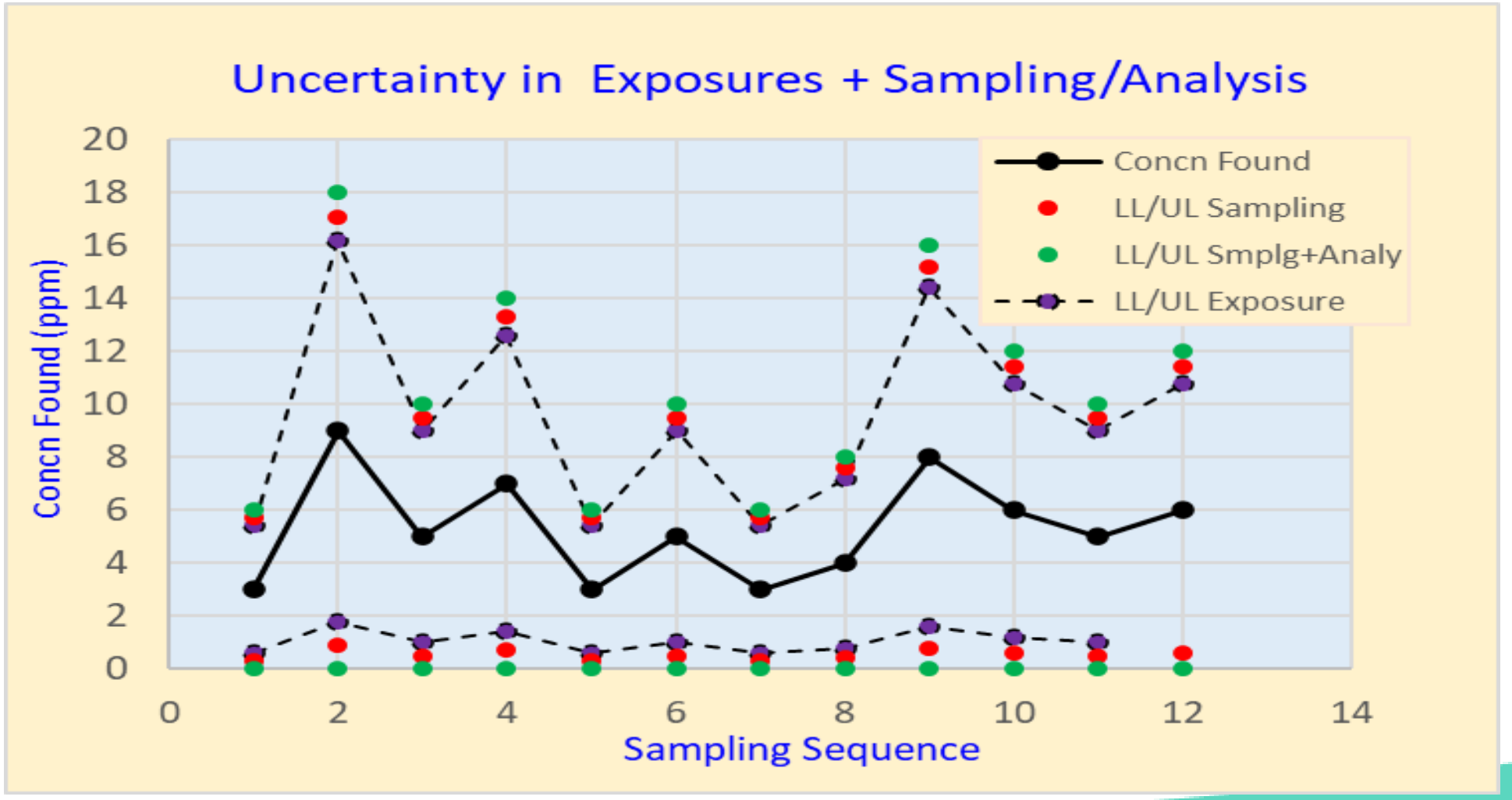
A shift in practice to improve exposure judgment

- **Use AIHA's suite of tools for improving exposure decisions**
  - Checklist Tool
  - IHMOD2.0 (estimate exposures)
  - IHSTAT (Bayesian Decision Analysis for monitoring data)
  - IHDA-AIHA (simplified IH Decision Analysis for interpreting monitoring data)

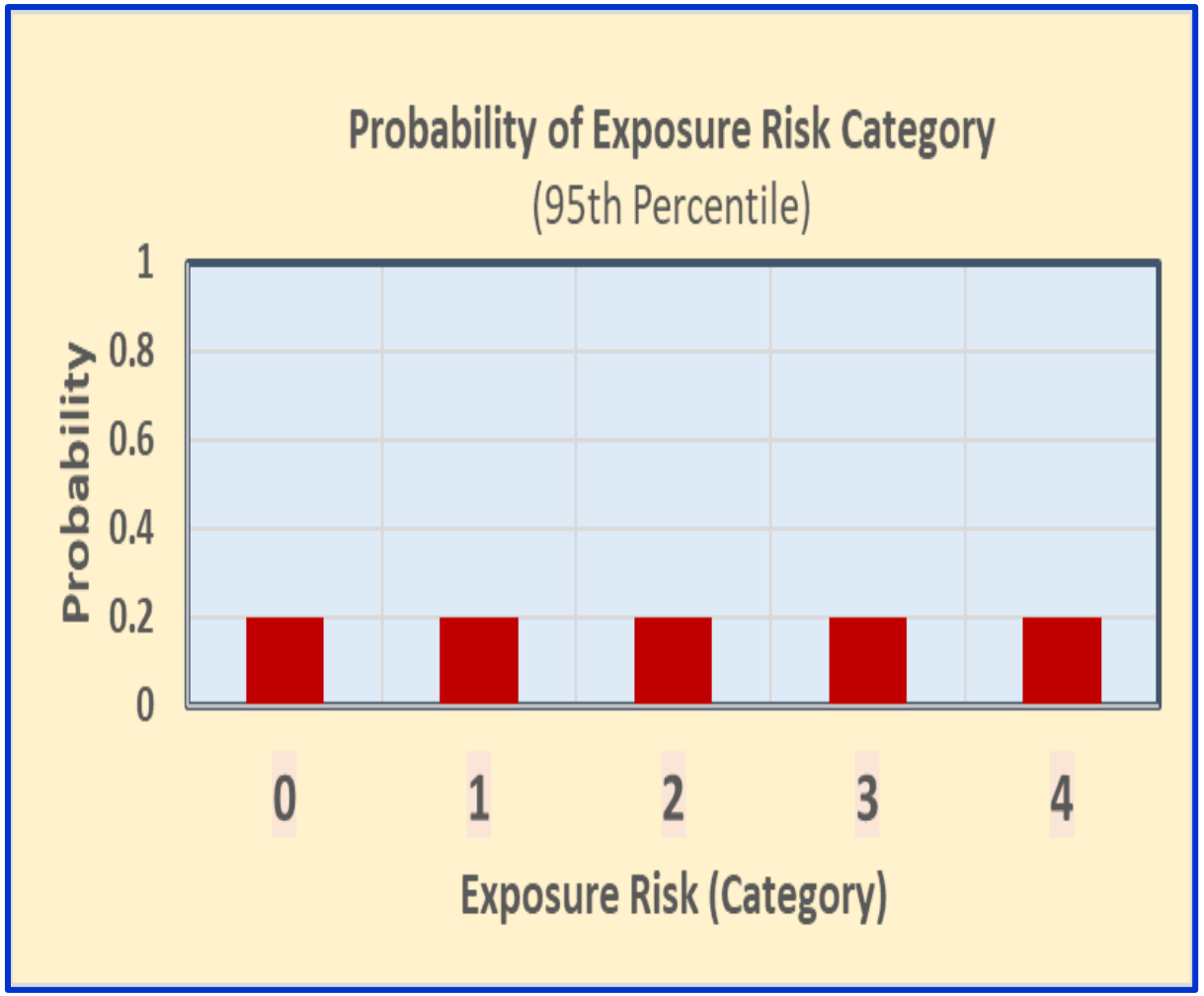
AIHA EXPOSURE ASSESSMENT AND MGMT MODEL

Exposure Category	Exposure Level (95th Percentile)	Employer Response	Level
0	<1% of OEL	No Action	Unexposed
1	1-10% of OEL	General Haz Com & Training	Low
2	10-50% of OEL	Specific Haz Com & Personal Monitoring	Med
3	50-100% of OEL	Surveillance & Regular Monitoring	Borderline
4	>100% of OEL	Implement Respirators & Implement Controls	Over Exposed

IH DATA SET A GSD = 1.5



IH DATA ANALYST (AIHA)

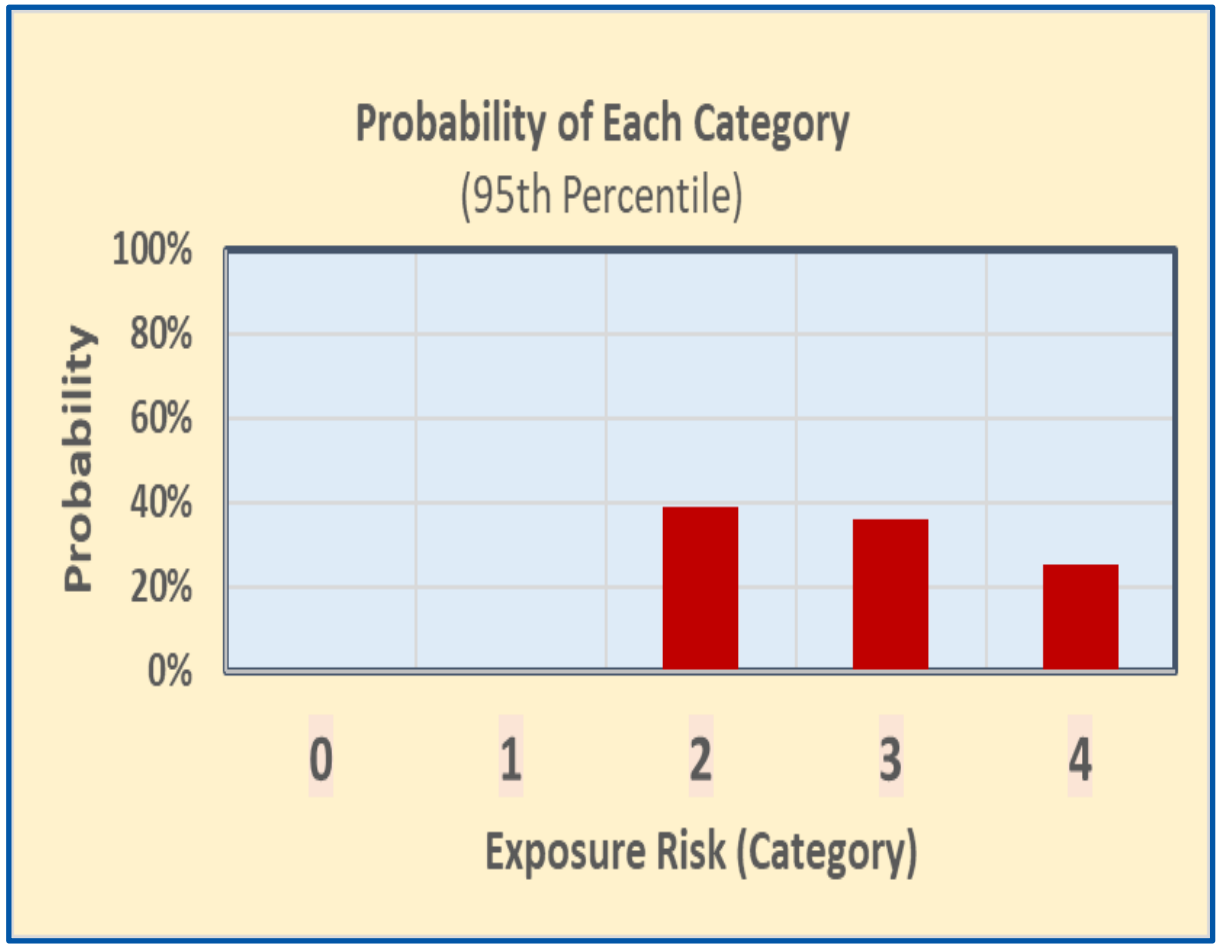


[OEL = 25 ppm; 0 samples]

Category		Response
O	<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 SET A



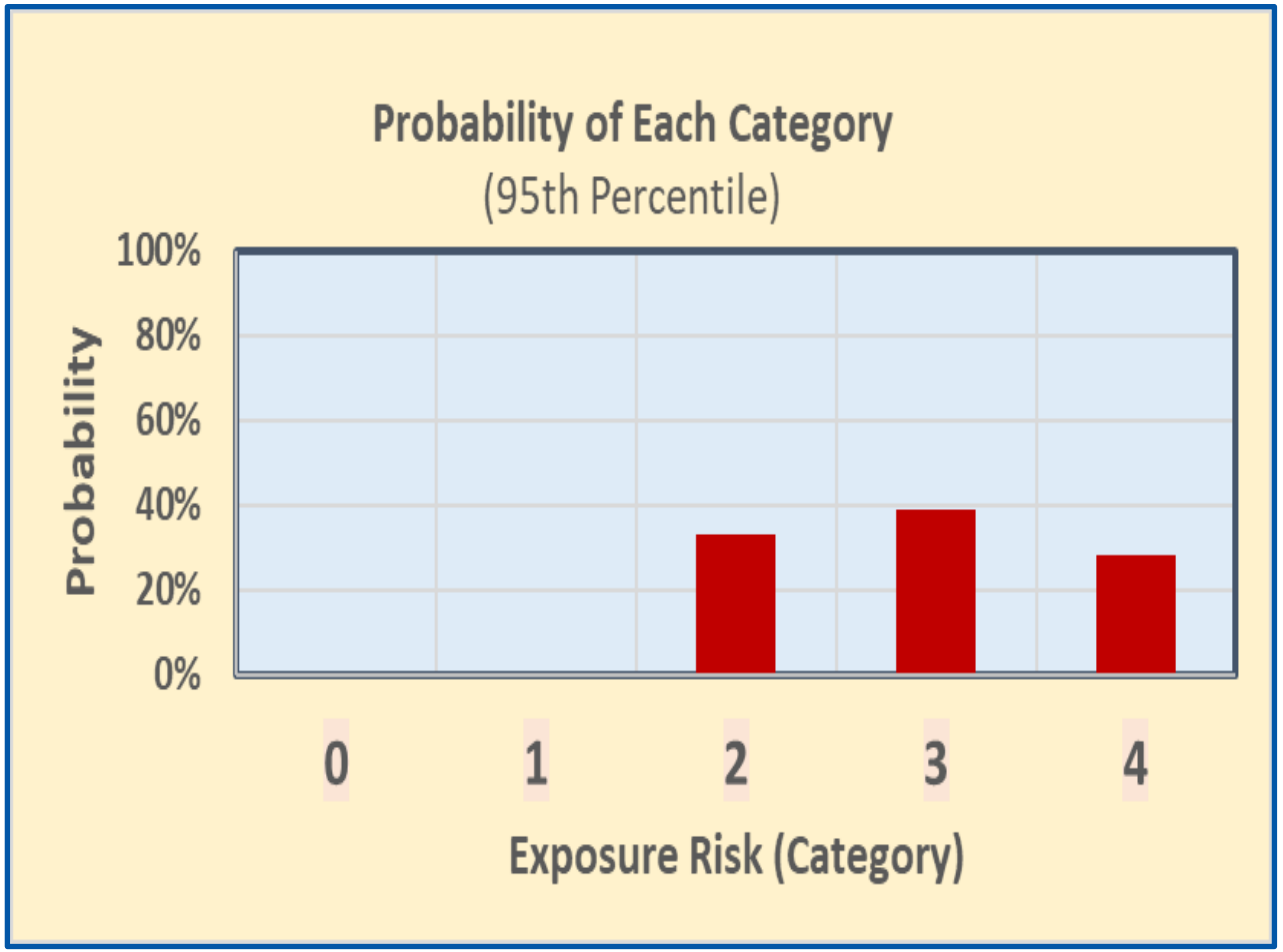
[OEL = 25 ppm; 1 sample]

[3 ppm]

Category		Response
O	<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 SET A



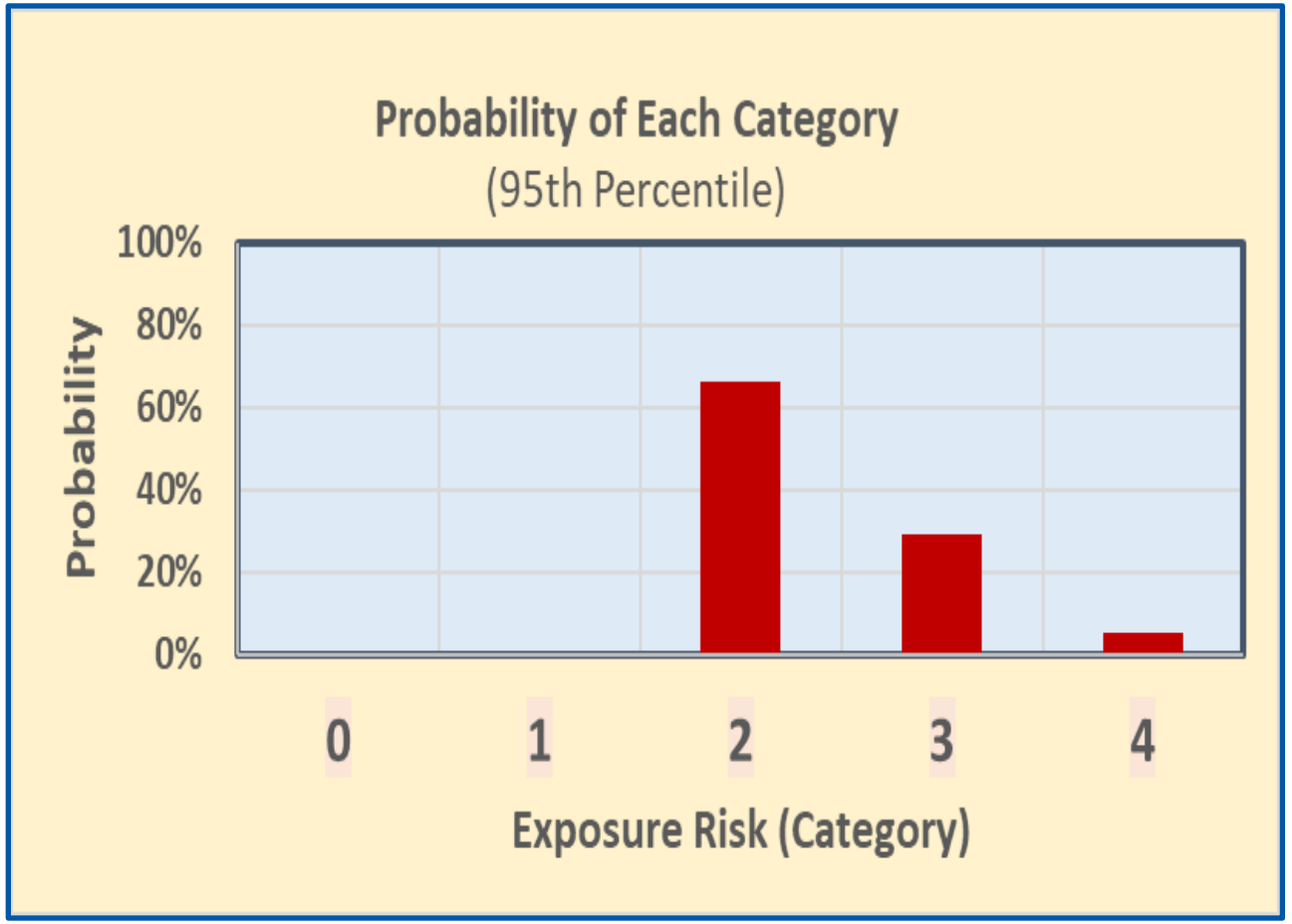
[OEL = 25 ppm; 3 samples]

[3, 9, 5 ppm]

Category		Response
O	<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 SET A



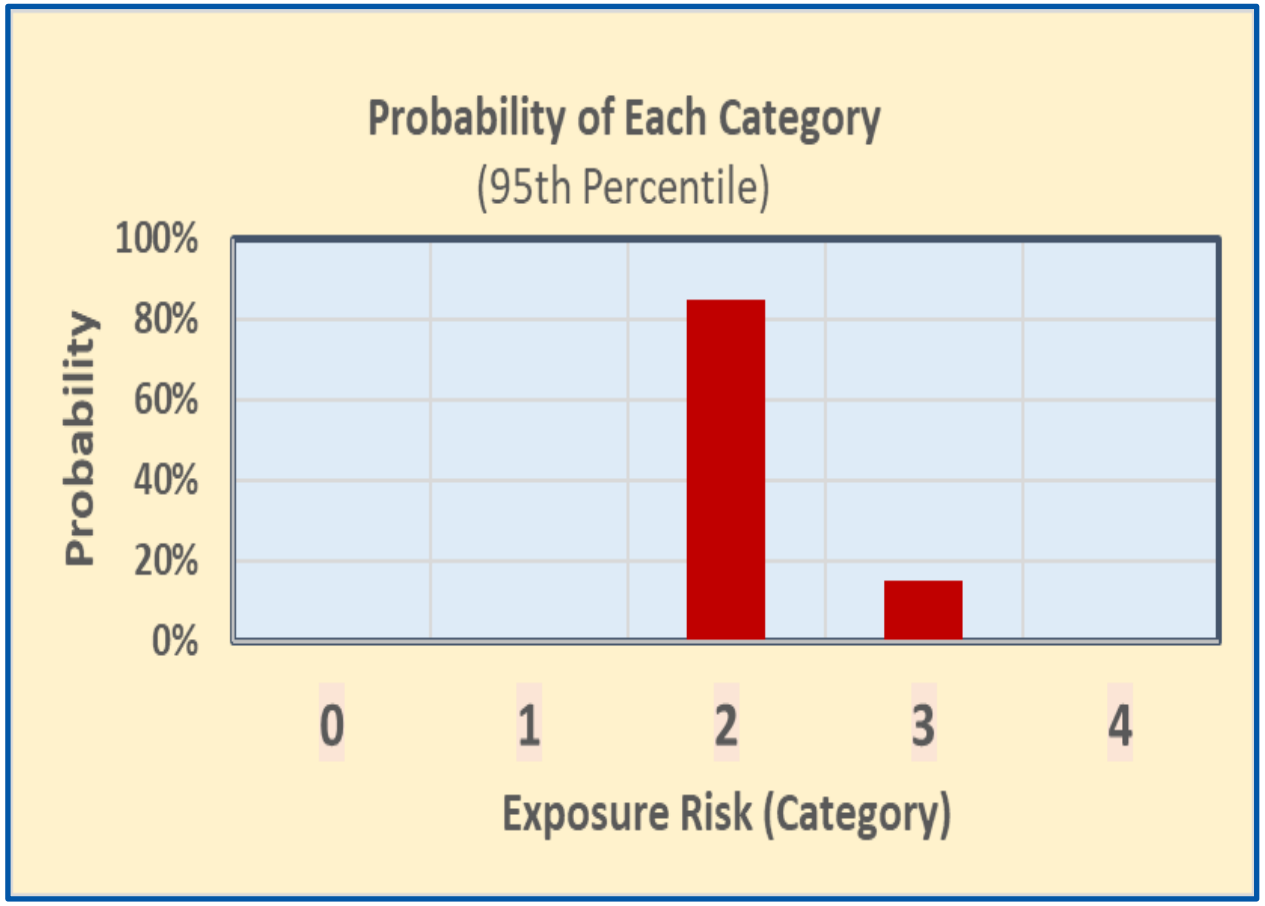
[OEL = 25 ppm; 7 samples]

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

Category		Response
O	<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 SET A



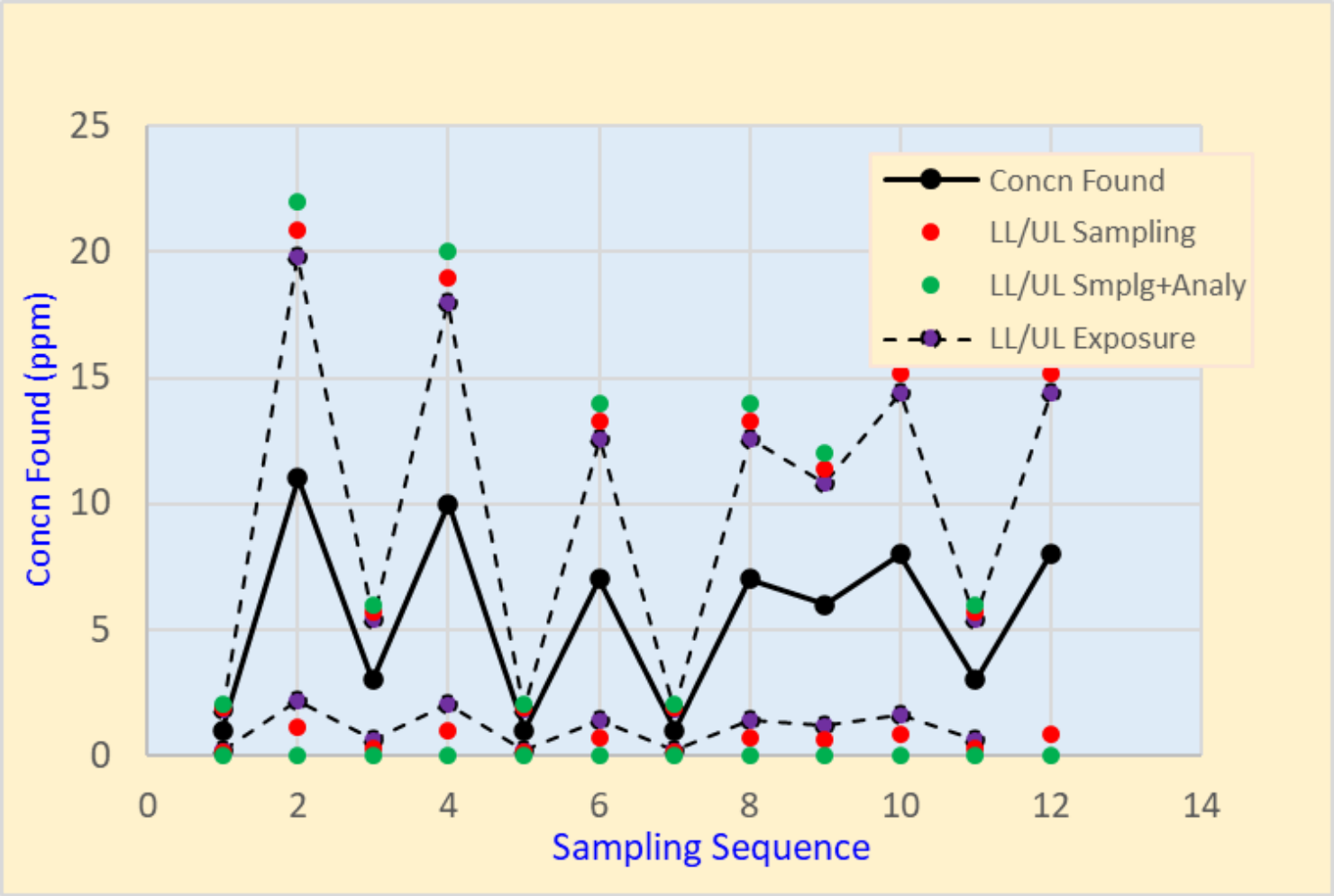
[OEL = 25 ppm; 12 samples]

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

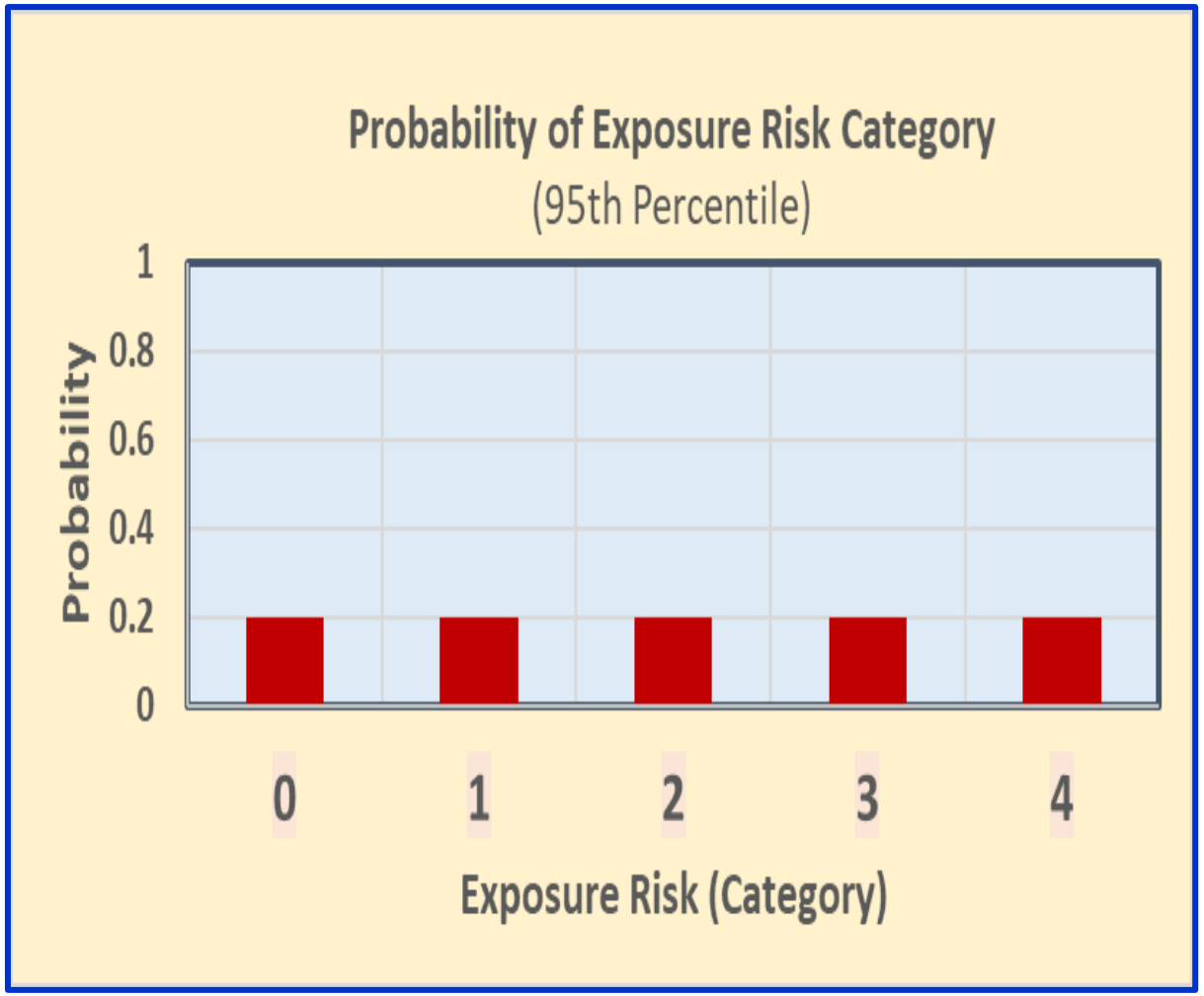
Category		Response
O	<0.01*OEL	No Action
1	<0.1* OEL	Haz Com/Training
2	<0.5* OEL	Haz Com/Monitor
3	<1.0* OEL	Surveillance/Monitor
4	>1.0* OEL	Respirators/Controls

(*) 95th percentile of SEG exposures

IH DATA SET B GSD = 2.6



IH DATA SET **B**

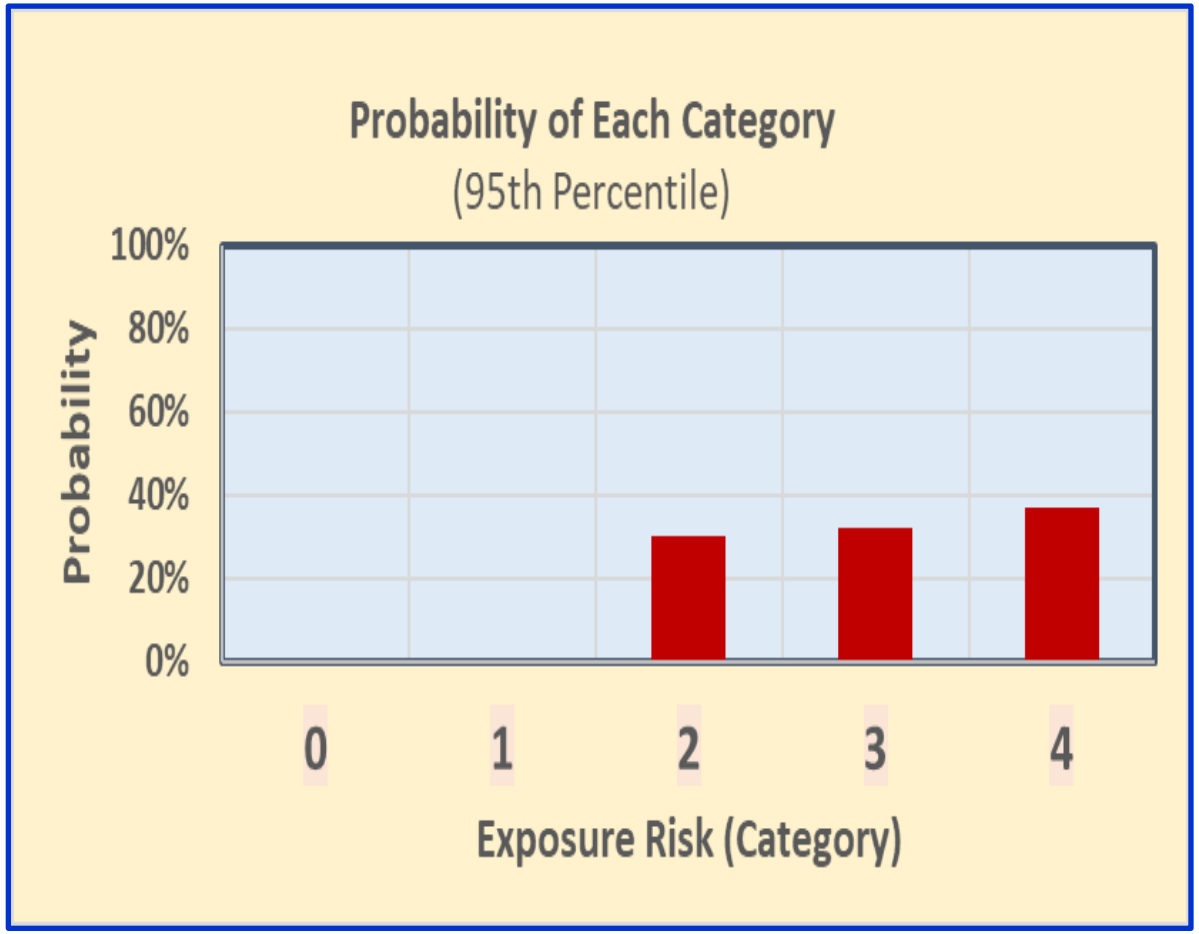


[OEL = 25 ppm; 0 samples]

Category		Response
O	<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 SET B



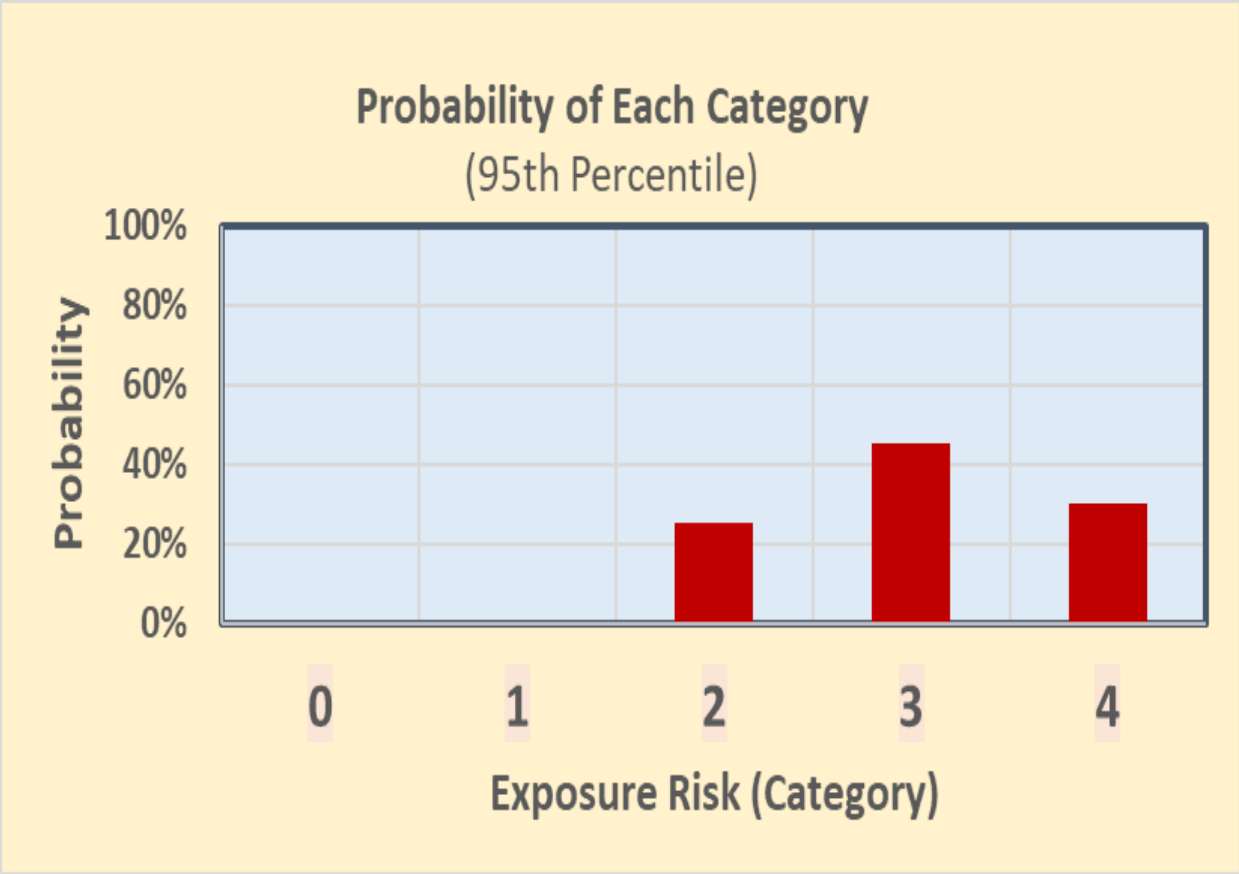
[OEL = 25 ppm; 2 samples]

[1,11 ppm]

Category		Response
O	<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 SET B



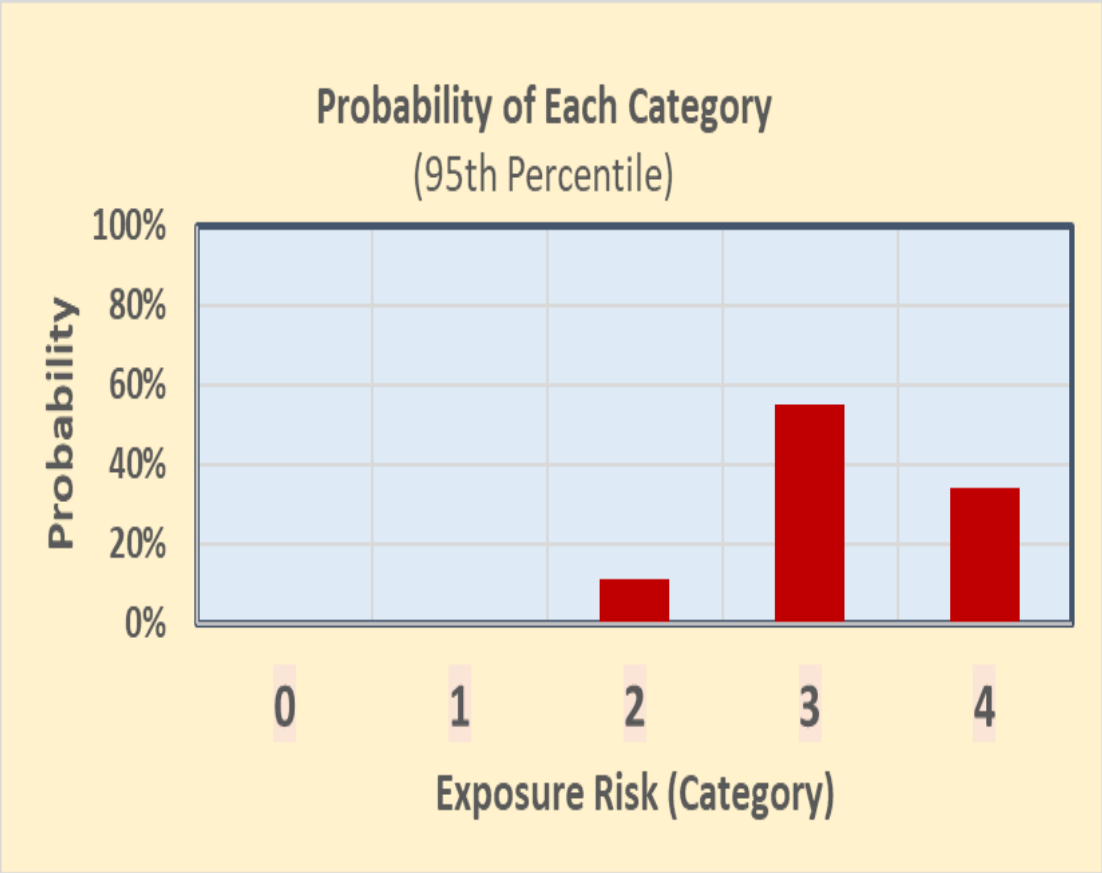
[OEL = 25 ppm; 5 samples]

[1,11,3,10,1 ppm]

Category		Response
O	<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 SET B



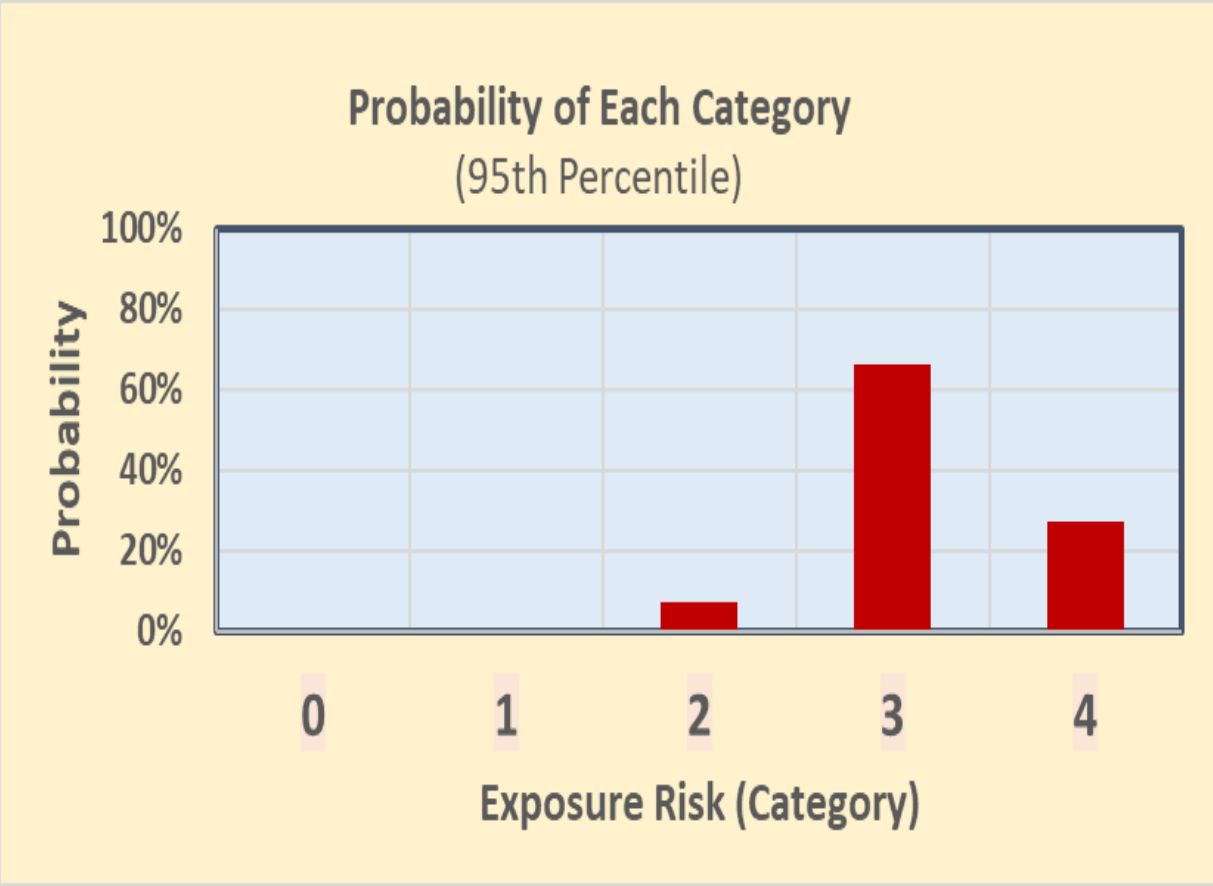
[OEL = 25 ppm; 10 samples]

[1,11,3,10,1,7,1,7,6,8 ppm]

Category		Response
O	<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 SET B



[OEL = 25 ppm; 18 samples]

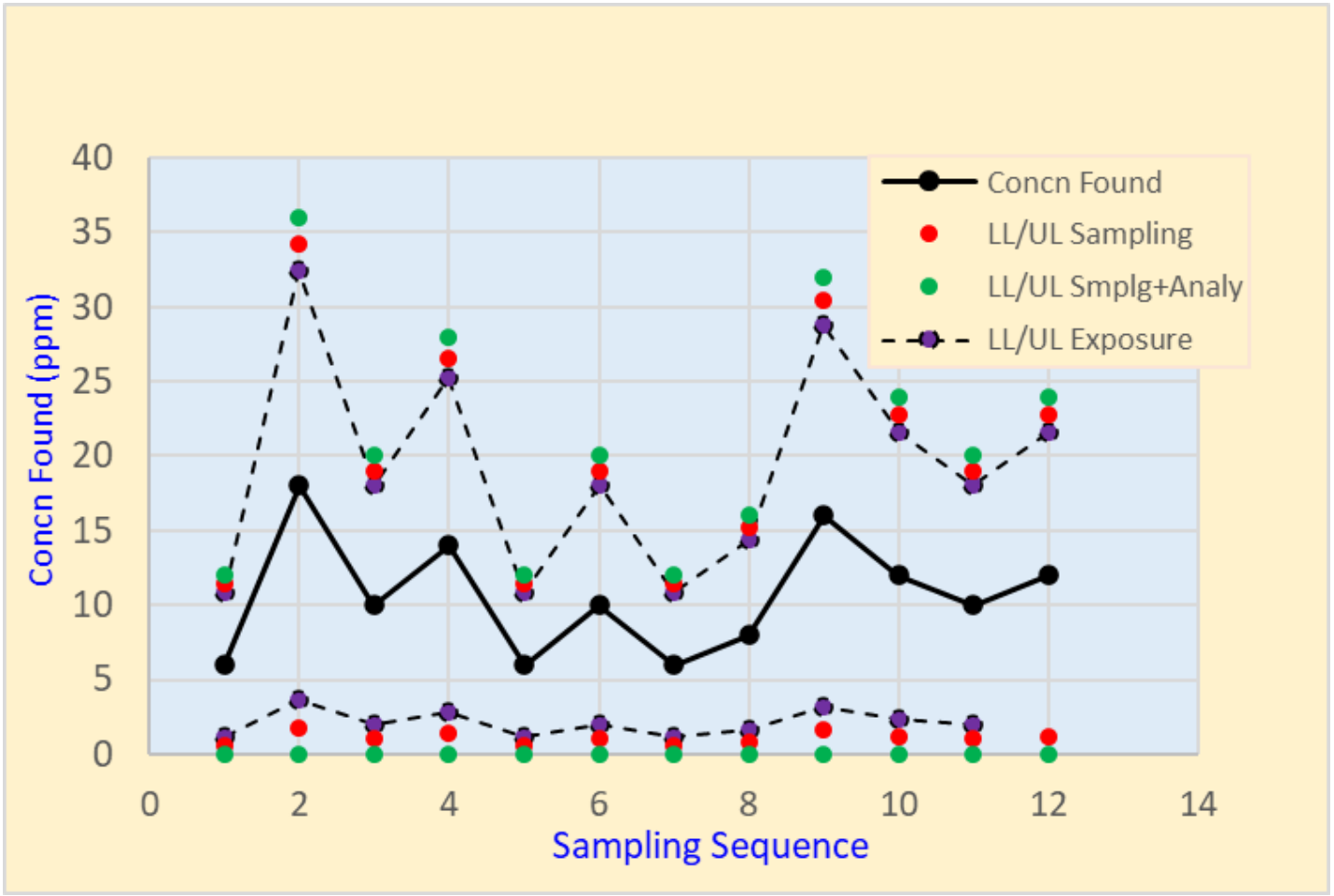
[1,11,3,10,1,7,1,7,6,8,3,8,1,11,3,10,1,7 ppm]

Category		Response
O	<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 SET C

HIGHER VALUES & GSD = 1.5



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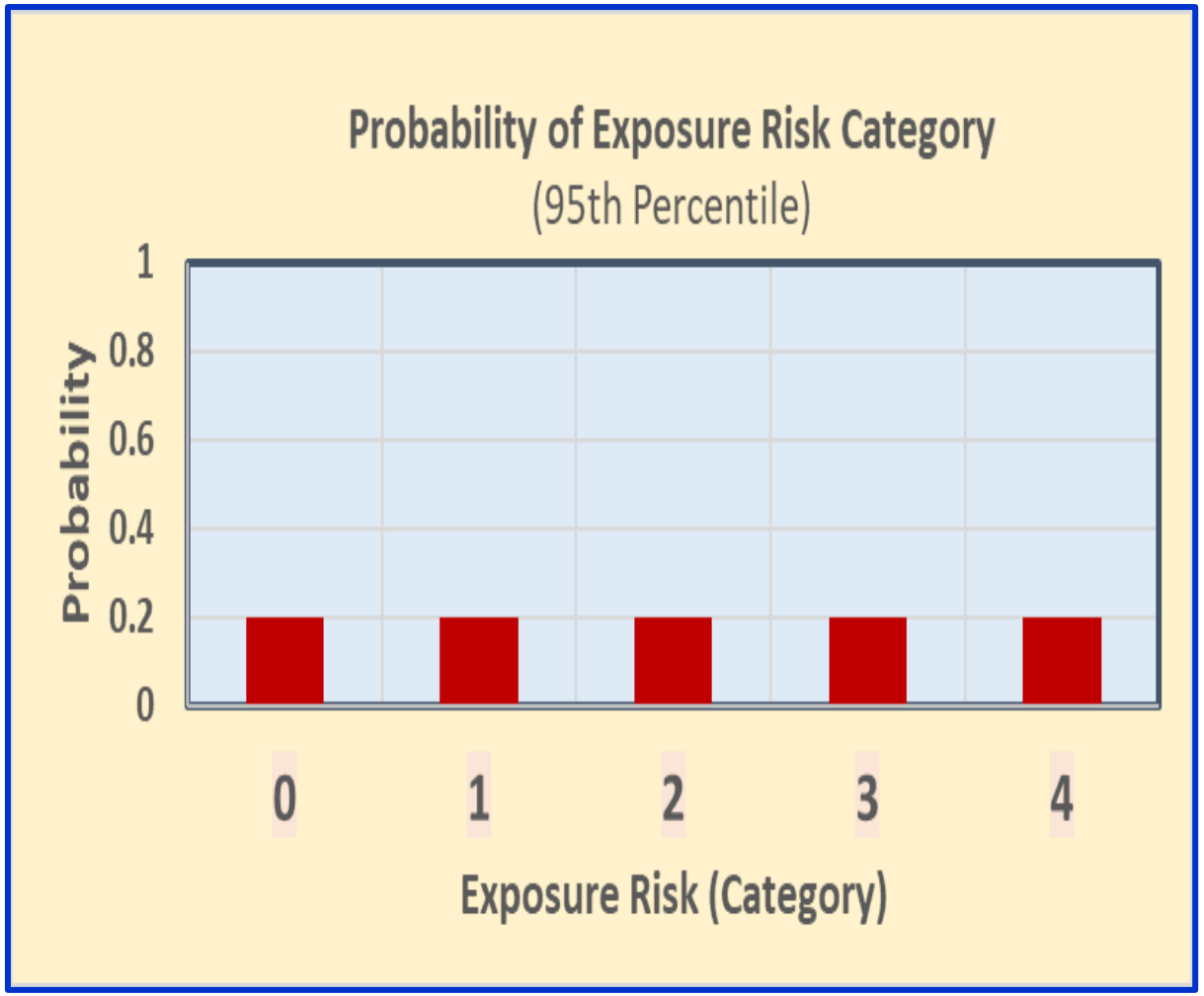
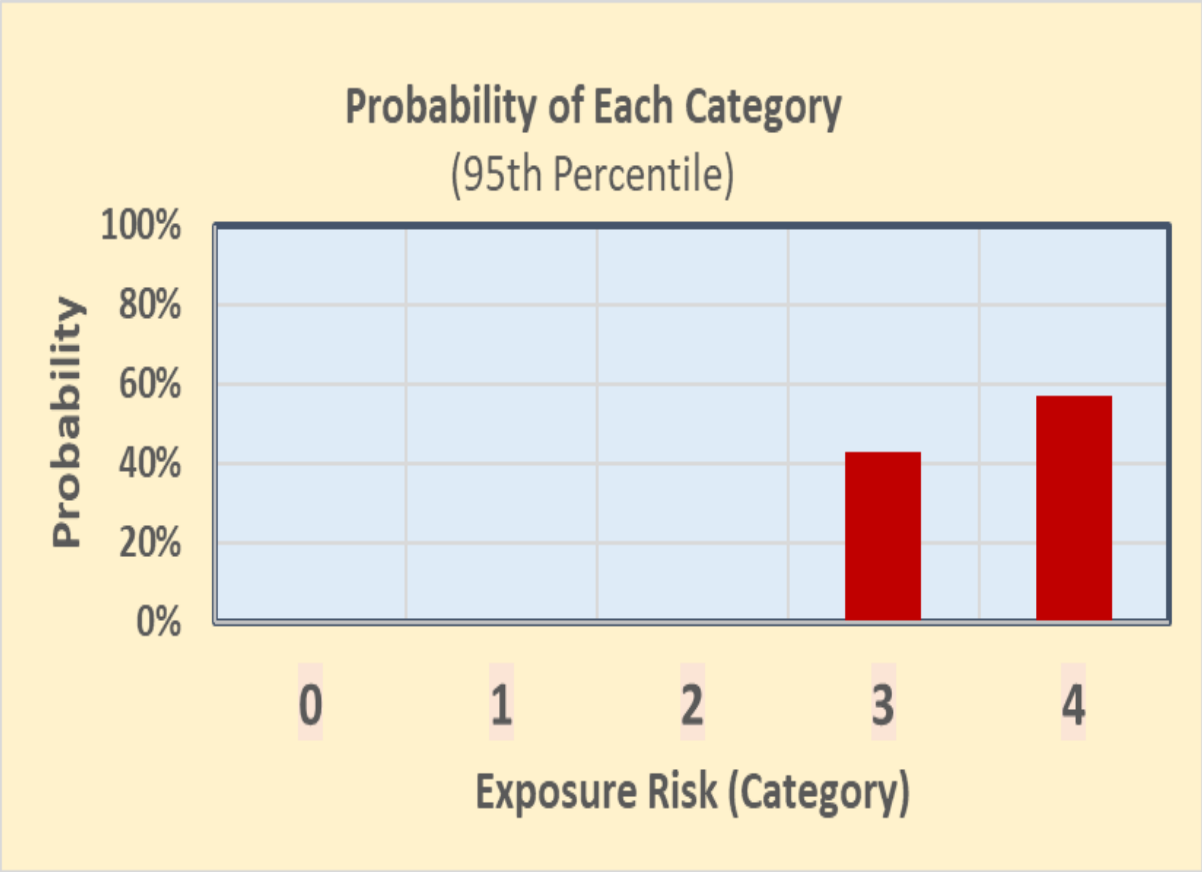


[OEL = 25 ppm; 0 samples]

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 SET C



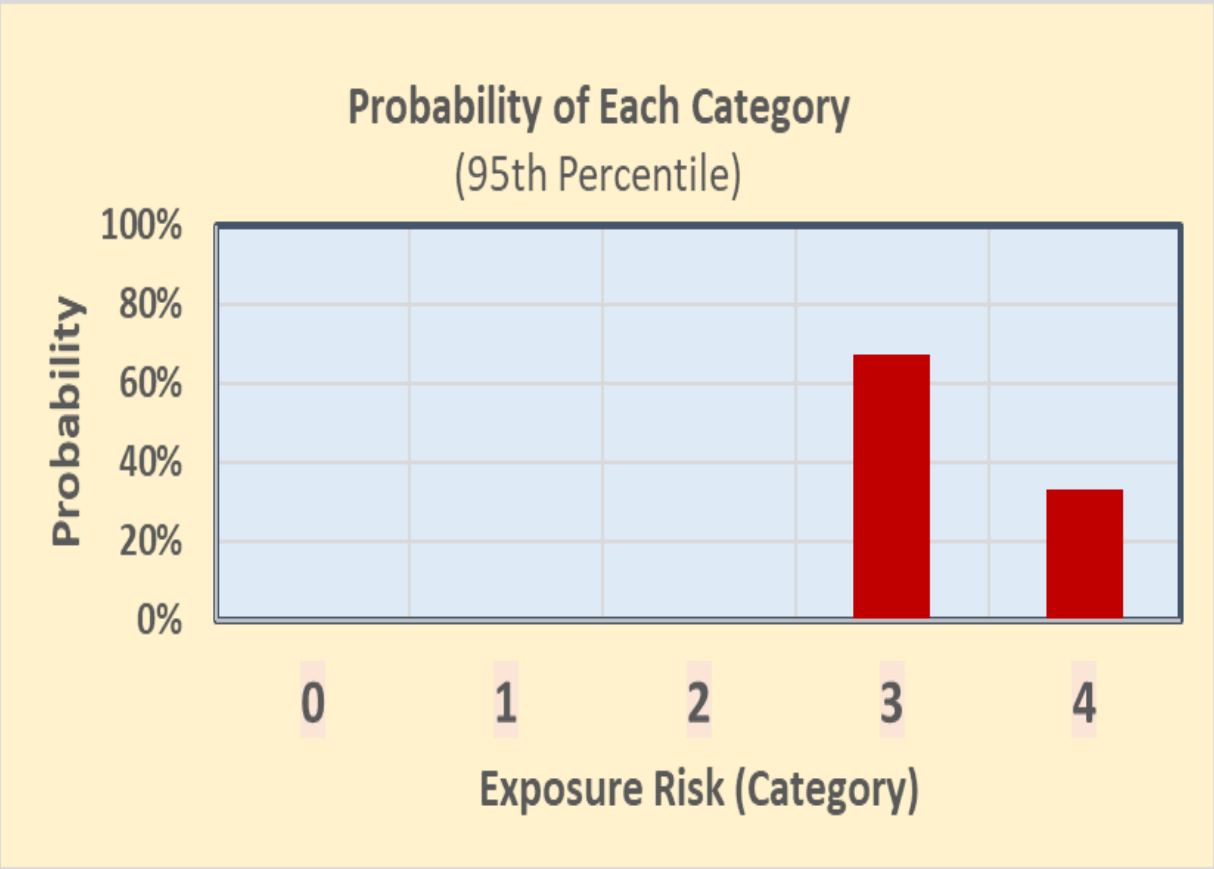
[OEL = 25 ppm; 9 samples]

[6,18,10,14,6,10,6,8,16 ppm]

Category		Response
O	<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 SET C



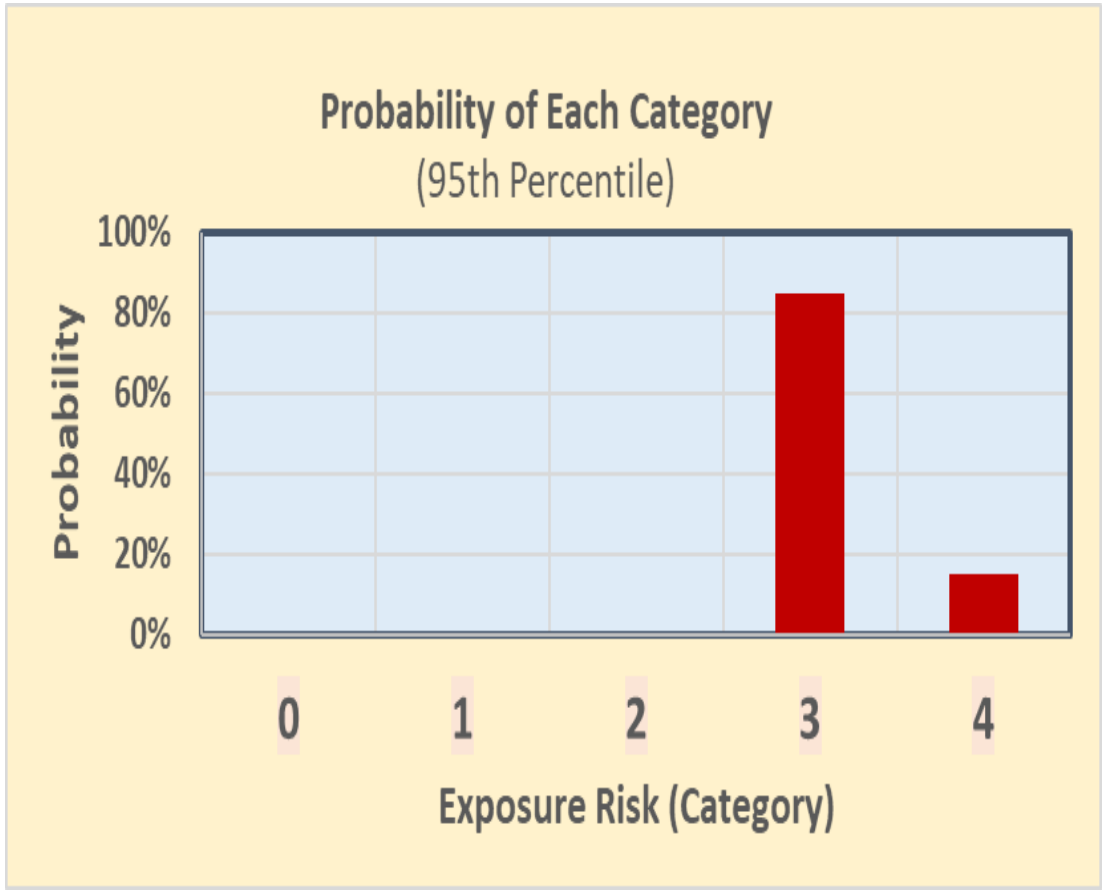
[OEL = 25 ppm; 15 samples]

[6,18,10,14,6,10,6,8,16,12,10,12,6,18,10 ppm]

Category		Response
O	<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 SET C



[OEL = 25 ppm; 20 samples]

[6,18,10,14,6,10,6,8,16,12,10,12,6,18,10,14,6,10,6,8 ppm]

Category		Response
O	<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

CONCLUSION

- AIHA IH Data Analyst (free) tells you the likelihood of your 95th percentile exposure being in Range 0, 1, 2, 3 or 4

0 = 0-1% (No) 1 = 1-10% OEL (Low) 2 = 10-50% OEL (Med)

3 = 50-100% of OEL (Borderline) 4 = > 100% of OEL (OVER)

- **IHDA Tells You How Many Samples to Collect**
  - **To reach a reasonable level of certainty**

SUMMARY

- Variations in Exposures >> more significant than Sampling Errors
- Intuition Works Poorly in Assessing lognormal Exposure Data
- IH Data Analyst tells you the probable range of 95th percentile exposure
- **IHDA Will Tell You How Many Samples to Collect**
  - **but You MUST listen to it**

THANK YOU FOR ATTENDING!

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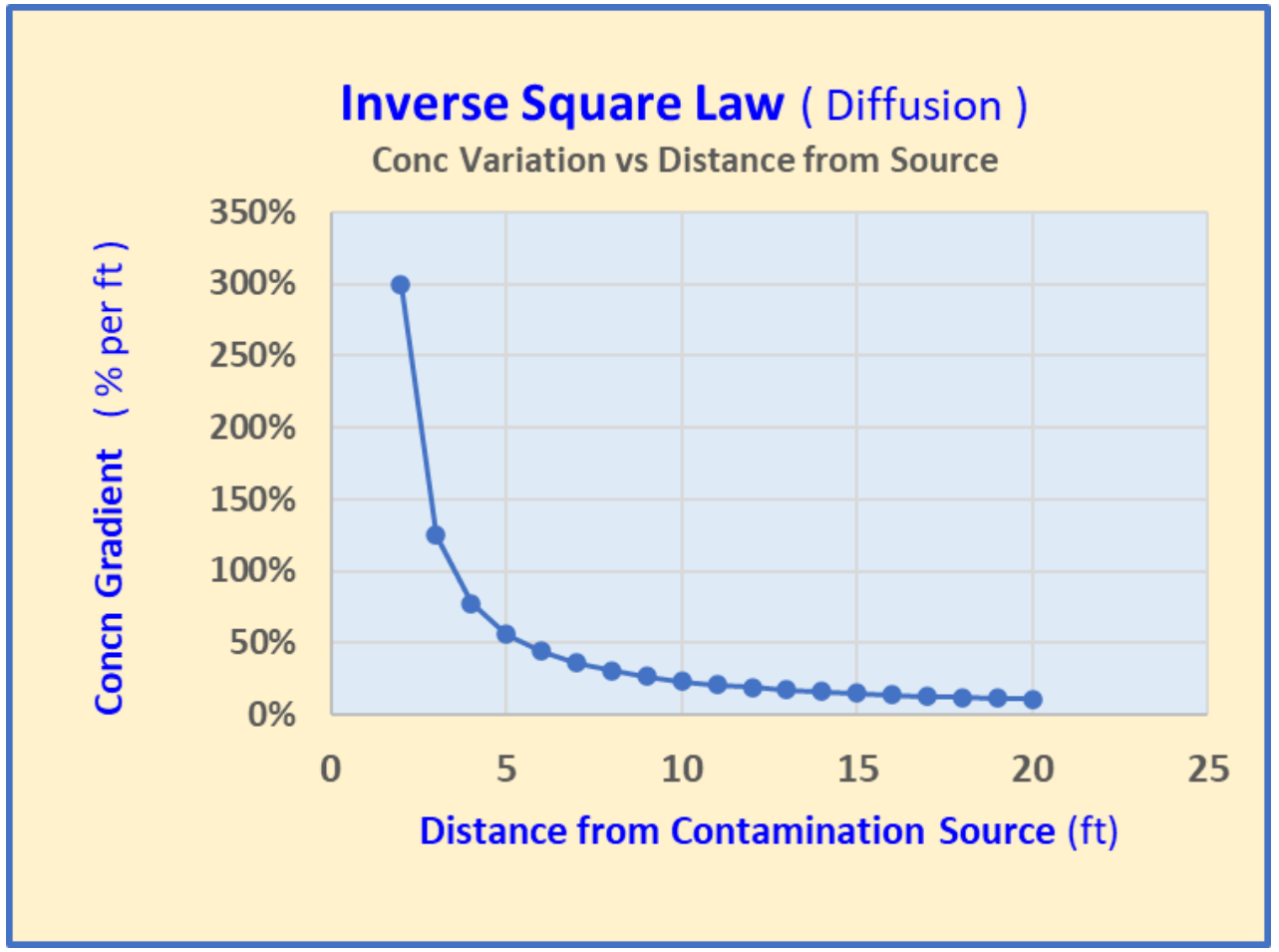
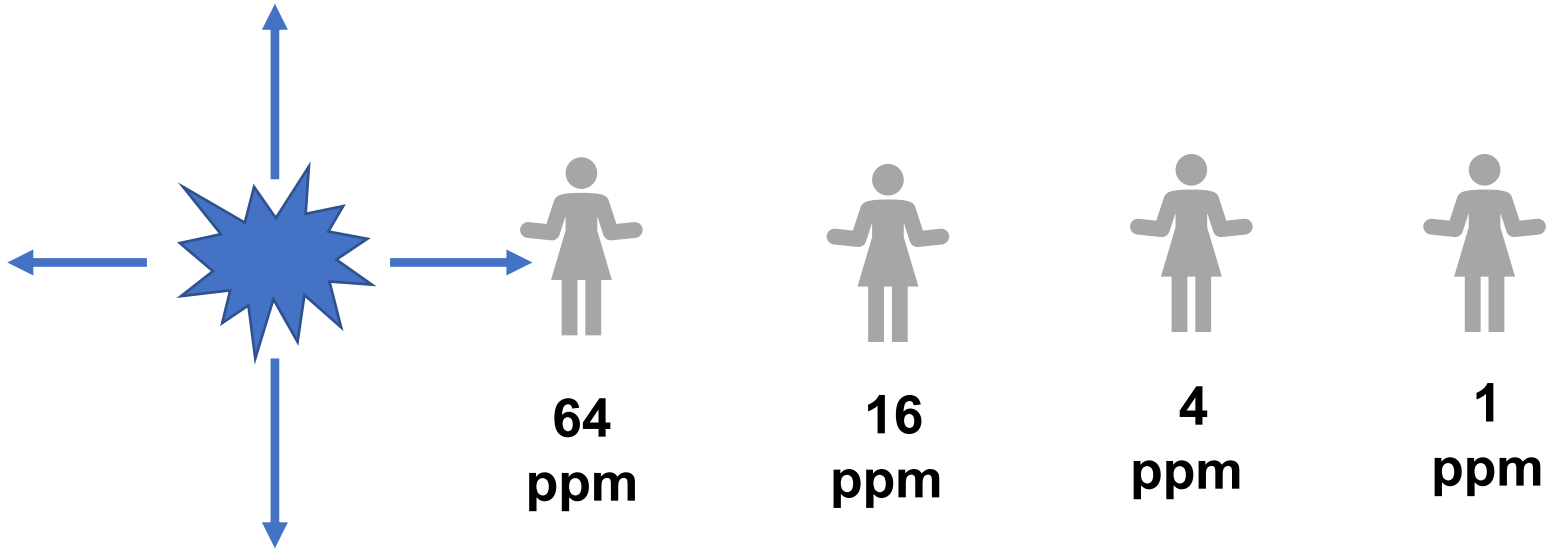

Inverse Square Law (Diffusion)
Conc Variation vs Distance from Source
Concn Gradient (% per ft)
350%
300%
250%
200%
150%
100%
50%
0%
0
5
10
15
20
25
Distance from Contamination Source (ft)

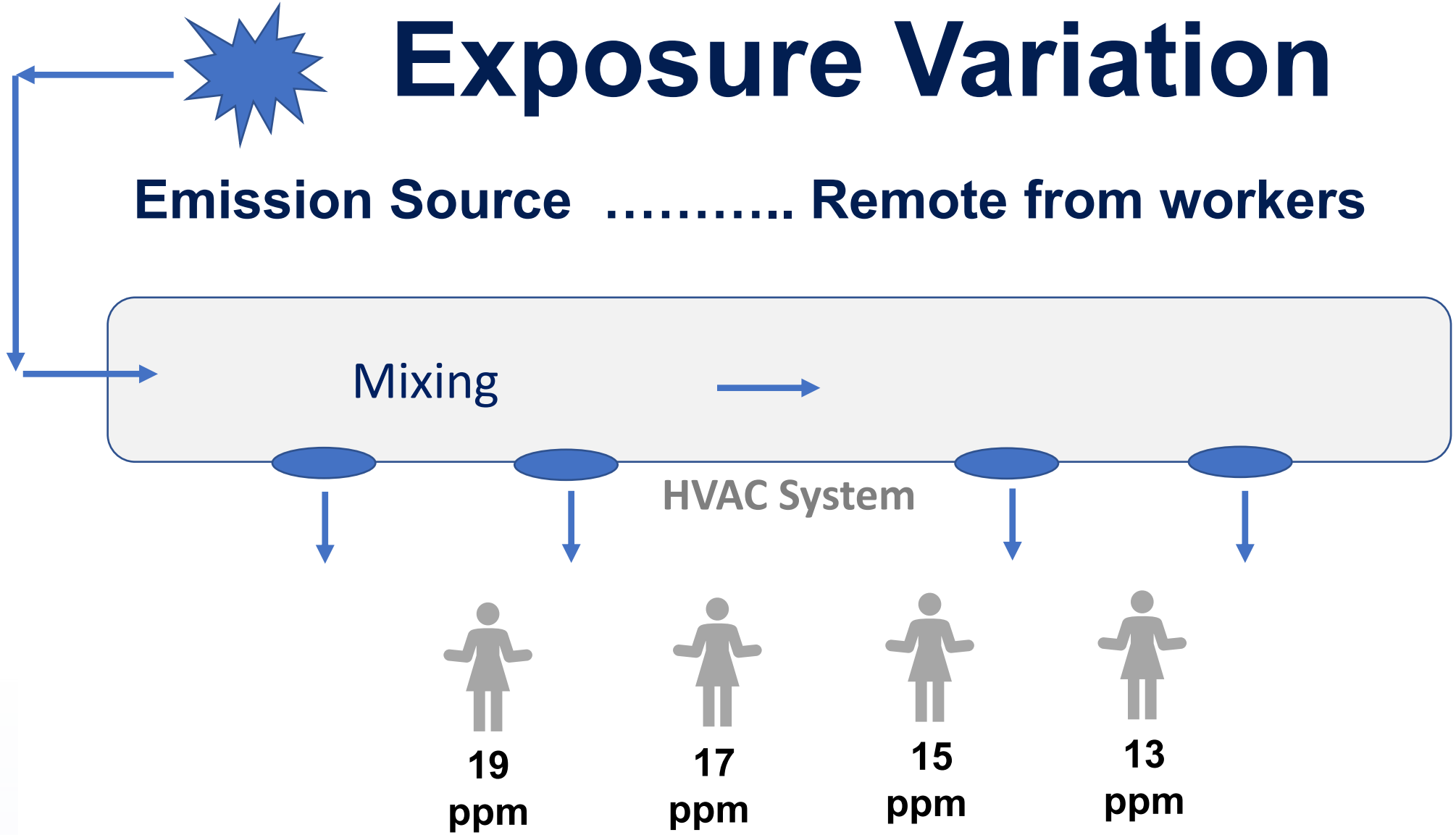
Exposure Variation

Emission Source ……. close to workers



Exposure Variation

Emission Source ……. Remote from workers



DEFINITIVE STUDY - WORKPLACE VARIATION

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