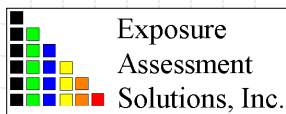


Innovative Tools for Understanding the Overall Performance of Your Exposure Risk Management Strategy

Paul Hewett Ph.D. CIH
Exposure Assessment Solutions, Inc.



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Innovative Tools ...

- I. Test
- II. Issues
- III. Performance-based Strategies
- IV. Bayesian Decision Analysis

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I. Test

- ◆ What percentage of exposure assessment decisions are based upon exposure measurements?
 - ~ 0%
 - ~ 5%
 - ~ 100%
- ◆ What is the most common sample size in industry?
 - n=0
 - n=100
 - n=1000
- ◆ Most decisions are based upon zero or very few data. Professional judgment is used to fill the *data gap*.

II. Issues

- ◆ Strategy power
 - The **power** of our strategy to detect poorly-controlled work environments is often unknown.
- ◆ Use of professional judgment
 - How is **professional judgment** used ...
 - *initially*, when designing a specific sampling strategy for a specific SEG
 - *later*, during the decision making process.

III. Performance-based Strategies

- ◆ What is the power of your strategy to detect a poorly-controlled exposure profile?
- ◆ Is that strategy *effective* and *efficient*?
 - **Effective** – it is highly likely that your strategy will lead to the correct decision
 - **Efficient** – on average, your strategy requires a tolerable level of resources
- ◆ That is, is your strategy *performance-based*?

Definitions

- ◆ Specification-based strategy
 - You use an off-the-shelf strategy.
 - **No performance goal is specified. Probability of correct classification is unknown.**
- ◆ Performance-based strategy
 - You design (or modify) a strategy.
 - **A performance goal is specified and actual performance regarding correct classification has been estimated.**

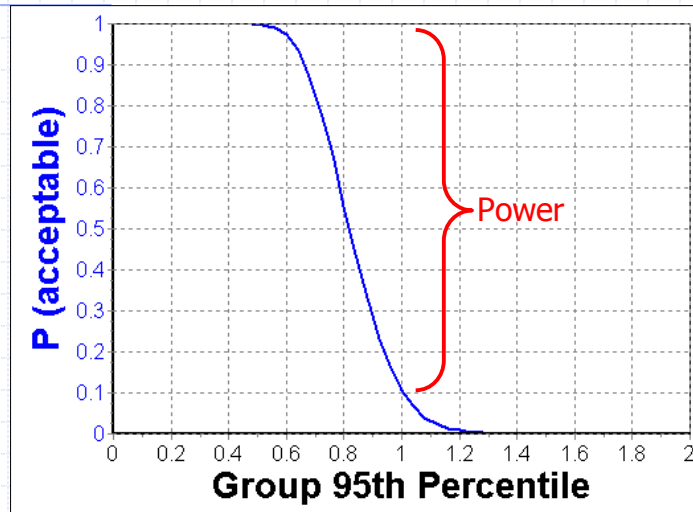
Design Procedure:

1. Define a **clearly unacceptable exposure profile**
2. Specify **target Employees' Risk**
3. Specify proposed (or existing) strategy
4. Estimate Employees' Risk
 - using computer simulation
5. Compare estimated and target risks
6. Accept, modify, or reject proposed strategy

Set the Performance Goal:

- ◆ **Clearly unacceptable** could be defined as...
 - $X_{0.95} > 100\%$ of the OEL
- ◆ The **Employee's Risk** of deciding that an exposure profile is "acceptable", when it is truly "unacceptable", should be ≤ 0.10
 - i.e., the probability of a false negative decision should be 0.10 or less
- ◆ Therefore, the **power of the survey** to detect a clearly unacceptable exposure profile should be ≥ 0.90 .

Ideal Performance Curve (OEL=1)



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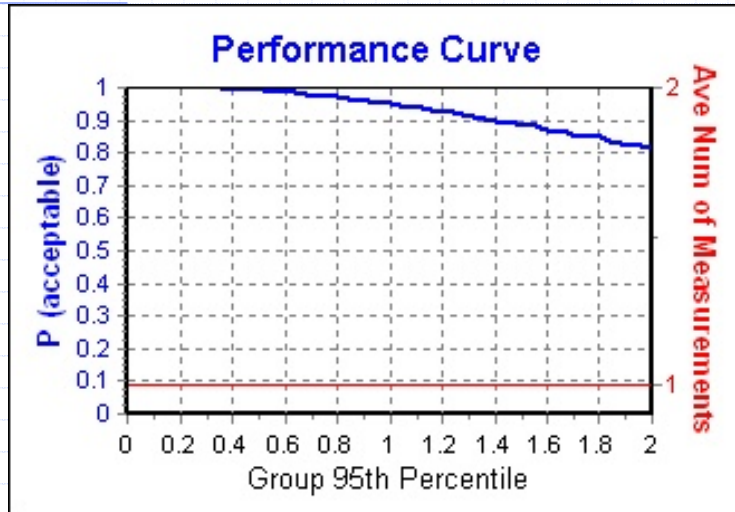
Three off-the-shelf Strategies

- ◆ OSHA Inspector Strategy
- ◆ OSHA-NIOSH "6b Rule" Strategy
 - i.e., the NIOSH 1977 strategy
- ◆ AIHA "SEG" Strategy

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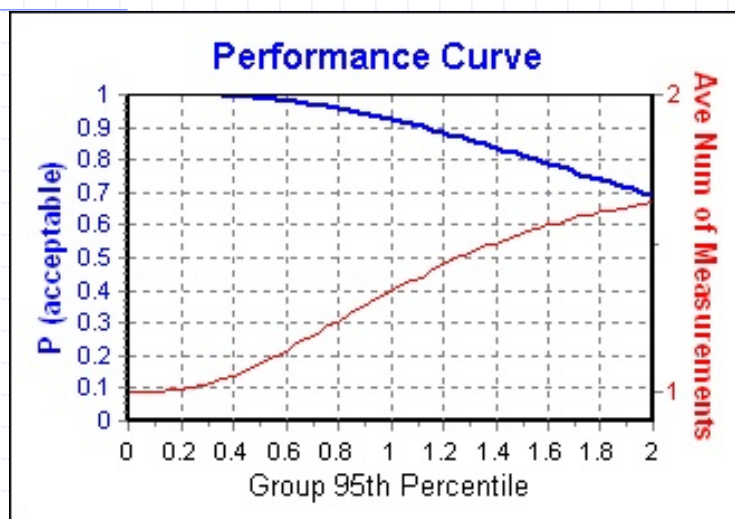
OSHA Inspector Strategy (OEL=1)



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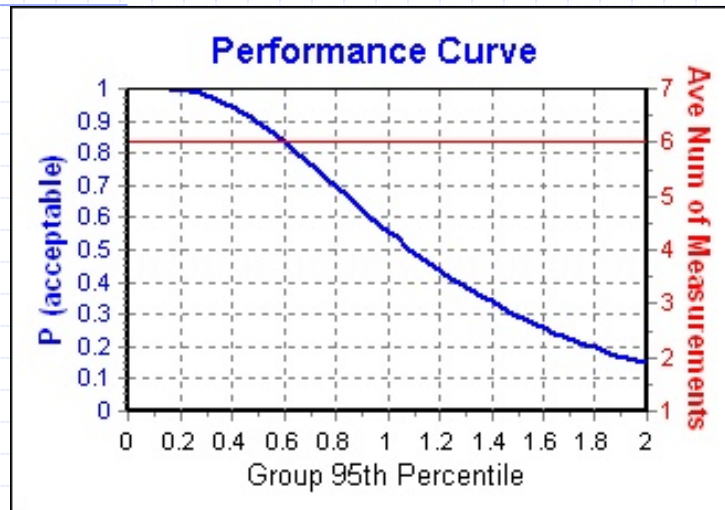
OSHA-NIOSH "6b Rule" Strategy (OEL=1)



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AIHA "SEG" Strategy (OEL=1)



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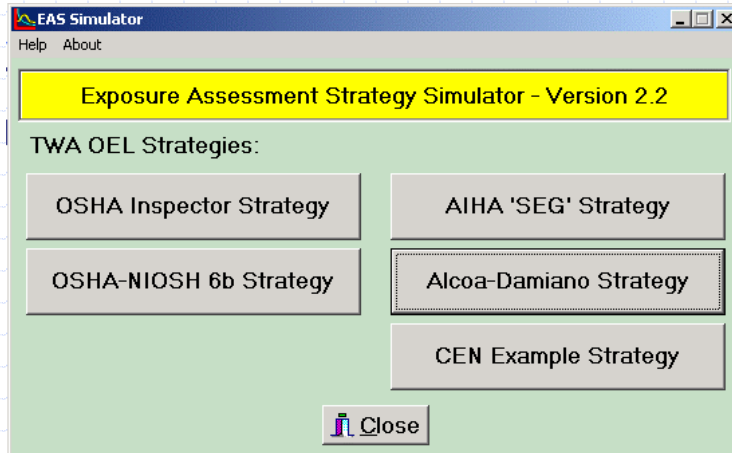
Results – all need modification

- ◆ OSHA Inspector Strategy
 - **Power = 0.05**
 - Probability of a false negative = 0.95
- ◆ OSHA-NIOSH "6b Rule" Strategy
 - **Power = 0.07**
 - Probability of a false negative = 0.93
- ◆ AIHA "SEG" Strategy
 - **Power = 0.45**
 - Probability of a false negative = 0.55

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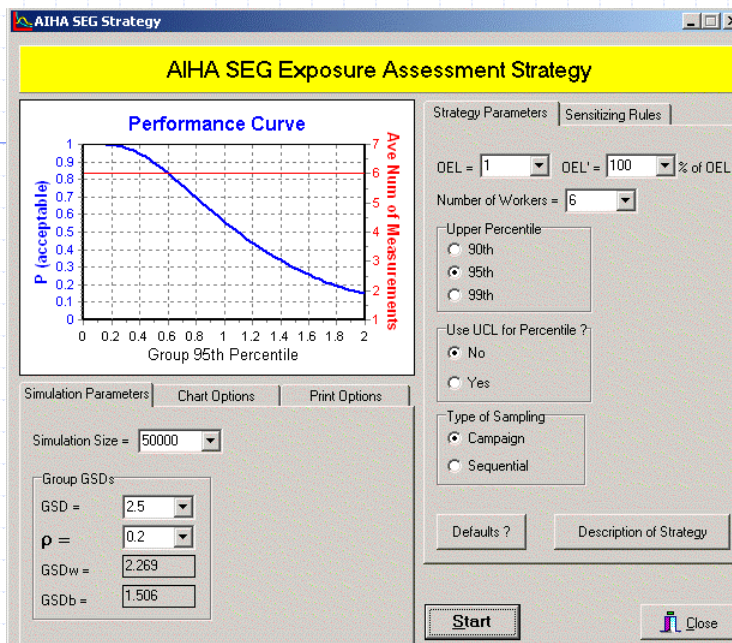
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◆ To computer simulate these strategies I used the EAS Simulator V2.2.



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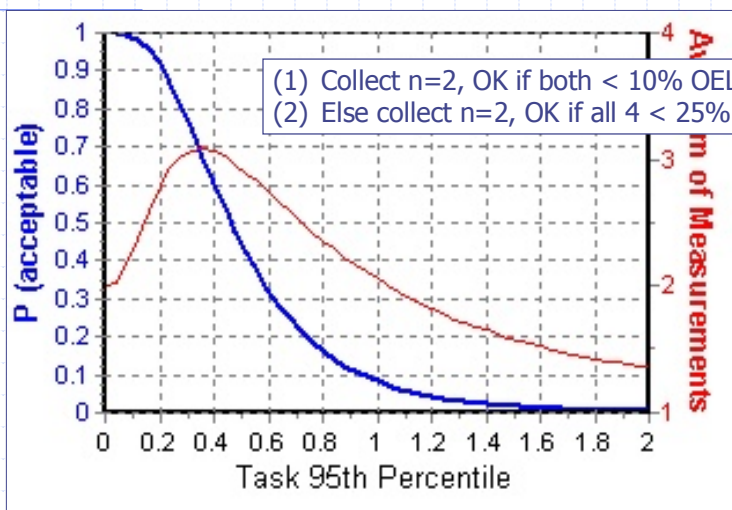
Resources

◆ Hewett, P.:

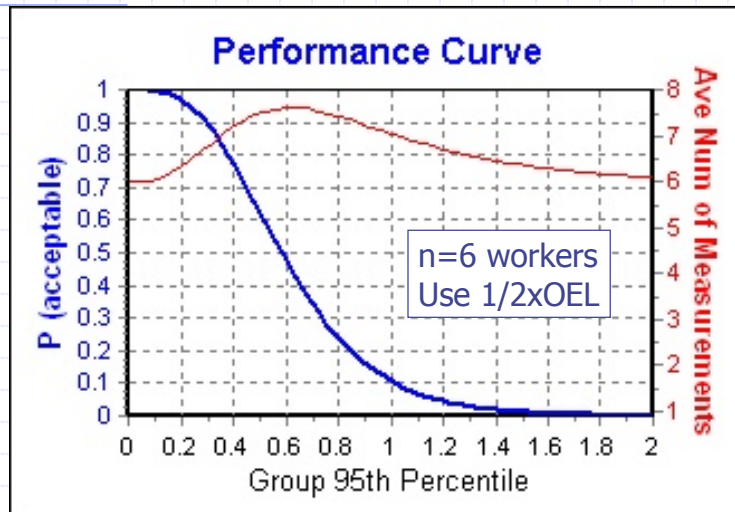
- A model for designing a performance-based exposure assessment strategy for TWA OELs.
 - ◆ Technical Report No. 05-03. Exposure Assessment Solutions, Inc. (2005)
- Exposure Assessment Strategy Simulator, Version 2.2

◆ Both are available free at www.oesh.com (open June 1)

A Modified OSHA Inspector Strategy



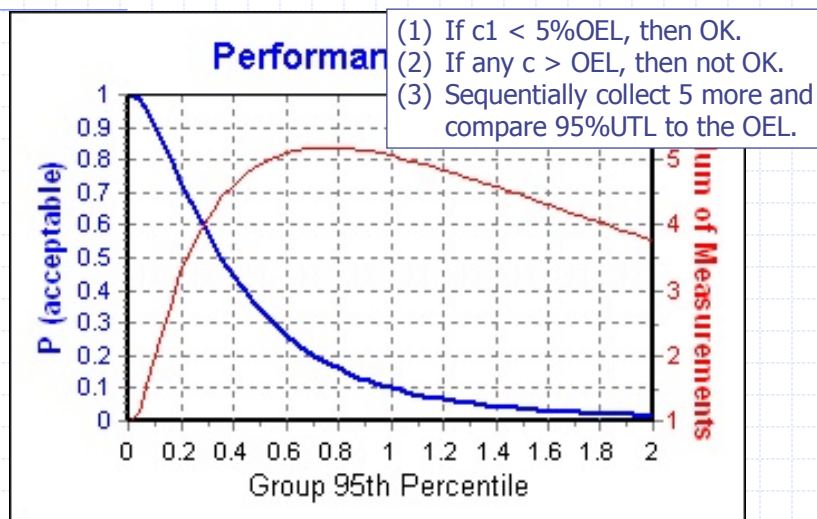
A Modified OSHA-NIOSH "6b Rule" Strategy



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A Modified AIHA "SEG" Strategy



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Observations

- ◆ Each strategy can be modified to perform as desired.
- ◆ Both sample size and number of *false positives* may be unacceptably high for true Category 0, 1, & 2 exposure profiles.
- ◆ **Sensitizing Rules** can help...
 - decrease sample size and increase the probability of passing true Category 0, 1, & 2's
 - increase power to detect true Category 4's

Observations (cont'd)

- ◆ There is no provision for professional judgment:
 - The strategy does not vary even if you strongly believe that the exposures are truly Category 0, 1, or 2.
 - The final decision does not explicitly take into account professional judgment.

IV. Bayesian Decision Analysis (BDA)

- ◆ An adjunct or alternative to the calculation and interpretation of traditional statistics.
- ◆ The goal of BDA is to estimate the **probability** that the *true* exposure profile falls into a particular category, or *Exposure Rating*.
- ◆ BDA can explicitly incorporate professional judgment.

Example Survey

- ◆ OEL = 1 ppm
- ◆ During a baseline/initial exposure assessment, an IH collected the following full-shift measurements from an SEG:
 - 0.20, 0.05, & 0.10 ppm
- ◆ $n = 3$; $gm = 0.10$; $gsd = 2.00$
- ◆ The sample 95th percentile was 0.31 ppm
- ◆ but with a **95%UCL of 20 ppm**

When n is small, confidence intervals are often extremely broad.

◆ $X = \{0.20, 0.05, 0.10 \text{ ppm}\}$

◆ $n = 3$

◆ $gm = 0.1 \text{ ppm}$ 90%CI(0.03, 0.32)

◆ $gsd = 2.0$ 90%CI(1.5, 21)

◆ $\hat{X}_{0.95} = 0.31 \text{ ppm}$ 90%CI(0.16, 20)

Example Survey (cont'd)

◆ The point estimate of the 95th percentile is $< 50\%$ of the limit.

◆ Exposures *appear* to be a Category 2 exposure.

◆ However, the 95%UCL($X_{0.95}$) is considerably greater than the OEL.

◆ **What would you do?**

- **Make a decision ?**
- **Collect more data ?**

Example (cont'd)

- ◆ Our IH concludes:
 - This operation is well-controlled with just the existing dilution ventilation.
 - Although the 95%UCLs were excessive, our IH took into account his extensive past experience with this type of operation.
- ◆ His recommendations:
 - Further sampling is not necessary.
 - Routine surveillance samples should be collected using the established schedule for well-controlled operations.
- ◆ Is such a decision making process a Bayesian Decision Analysis?

Foundation of BDA: Bayes' Theorem



Posterior Likelihood Prior

$$P(\text{Pop}_i|\text{data}) = \frac{P(\text{data}|\text{Pop}_i) \cdot P(\text{Pop}_i)}{\sum [P(\text{data}|\text{Pop}_i) \cdot P(\text{Pop}_i)]}$$

Correction Factor

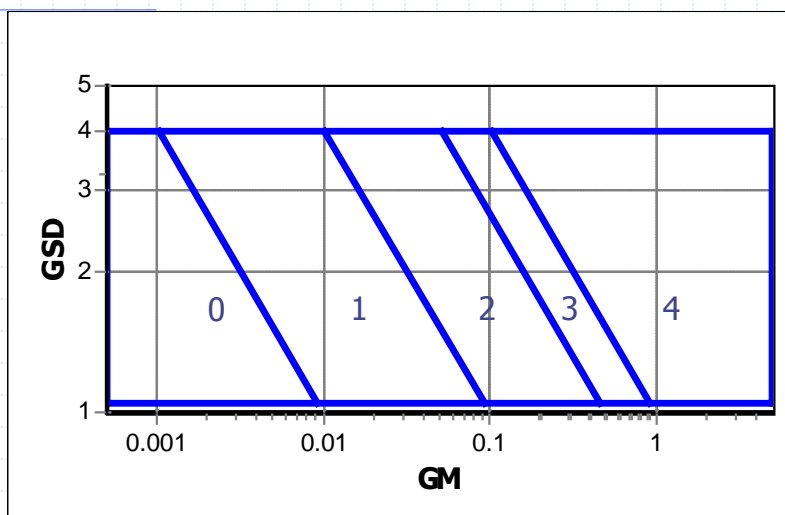
Exposure Ratings – A “rating zone” represents a population of exposure profiles

Exposure Rating	Cutoff (%OEL)
0	$X_{0.95} \leq 1\%$
1	$1\% > X_{0.95} \leq 10\%$
2	$10\% > X_{0.95} \leq 50\%$
3	$50\% > X_{0.95} \leq 100\%$
4	$X_{0.95} > 100\%$

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Exposure Ratings translated into *parameter space* for OEL=1ppm



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Key Concept – “Decision” Distributions

◆ **Prior** decision distribution

- Represents our professional judgment regarding the probability of each of the five Exposure Ratings.

◆ **Likelihood** decision distribution

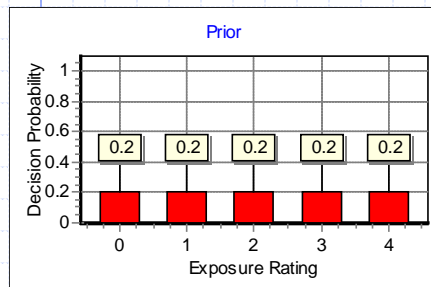
- The set of probabilities of each Exposure Rating *calculated using only the collected data.*

◆ **Posterior** decision distribution

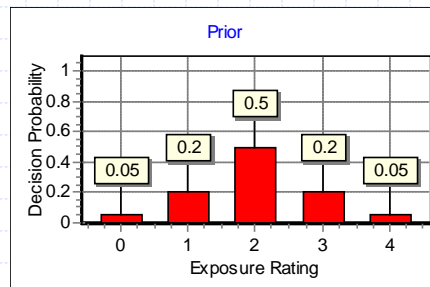
- The set of probabilities of each Exposure Rating *calculated using Bayes' equation.*

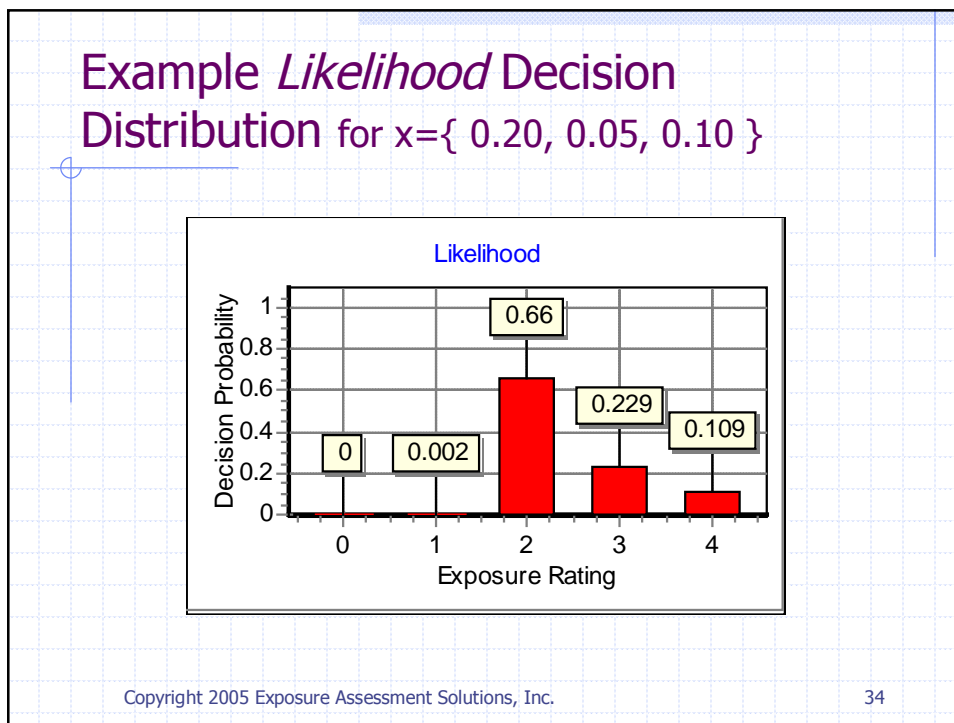
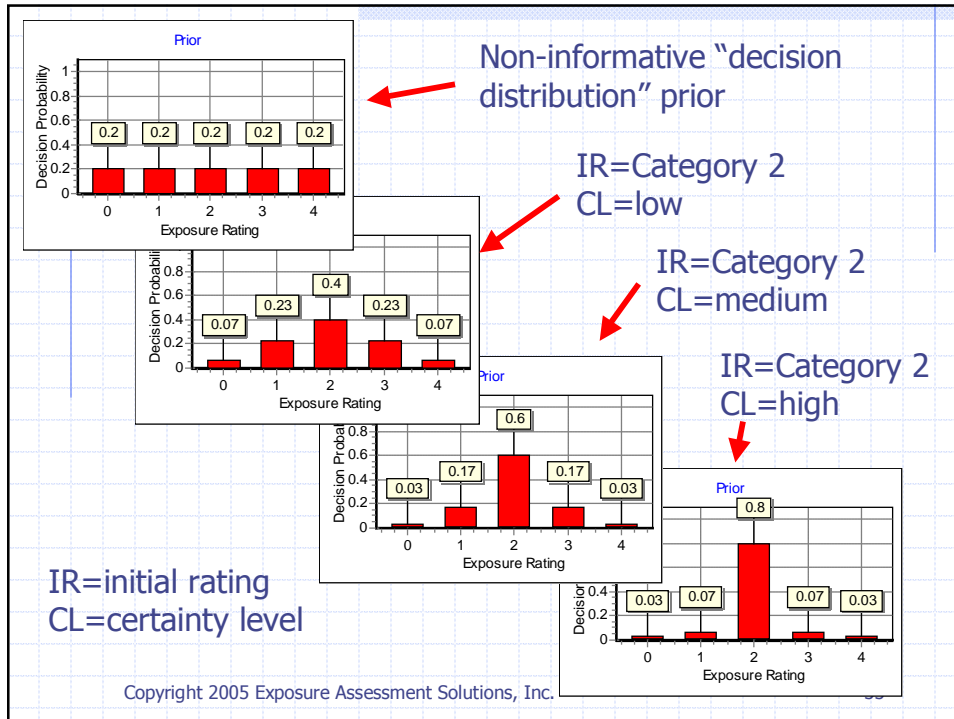
Example *Prior* Decision Distributions

Non-informative prior



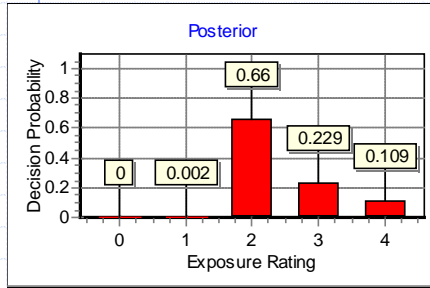
Informative prior



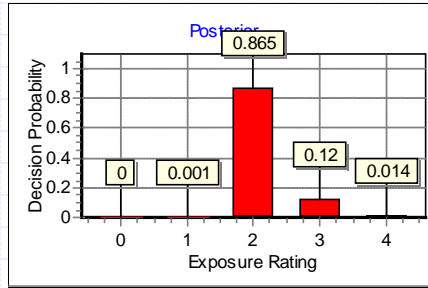


Example *Posterior* Decision Distributions

Using the non-informative prior



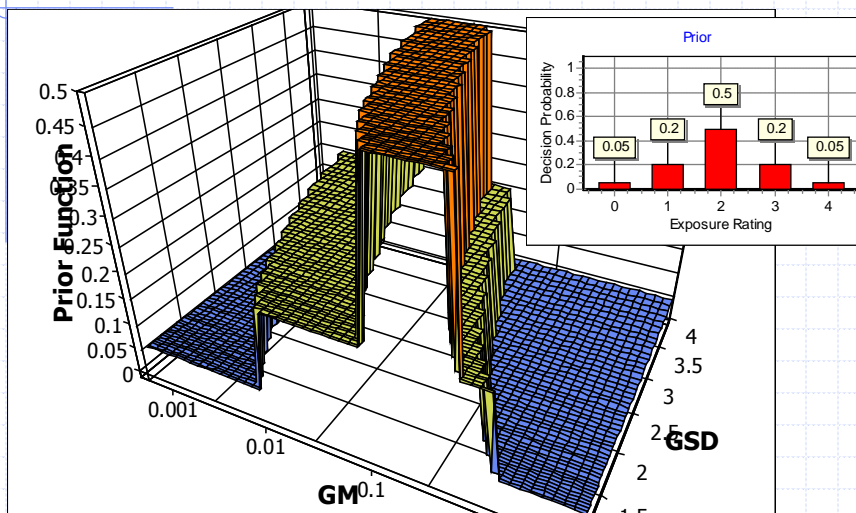
Using the informative prior



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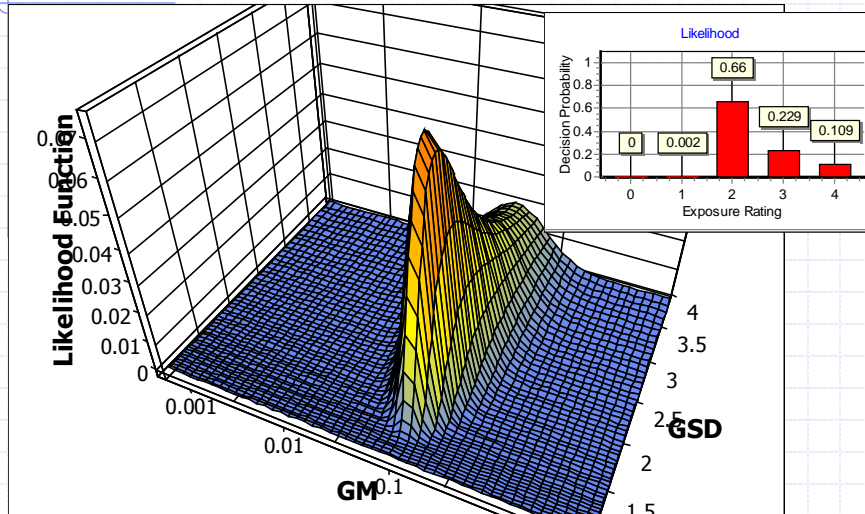
Prior decision function (i.e., prior decision distribution spread across parameter space)



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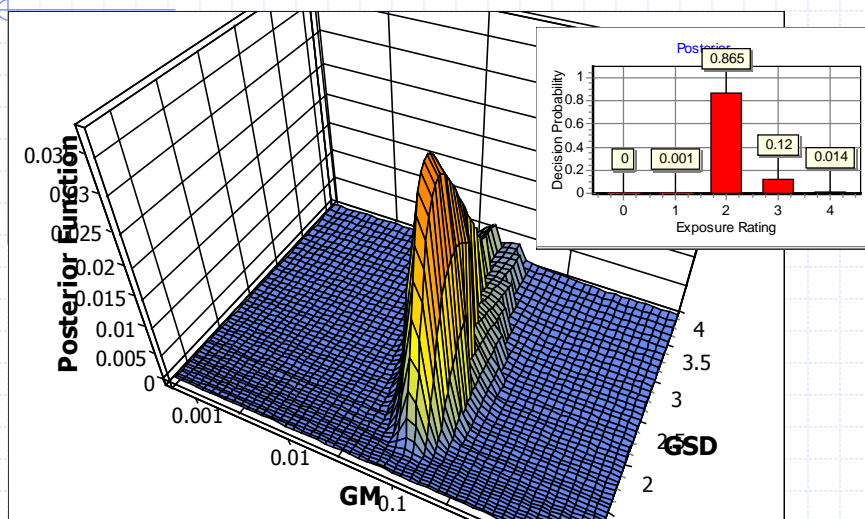
Likelihood function for $x=\{0.20,0.05,0.10\}$



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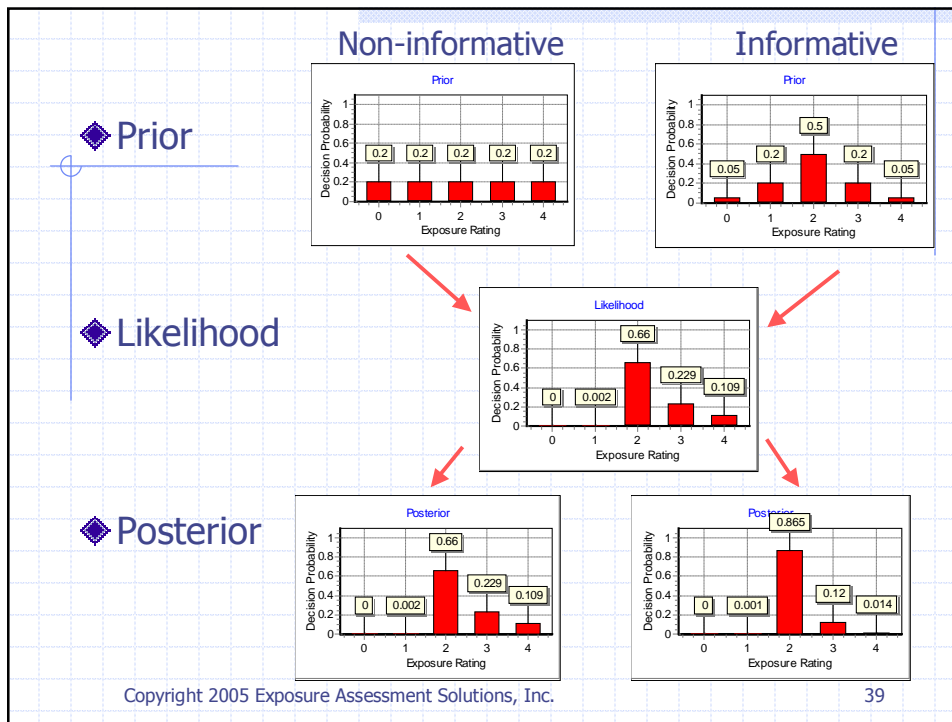
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Posterior function



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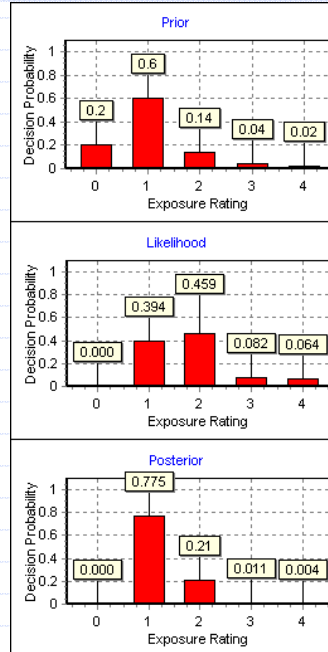
Resources

- ◆ pdfs of this and past presentations
 - available at www.oesh.com
- ◆ two *freeware* Excel spreadsheets
 - Category 0 .. 4 exposure zones
 - Category 1 .. 5 exposure zones
 - available at www.oesh.com
 - CAUTION: these spreadsheets provide approximate estimates and are more accurate for small sample sizes
- ◆ a manuscript is in preparation

Other BDA Examples

- ◆ OEL=1 ppm
- ◆ $n = 1$
- ◆ $x = 0.05$ ppm

- ◆ BDA can be applied to sample sizes as low as $n=1$.
- ◆ Professional judgment can *sharpen* the decision.



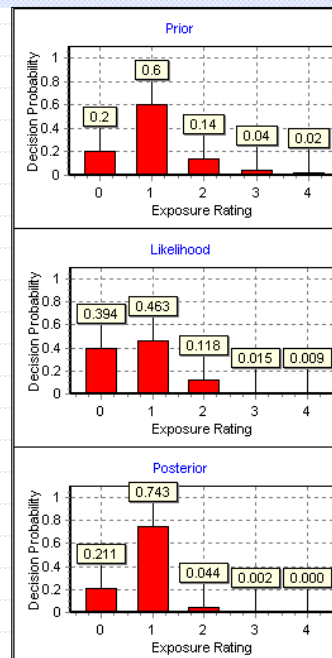
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Other BDA Examples

- ◆ OEL=1 ppm
- ◆ $n = 1$
- ◆ $x < \text{LOD}$
- ◆ $\text{LOD} = 0.05$ ppm

- ◆ BDA can be applied to censored datasets, even 100% censored or w/ multiple LODs.



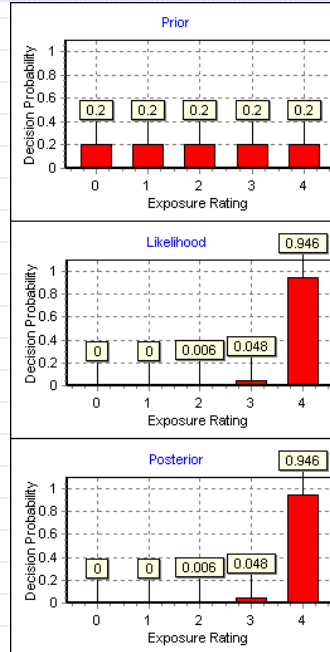
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Other BDA Examples

- ◆ OEL=1 ppm
- ◆ $n = 1$
- ◆ $x = 0.99$ ppm

- ◆ "Yes, the measurement is <OEL. But I strongly suspect that that exposures are not acceptable."
- ◆ BDA would lead to the same conclusion.



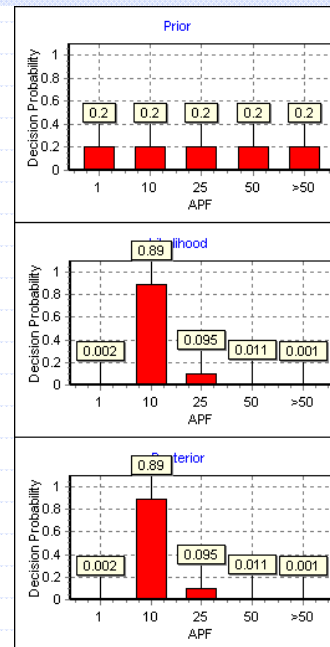
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Other BDA Examples

- ◆ OEL=1 ppm
- ◆ $n = 3$
- ◆ $x_1 = 0.99$ ppm
- ◆ $x_2 = 0.50$ ppm
- ◆ $x_3 = 2.0$ ppm

- ◆ BDA can be used to guide PPE selection.



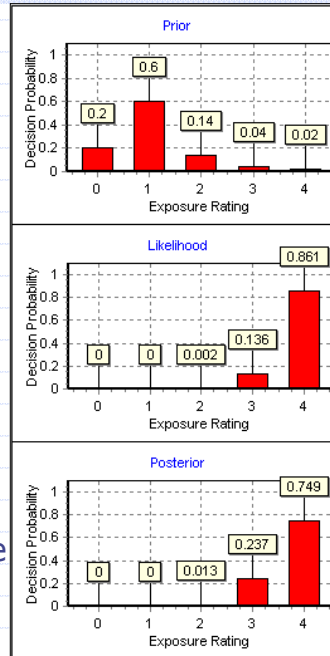
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Other BDA Examples

- ◆ OEL=1 ppm
- ◆ $n = 3$
- ◆ $x_1 = 0.25$ ppm
- ◆ $x_2 = 0.50$ ppm
- ◆ $x_3 = 1.00$ ppm

- ◆ The Prior is inconsistent with the Likelihood.
- ◆ BDA can be used to help improve professional judgment.



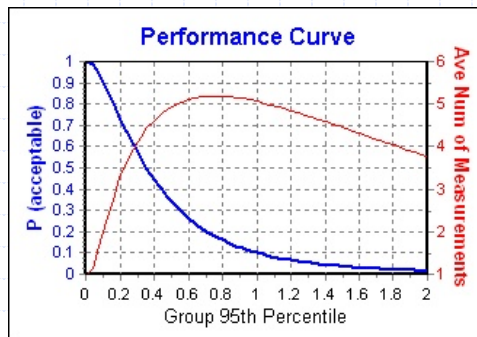
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Decision Making Using Performance-based Strategies vs. BDA

- ◆ The performance curve tells us the *long-run probability* of detecting a poorly-controlled exposure profile.

Modified AIHA
"SEG" Strategy

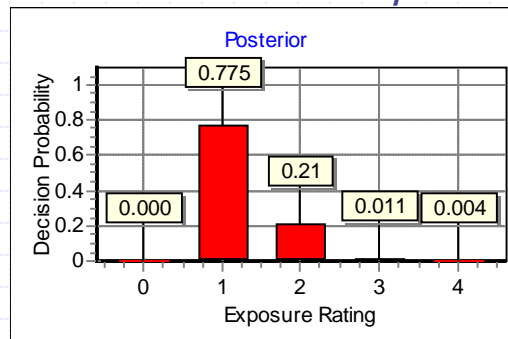


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Decision Making Using Performance-based Strategies vs. BDA

- ◆ BDA tells us the probability of the exposure profile being in each exposure zone *given the current data and prior*.



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In Summary, ...

- ◆ Strategies should be performance-based.
- ◆ Bayesian Decision Analysis can be used to make *decisions*, using *both* “professional judgment” and quantitative data (especially when n is small).

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The Challenge ...

◆ Advantages to BDA ...

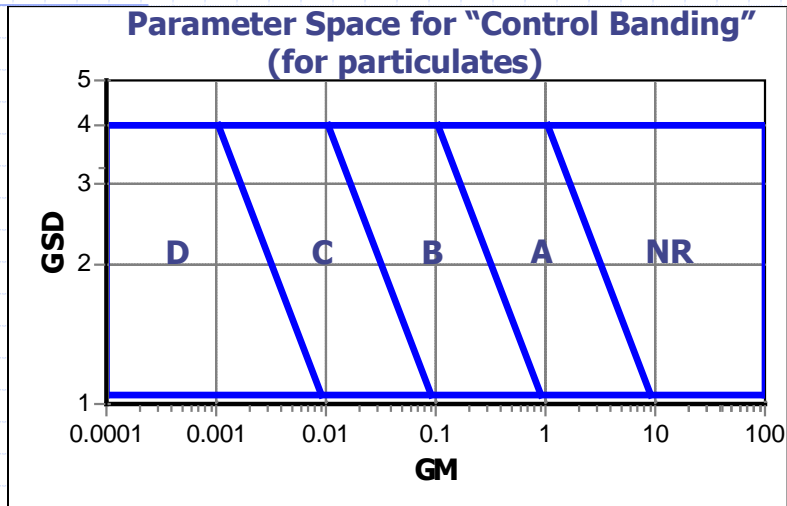
- provides a means to objectively and reproducibly quantify and use “professional judgment” in decision making
- permits decision making with fewer resources
- can be used to improve professional judgment
- improves risk communication

◆ How do we combine the use of performance-based exposure assessment strategies with Bayesian Decision Analysis?

Contact Information

Paul Hewett PhD CIH
Exposure Assessment Solutions, Inc.
phewett@oesh.com
304.685.7050

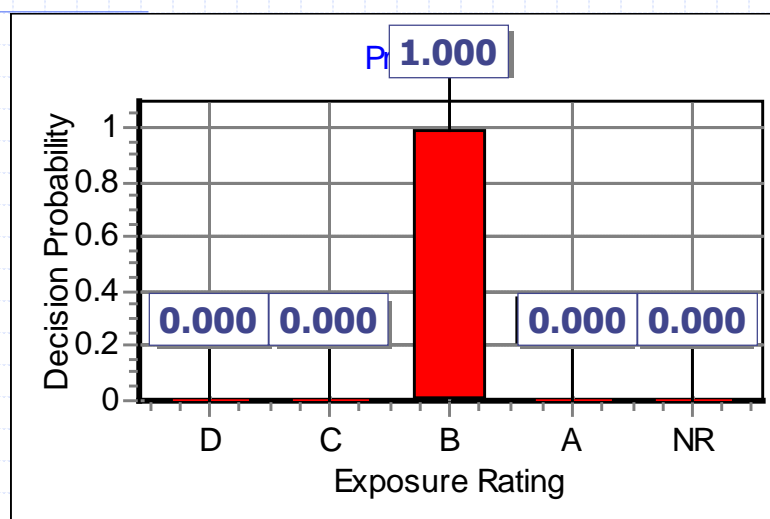
BDA is implicitly used in Control Banding



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Example "Control Banding" Prior and Posterior



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