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

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Innovative Tools …

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

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.

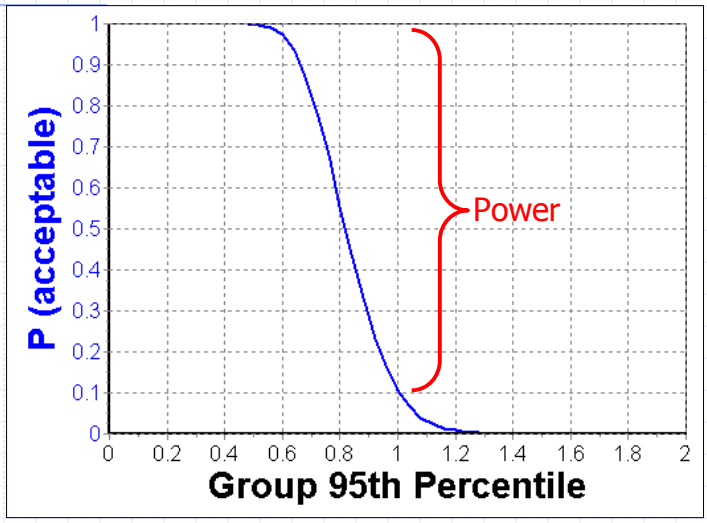
Design Procedure:

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 $\leq$ 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 $\geq$ 0.90.

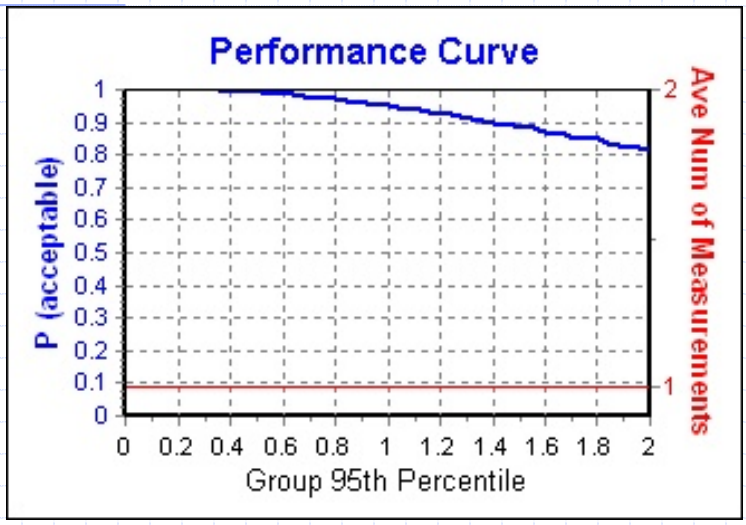
Ideal Performance Curve (OEL=1)



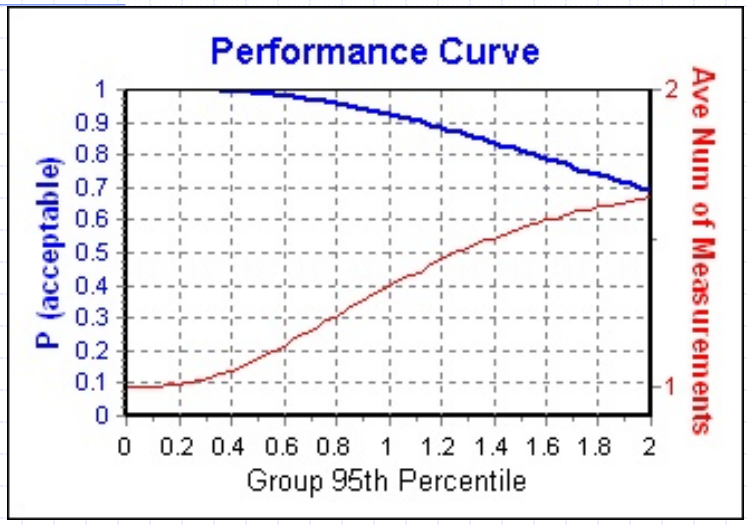
Three off-the-shelf Strategies

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

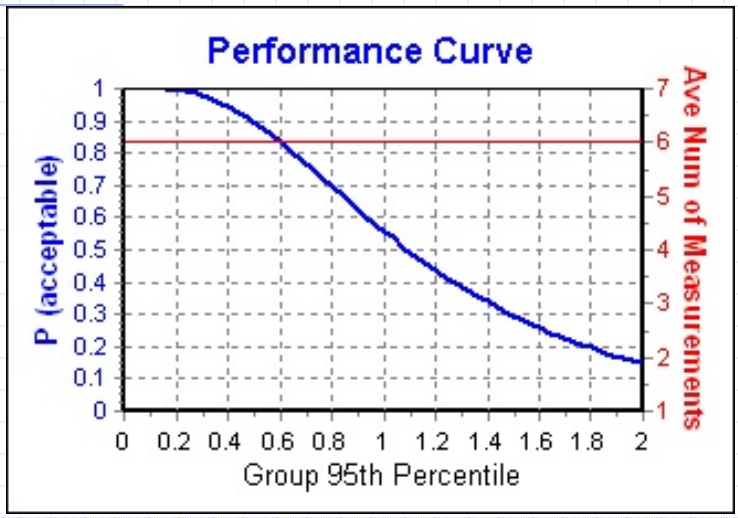
OSHA Inspector Strategy (OEL=1)



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



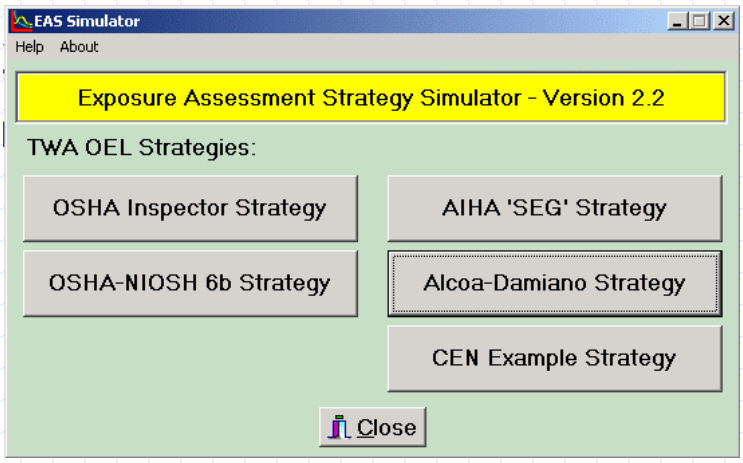
AIHA "SEG" Strategy (OEL=1)

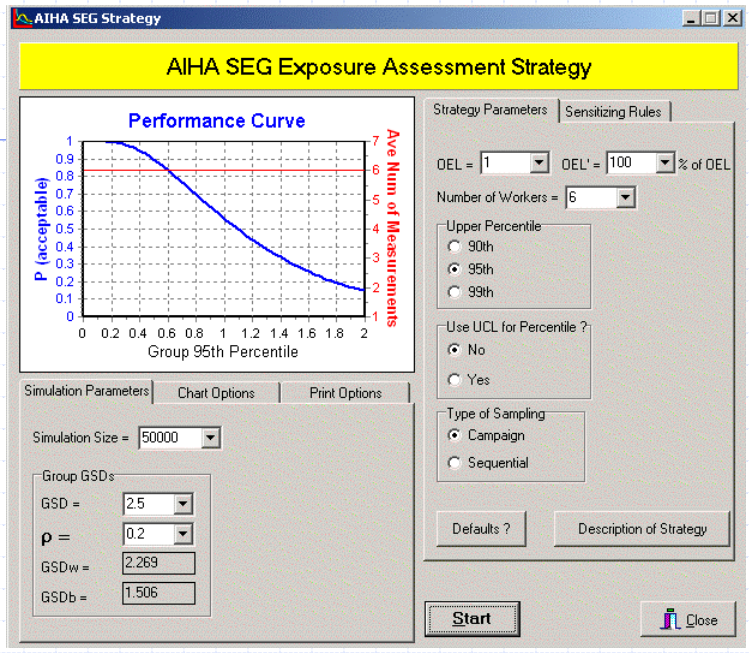


Results – all need modification

- 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

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

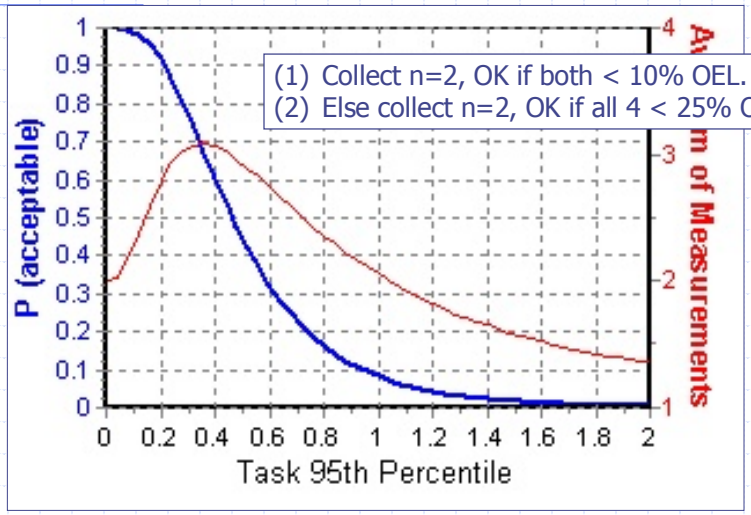




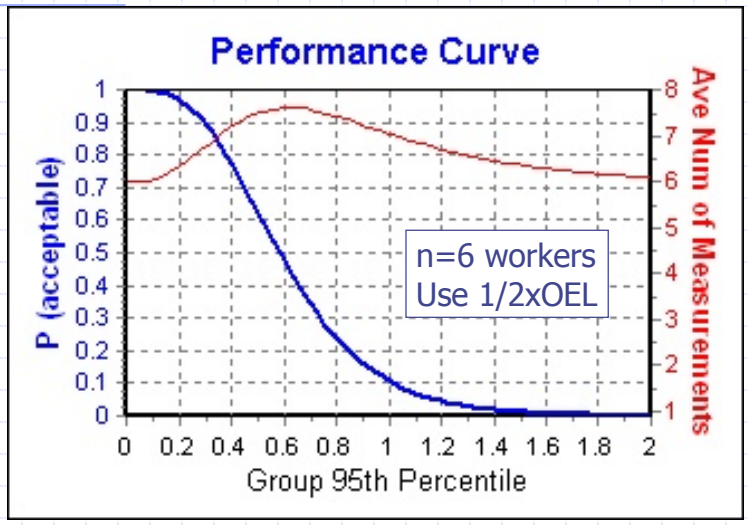
Resources

- 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)

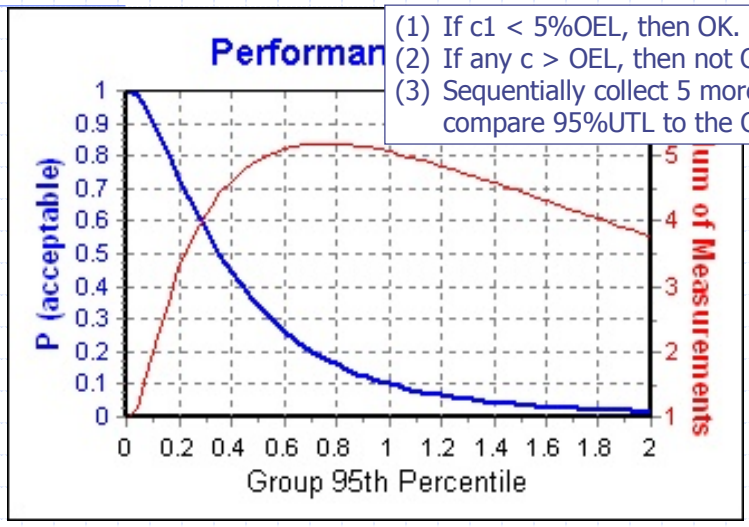
A Modified OSHA Inspector Strategy



A Modified OSHA-NIOSH "6b Rule" Strategy



A Modified AIHA "SEG" Strategy



(1) If c1 < 5%OEL, then OK.
(2) If any c > OEL, then not OK.
(3) Sequentially collect 5 more and compare 95%UTL to the OEL.

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 ppm}
- n = 3

- gm = 0.1 ppm 90%CI(0.03, 0.32)
- gsd = 2.0 90%CI(1.5, 21)

- $\hat{X}_{0.95}$ = 0.31 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

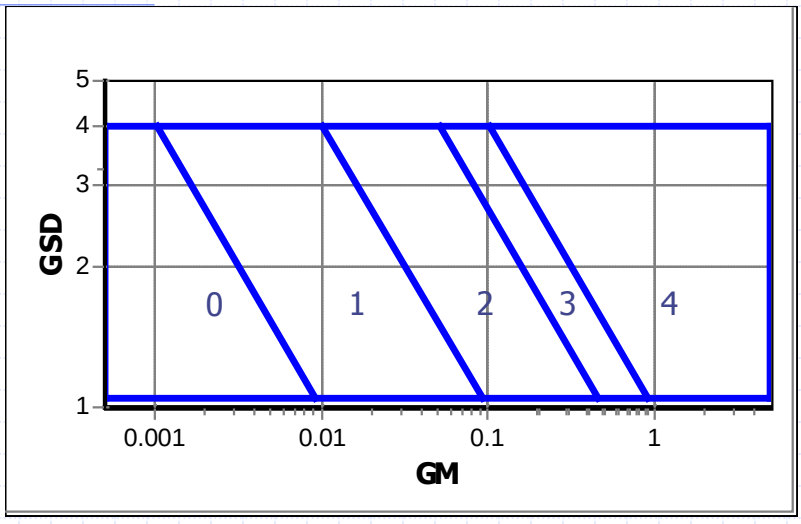
$$P(Pop_i|data) = \frac{P(data|Pop_i) \cdot P(Pop_i)}{\sum \left[P(data|Pop_i) \cdot P(Pop_i)\right]}$$

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	$X_{0.95} > 100\%$

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

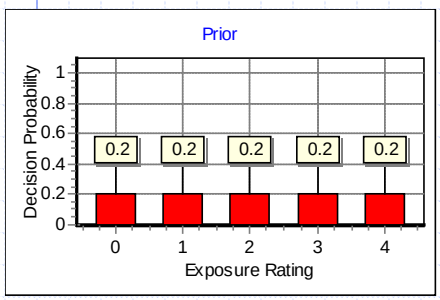


Key Concept – "Decision" Distributions

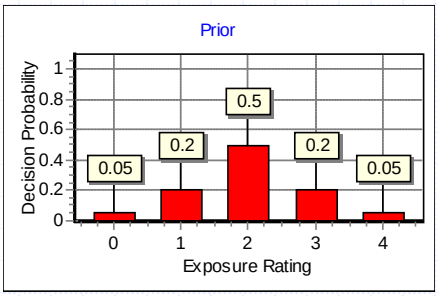
- **Prior** decision distribution
  - Represents our professional judgment regarding the probability of each of the five Exposure Ratings.
- **Likelihood** decision distribution
  - The set of probabilities of each Exposure Rating *calculated using only the collected data.*
- **Posterior** decision distribution
  - The set of probabilities of each Exposure Rating *calculated using Bayes' equation.*

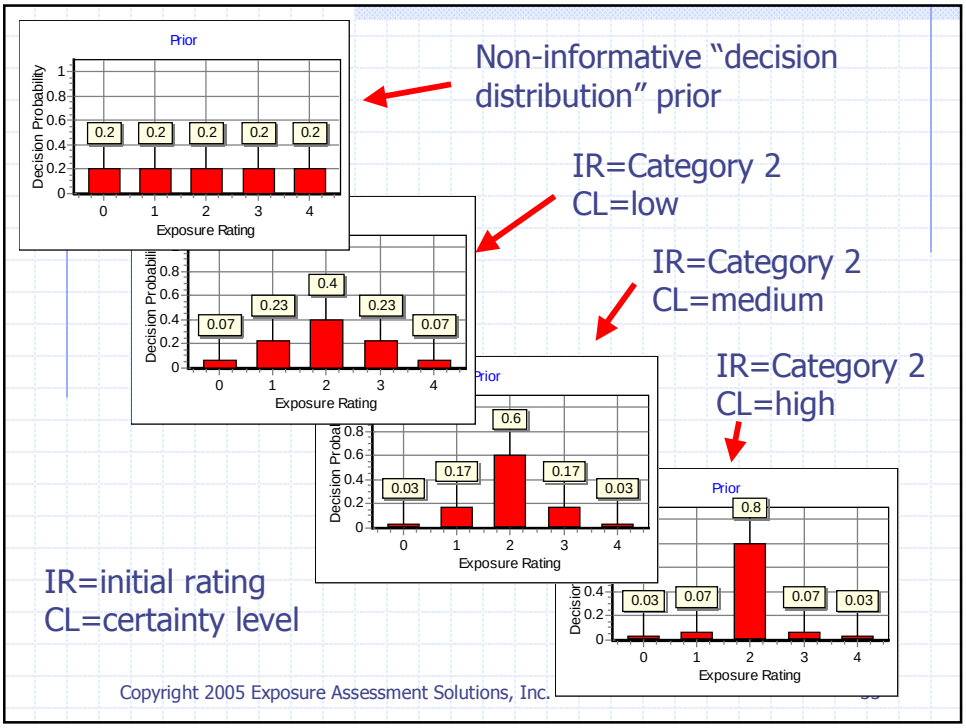
Example *Prior* Decision Distributions

Non-informative prior

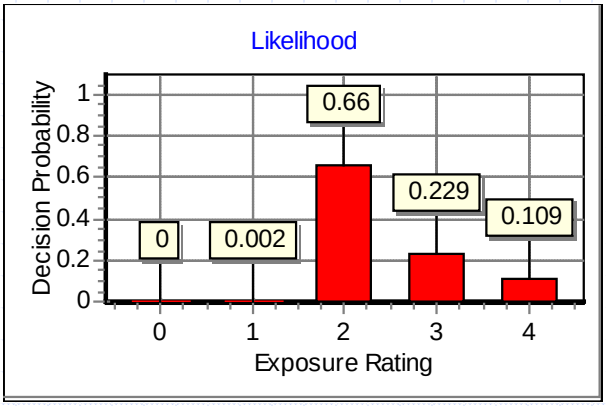


Informative prior



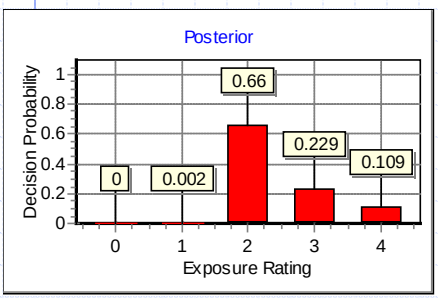


Example *Likelihood* Decision Distribution for x={ 0.20, 0.05, 0.10 }

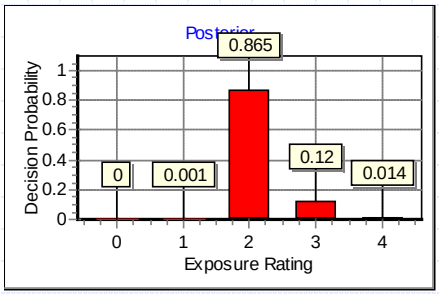


Example *Posterior* Decision Distributions

Using the non-informative prior



Using the informative prior



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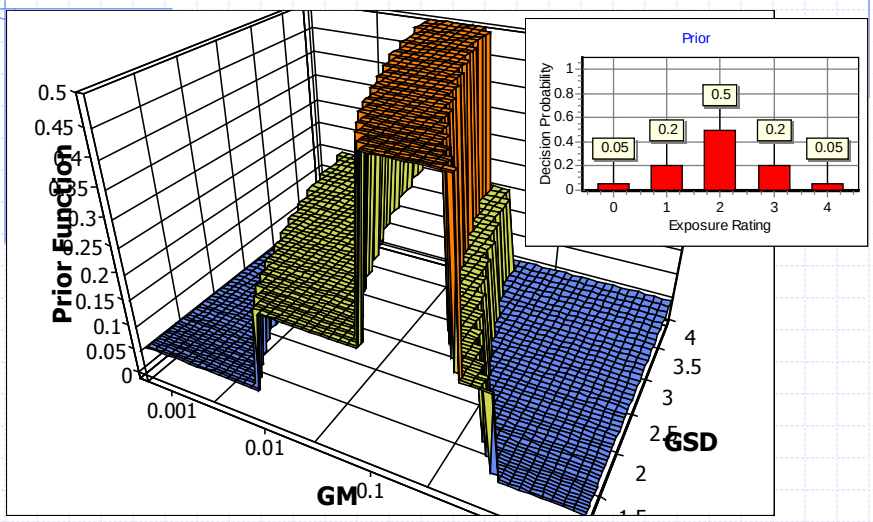
Prior decision function (i.e., prior decision distribution spread across parameter space)



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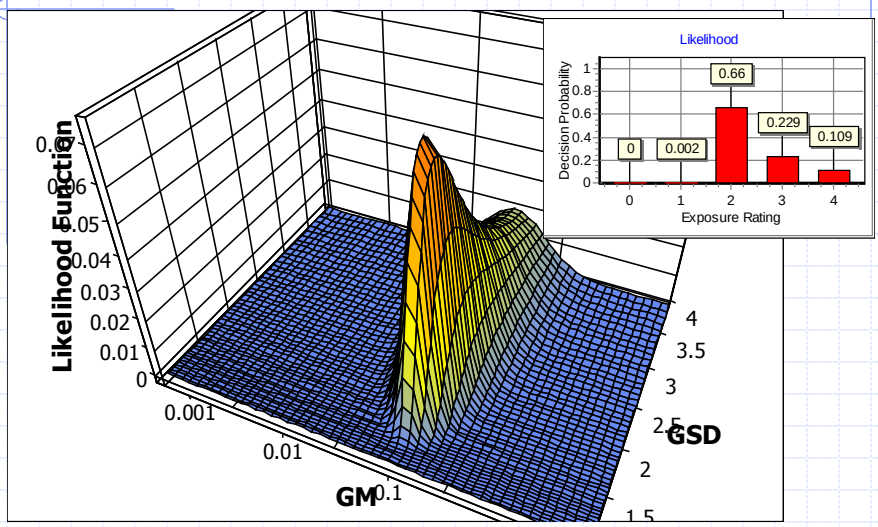
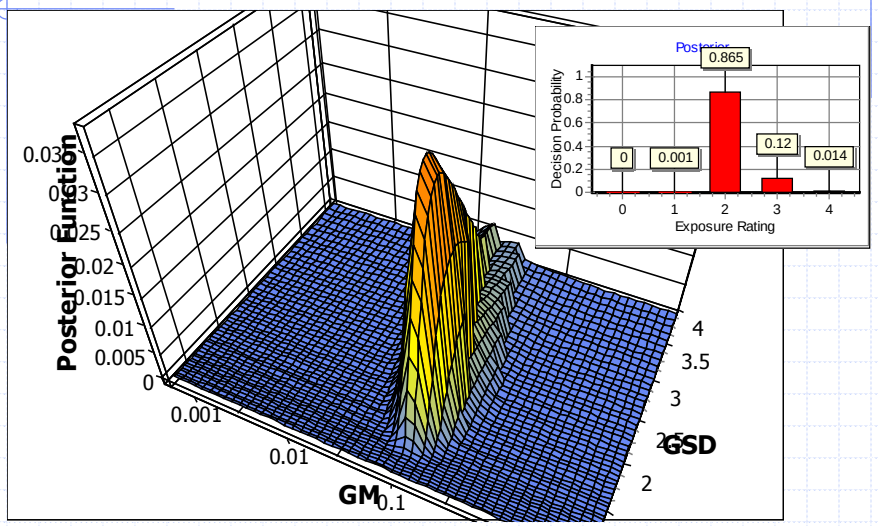
Likelihood function
for x={0.20,0.05,0.10}



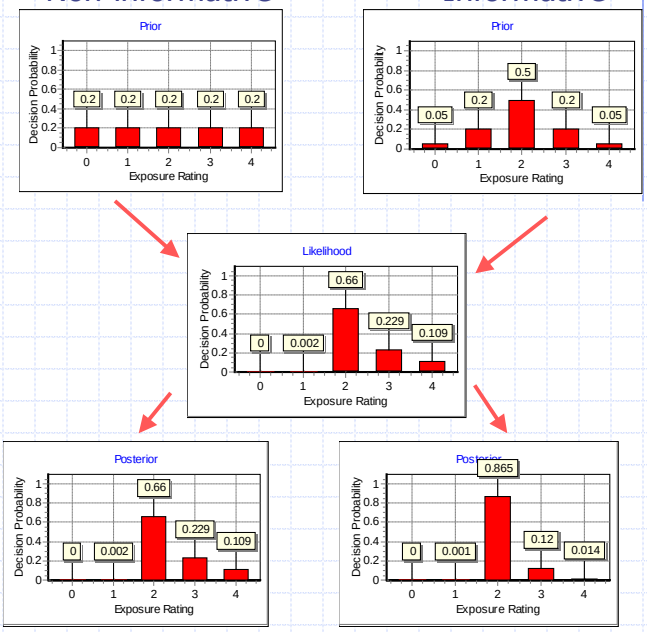
Posterior function



Non-informative

Informative

- Prior
- Likelihood
- Posterior



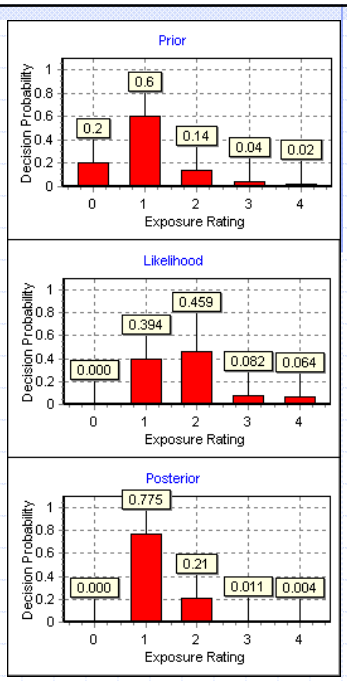
Resources

- 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

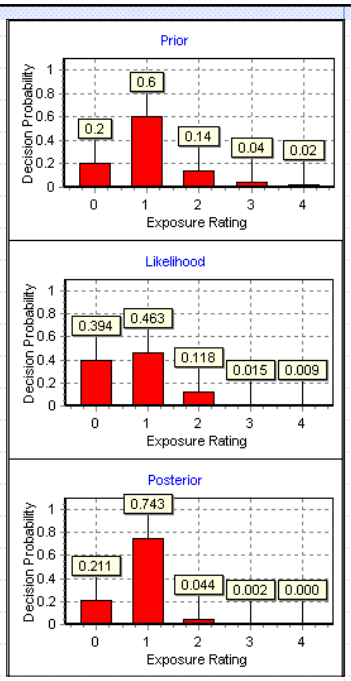
- BDA can be applied to sample sizes as low as n=1.
- Professional judgment can *sharpen* the decision.



Other BDA Examples

- OEL=1 ppm
- n = 1
- x < LOD
- LOD = 0.05 ppm

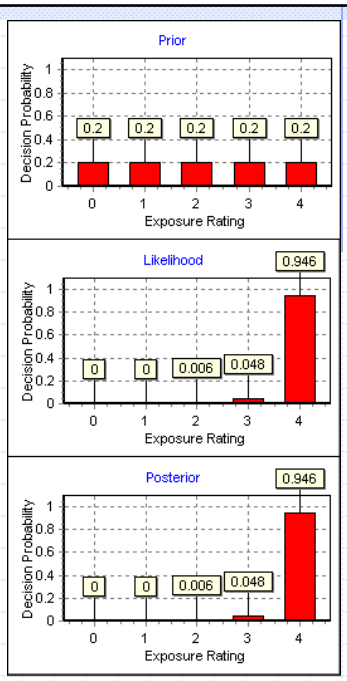
- BDA can be applied to censored datasets, even 100% censored or w/ multiple LODs.



Other BDA Examples

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

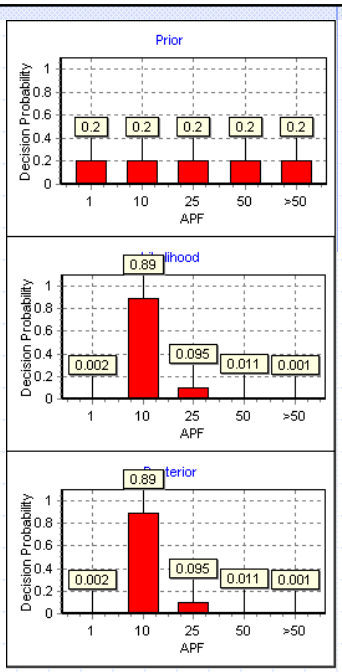
- "Yes, the measurement is <OEL. But I strongly suspect that that exposures are not acceptable."
- BDA would lead to the same conclusion.



Other BDA Examples

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

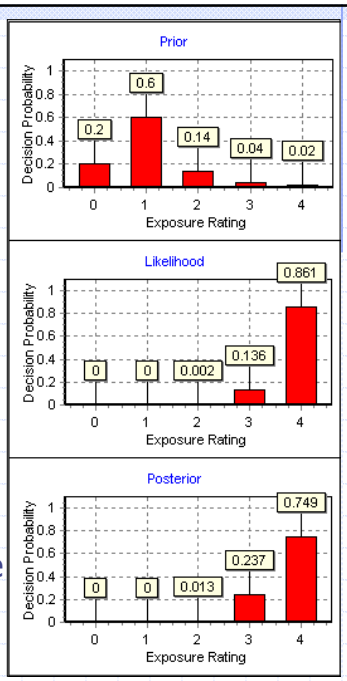
- BDA can be used to guide PPE selection.



Other BDA Examples

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

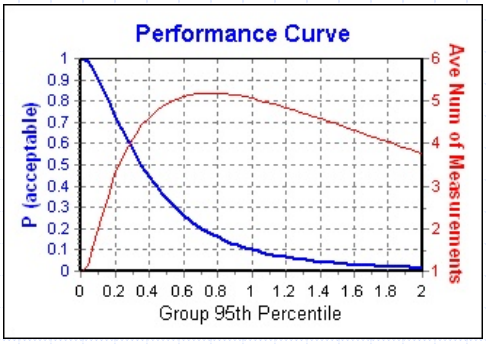
- The Prior is inconsistent with the Likelihood.
- BDA can be used to help improve professional judgment.



Decision Making Using Performance-based Strategies vs. BDA

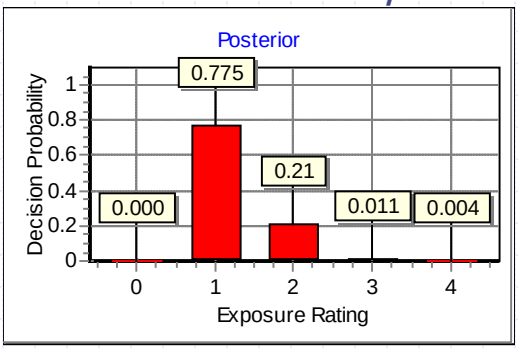
- The performance curve tells us the *long-run probability* of detecting a poorly-controlled exposure profile.

Modified AIHA "SEG" Strategy



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.*



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).

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

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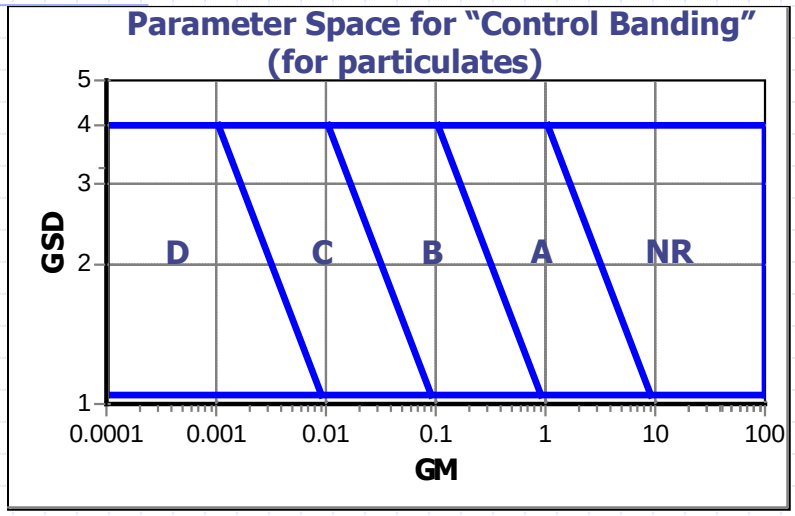
BDA is implicitly used in Control Banding



Example "Control Banding" Prior and Posterior