Improving Accuracy of Professional Judgments in Exposure Assessment

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Background

• Effective exposure assessment strategies result in correct exposure judgments which, in turn, lead to proper decisions on control.

• Frequently, insufficient measurements are available for properly characterizing exposure profiles of (SEGs).

• Use of professional judgment to supplement actual exposure measurements.
Assigning Initial Exposure Ratings

- Professional judgment
- Personal experience with operation
- Review of similar operations
- Exposure predictions developed using exposure modeling
- The OH then assigns a subjective initial “exposure rating” that defines further actions.
## Example of Exposure Ratings

<table>
<thead>
<tr>
<th>Control Zone Description</th>
<th>AIHA Recommended Statistical Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly-controlled (HC)</td>
<td>$X_{0.95} \leq 0.10$ OEL</td>
</tr>
<tr>
<td>Well-controlled (WC)</td>
<td>$0.10$ OEL $&lt; X_{0.95} \leq 0.5$ OEL</td>
</tr>
<tr>
<td>Controlled (C)</td>
<td>$0.5$ OEL $&lt; X_{0.95} \leq$ OEL</td>
</tr>
<tr>
<td>Poorly controlled (PC)</td>
<td>OEL $&lt; X_{0.95}$</td>
</tr>
</tbody>
</table>
Baseline Exposure Monitoring

• This sets priorities for gathering measurements.
• AIHA strategy – 6-10 measurements
• HSE strategy – 5-10 measurements
• Get repeat measurements on workers
• Exposure ratings for a given SEG could change as a result of new data.
Example of Medium Sized Manufacturing Facility

<table>
<thead>
<tr>
<th></th>
<th>Number of Employees</th>
<th>Exposure tasks</th>
<th>Chemicals x tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>200</td>
<td>20</td>
<td>300-400</td>
</tr>
<tr>
<td>Maintenance</td>
<td>40</td>
<td>40</td>
<td>600-800</td>
</tr>
<tr>
<td>Engineering</td>
<td>60</td>
<td>25</td>
<td>350-500</td>
</tr>
<tr>
<td>Admin.</td>
<td>10</td>
<td>2</td>
<td>30-40</td>
</tr>
<tr>
<td>Other</td>
<td>15</td>
<td>8</td>
<td>120-160</td>
</tr>
</tbody>
</table>

Assumption: 15-20 chemicals per task
Availability of monitoring data for exposure assessment

- There are a large number of chemical-task combinations
- Not feasible to obtain 6-10 measurements for each combination
- Typically, much fewer measurements are available.
- Most often, zero measurements are available.
- **Decisions are not data driven.**
Criticisms of using subjective judgments

- Basis for judgments often not transparent

- No evidence that this *ad hoc* approach always leads to correct exposure judgments and decisions regarding control.

- Subjective assessments of exposure may be affected by variables such as experience, educational background, and training that are at present, not well understood.
Goals of University of Minnesota Study (NIOSH-funded)

• To assess the accuracy of subjective assessments of exposure by professional OHs.

• To identify the determinants of accurate subjective assessments of exposure by OHs.

• To assess the efficacy of targeted training to improve accuracy of professional judgment in occupational hygienists.

• To incorporate exposure modeling into exposure decision-making
Participating Institutions

Industrial Hygienists recruited from a cross-section of US Companies and DOE

- 3M Company
- Rohm and Haas Co.
- W.L. Gore and Associates, Inc.
- Merck and Co., Inc.
- Novelis, Inc.
- Intel, Inc.
- Pfizer, Inc.
- Corning, Inc.
Distribution of decision parameter (e.g., 95\textsuperscript{th} percentile)

<table>
<thead>
<tr>
<th>Exposure Categories</th>
<th>Percent Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10% OEL, Highly Controlled</td>
<td>25</td>
</tr>
<tr>
<td>10-50% OEL, Well Controlled</td>
<td>45</td>
</tr>
<tr>
<td>50-100% OEL, Controlled</td>
<td>15</td>
</tr>
<tr>
<td>&gt; 100% OEL, Poorly Controlled</td>
<td>10</td>
</tr>
</tbody>
</table>
BAYESIAN METHODOLOGY

“Prior” decision based on professional judgment

Decision based on actual measurements alone

“Posterior” decision based on prior and actual measurements
Assessing accuracy of the “prior” decision
Methods (Prior Evaluation)

- Several tasks selected within each company
- Industrial hygienists (IHs) at the company become familiar with the process, task, materials, and engineering controls.
- Each IH then makes exposure judgments about each task (PRIORS).
- One exposure measurement at a time (for each task) is revealed to the IHs, and they are asked to update their exposure judgments about the task.
Planned Data Set

- Nine companies
- 3-10 tasks per company
- 4-10 industrial hygienists per company
- 5-8 monitoring data (personal exposures) per task
- IH judgments before and after each monitoring data point
### Fraction of IHs making the “correct” decision

<table>
<thead>
<tr>
<th>Measure</th>
<th>Task 1 ...</th>
<th>Task i ...</th>
<th>Task N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **x** = # of IHs making the correct decision for task *i*
- **M** = Total # of IHs providing a decision for task *i*. 

**x/M**
Fraction of IHs making the “correct” decision

- Probability of making a correct decision purely by chance = 0.25 (1 out of 4 tasks)

- For how many task-measurement scenarios do IHs perform better than random chance?
Accuracy of Individual IHs – Hypothetical Data

Fraction of correct decisions

Hygienist
Fraction of correct decisions by IHs

- 15/32 hygienists are correct < 25% of the time (worse than random chance).
- 4/32 hygienists are correct > 75% of the time.
Fractional agreement between hygienists

- Each cell in this matrix shows the number of times (out of 27) that two IHs make the same decision.

- Baseline probability of 2 IHs agreeing = 0.25

<table>
<thead>
<tr>
<th></th>
<th>IH-1</th>
<th>IH-2</th>
<th>...</th>
<th>IH-32</th>
</tr>
</thead>
<tbody>
<tr>
<td>IH-1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IH-2</td>
<td>x/27</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IH-32</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
What characteristics of the hygienists are related to their ability to make correct decisions?

What characteristics of the hygienists are related to their agreeing or disagreeing with each other?
Methods (Hygienist Traits)

- Obtain information on educational, exposure assessment, modeling, statistics and other relevant experiences of IHs.

- Logistic regression modeling to identify significant determinants of exposure judgments by IHs.
Determinants of Exposure Decisions

- CIH or CSP certification
- Number of years making exposure judgments
- Number of years since last engaged in EA
- Estimated total number of process-task EAs
- Number of sampling surveys collected for whole career
- Experience using physical / chemical exposure models
- Score on statistics test for decision making
- Experience with IH related statistics
- Years experience with exposure assessments on similar type of task
- Number of air sampling surveys for the chemical
- Familiarity with sampling data for the task
Significant Determinants of Correct Exposure Decisions

- CIH or CSP certification
- Number of years making exposure judgments
- Number of years since last engaged in EA
- Estimated total number of process-task-chemical EAs
  - Number of sampling surveys collected for whole career
- Experience using physical / chemical exposure models
- **Score on data interpretation test**
  - Experience with traditional IH related statistics
  - Years experience with exposure assessments on similar type of task
  - Number of air sampling surveys for the chemical
  - Familiarity with sampling data for the task
Data Interpretation Test

• IHs are provided with small number of sampling data ($\leq 8$) for several hypothetical tasks.

• They are then asked to estimate the exposure category in which the 95$^{th}$ percentile of the exposure distribution will lie.
Data Interpretation Test

Targeted Training

Data Interpretation Test
Data Interpretation Test Results PCIH05

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre Stats Training</th>
<th>Post Stats Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 3</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Below 2</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Below 1</td>
<td>36%</td>
<td>13%</td>
</tr>
<tr>
<td>Correct</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>Above 1</td>
<td></td>
<td>23%</td>
</tr>
<tr>
<td>Above 2</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Above 3</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
• Pre- and post-training results indicate that the training improves scores on the test.

• Can this training also improve judgment accuracy?
Methods (Effect of Training)

- Targeted training of IHs in interpreting small data sets to estimate the 95th percentile
- Obtain exposure judgments for all tasks from all IHs after the training.
- Evaluate effect of training on accuracy of judgments
Exposure Judgments for all tasks

Targeted Training

Exposure Judgments for all tasks
Qualitative Assessment or Validated Model

Integrated Exposure Assessment

BDA

Monitoring Results
Alternate paths to Exposure Decisions

IH Traits
• Experience
• Training
• Knowledge of process/task

Prior based on Subjective IH Professional Judgment

Monitoring Data

Posterior decision based on
• IH Professional judgment
• Monitoring data

Subjective IH estimates of model parameter distributions

Prior developed using 2-D Monte Carlo with model parameter distributions

Posterior decision based on
• Model parameter distributions
• Monitoring data
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- Merck and Co., Inc.
- Novelis, Inc.
- Intel, Inc.
- Pfizer, Inc.
- Corning, Inc.

Would you like your company to participate in this study?

Please contact me after this talk.