Comparison of Short-Term Sample Data With Corresponding Long-Term Results: STEL Data Over Predicts an 8-hr TWA

M. Weeks, CIH
F.W. Boelter, CIH, PE
C.E. Simmons, CIH

American Industrial Hygiene Conference and Exposition – Anaheim, California
May 25, 2005
Our Premise...

- Using multiple, consecutive or non-consecutive short-term samples in order to calculate a time-weighted average may produce results different from long-term sampling.
Exposure Measurement Strategies - NIOSH

- Full period single sample
- Full period consecutive samples
- Partial period consecutive samples
  - Sampling covers part of the work shift consecutively; assumptions are made regarding unsampled time
- Grab samples
  - Samples are taken intermittently, and sometimes randomly; samples are generally <1 hour

Which strategy do we choose?

- Decision based on:
  - Effects of hazard (acute, chronic)
  - Type of OEL being used for comparison
  - Nature of work activity (constant vs. intermittent exposure, access to worker, etc.)
  - Initial estimation of exposure (based on prior sampling, modeling, statistics, etc.)
  - Analytical sensitivity/confidence of results
  - Cost
  - Professional judgment
Methods of Evaluating Exposure to Hazards

- 8-hour Time-Weighted Average (TWA)
  - Long-term sampling conducted over course of work shift, using one or more samples; effects of exposure usually chronic

- Short-Term Exposure Limit (STEL)
  - 15- or 30-minute samples
  - Samples taken at times of “peak” exposure, or exposures are brief or intermittent; effects of exposure usually acute

- Ceiling Value – never to exceed
Calculating a TWA

- The formula:

\[
\frac{(C_1 \times T_1) + (C_2 \times T_2) + \ldots + (C_n \times T_n)}{(T_1 + T_1 + \ldots + T_n)}
\]

Where:  
- \( C \) = Concentration of sample  
- \( T \) = Time of sample  
- \( n \) = Number of samples
So that means...

- Calculating a TWA for *any* number of samples taken over the course of a work shift should produce a similar result to a TWA using only long-term sampling.

\[
\frac{(C_1 \times T_1) + (C_2 \times T_2) + \ldots + (C_n \times T_n)}{(T_1 + T_1 + \ldots + T_n)}
\]

*Right?*
Not Necessarily!

- Short-term samples are often biased high because they represent peak exposures
- A greater number of samples introduces additional sources of error
- High limits of detection/quantification for short-term samples decrease statistical confidence
- Assumptions about unsampled time introduce uncertainty
Our Study

- Exposure reconstructions were conducted, designed to assess exposure to asbestos fibers:
  - While overhauling heavy equipment having asbestos-containing gaskets and friction products (brakes, clutches, etc.)
  - While overhauling farm equipment having asbestos-containing gaskets
Our Study

- Conducted long-term sampling over entire work shift
  - Eleven days of sampling events, multiple workers
  - 24 full working shifts evaluated (405-577 minutes)
  - 85 total long-term (i.e. T>30 minutes) samples
- Concurrently collected STEL samples during activities of interest
  - 152 total STEL (30-minute) samples
  - Average time of STELs per shift = 190 minutes
  - Average percentage shift covered by STEL = 39%
Our Study

- Samples were analyzed using NIOSH Method 7400 (PCM) for total fibers and NIOSH Method 7402 (TEM) for asbestos fibers*
- TWAs were calculated using long-term sample results
- TWAs were then calculated using STEL sample results, making various assumptions about the unsampled work period
- Results of the STEL-TWA were compared with the long-term TWA

*NIOSH 7402 analysis not performed if NIOSH 7400 result was < LOD
Sample Results

- Average long-term TWA result (n=24)
  - = 0.032 total fibers/cc
  - = 0.014 asbestos fibers/cc

- Average 30-minute STEL sample result (n=152)
  - = 0.095 total fibers/cc
  - = 0.056 asbestos fibers/cc
Assumptions About Unsampled Time

- Common methods: unsampled time =
  - Assumption 1: 0 exposure (recommended by NIOSH for governmental compliance officials)
  - Assumption 2: Exposure at a LOD/LOQ
  - Assumption 3: Exposure at lowest sample result
  - Assumption 4: Exposure at the partial period TWA (recommended by NIOSH for employers)
### Calculated Time-Weighted Averages

Ratio of STEL-TWA to long-term TWA:

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Total fibers/cc</th>
<th>Asbestos fibers/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumption 1</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>Assumption 2</td>
<td>2.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Assumption 3</td>
<td>3.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Assumption 4</td>
<td>4.1</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Guidance - NIOSH

- Full-period consecutive samples
  - Is “best” (narrowest confidence limits)
- Full-period single sample
  - Essentially as good as consecutive samples
- Partial-period consecutive samples
  - Sampled portion should cover at least 70% of work shift, but if exposure is different during unsampled portion, should be avoided

Guidance – NIOSH

- **Grab Sampling**
  - Least desirable way to determine 8-hr TWA
  - Confidence limits are very wide
  - If exposures vary during shift, 8-11 samples should be taken during each exposure period
  - Time that sample is taken should be statistically random

One more question: What if…

you took STELs for an entire work shift?

(In other words, partial period consecutive sampling)

- Three of our 24 work shifts had STEL sampling for >70% of the shift
## Results

Ratio of STEL-TWA to long-term TWA:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Total fibers/cc</th>
<th>Asbestos fibers/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift 1</td>
<td>1.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Shift 2</td>
<td>1.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Shift 3</td>
<td>2.1</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Conclusions

- Projecting long-term exposures from short-term data produced results an average of 3.7 times higher than the actual exposure.

- Projecting long-term exposures from short-term data produces results that are difficult to support statistically because of significant uncertainty.

- Short-term samples are usually only appropriate for evaluating an acute hazard or for comparison to STEL or ceiling values.
Comparison of Short-Term Sample Data With Corresponding Long-Term Results: STEL Data Over Predicts an 8-hr TWA

Thank you!

Michael Weeks, CIH
Boelter & Yates, Inc.
Park Ridge, Illinois
(847) 692-4700
mweeks@boelter-yates.com
www.boelter-yates.com