Section A

Time-Weighted Averages
Exposure Profile

Source: Patrick Breysse and Peter S. J. Lees
Time-Weighted Average

- Apportions the measured exposure based on the interval of time during which the exposure occurred.
- Can apply to any time period but is typically used for 8-hour periods of time.
- Also applies to short term samples (i.e., a STEL is a 15-minute TWA).
Calculation of Time-Weighted Averages

- General formula:

\[
TWA = \frac{\sum_{i=1}^{n} c_i t_i}{\sum_{i=1}^{n} t_i}
\]

where:

- \( c_i \) = concentration during the \( i^{th} \) interval
- \( t_i \) = duration of the \( i^{th} \) interval
Calculation of Time-Weighted Averages

- **Common formula:**
  \[ TWA = \frac{t_1c_1 + t_2c_2 + \ldots + t_nc_n}{t_1 + t_2 + \ldots + t_n} \]

- **Compliance formula:**
  \[ 8hr \ TWA = \frac{t_1c_1 + t_2c_2 + \ldots + t_nc_n}{8hr} \]
Example of TWA Calculation

- Partial period samples (PEL=12ppm):
  - 4 hours @ 11ppm
  - 2 hours @ 14ppm
  - 2 hours @ 20ppm

\[
\text{TWA} = \frac{4\text{hr} \times 11\text{ppm} + 2\text{hr} \times 14\text{ppm} + 2\text{hr} \times 20\text{ppm}}{4\text{hr} + 2\text{hr} + 2\text{hr}}
\]
Example of TWA Calculation

\[
TWA = \frac{44\text{ppmhr} + 28\text{ppmhr} + 40\text{ppmhr}}{8\text{hr}}
\]

\[
TWA = \frac{112\text{ppmhr}}{8\text{hr}} = 14\text{ppm}
\]
Example of TWA Calculation

- Partial period samples:
  - 1 hours @ 11 ppm
  - 2 hours @ 14 ppm

\[
TWA = \frac{1 \text{ hr} \times 11 \text{ ppm} + 2 \text{ hr} \times 14 \text{ ppm}}{1 \text{ hr} + 2 \text{ hr}}
\]
Example of TWA Calculation

$$TWA = \frac{11\text{ppm/hr} + 28\text{ppm/hr}}{3\text{hr}}$$

3 - Hour TWA = \frac{39\text{ppm/hr}}{3\text{hr}} = 13\text{ppm}$$
Compliance and the 8-Hour TWA

- Partial period samples (PEL=12ppm):
  - 4 hours @ 11ppm
  - 2 hours @ 14ppm
  - 2 hours @ not sampled

\[
\text{TWA} = \frac{4\text{hr} \times 11\text{ppm} + 2\text{hr} \times 14\text{ppm} + 2\text{hr} \times 0\text{ppm}}{4\text{hr} + 2\text{hr} + 2\text{hr}}
\]
Compliance and the 8-Hour TWA

\[
TWA = \frac{44\text{ppmhr} + 28\text{ppmhr} + 0\text{ppmhr}}{8\text{hr}}
\]

\[
8\text{- Hour TWA} = \frac{72\text{ppmhr}}{8\text{hr}} = 9\text{ppm}
\]
Section B

Exposure Limits for Mixtures
Exposure Limits (ELs) for Mixtures

- Exposure limits set for single substances, but multiple simultaneous exposures is the industrial norm.
- Combined exposure limit can be calculated if:
  - Components have similar toxicological effects.
  - Combined effect is assumed to be additive.
Calculating EL for Mixtures

- Mixture in compliance if:

\[
\frac{C_1}{EL_1} + \frac{C_2}{EL_2} + \ldots + \frac{C_n}{EL_n} < 1.0
\]

where:
- \( C \) = measured 8-hour TWA concentration
- \( EL \) = exposure limit for substance
Example of EL for Mixtures

- **Mixture:**
  - Methyl isopropyl ketone @ 100 ppm (TLV=200ppm)
  - Methylcyclohexane @ 300ppm (TLV=400ppm)
  - Both TLVs set for protection against anesthetic (CNS) effects
Example of EL for Mixtures

\[
\frac{100 \text{ppm}}{200 \text{ppm}} + \frac{300 \text{ppm}}{400 \text{ppm}} = 0.5 + 0.75
\]

\[= 1.25 \text{ which is not less than } 1.0,\]
so this mixture is NOT in compliance
Section C

Exposure Limits for Extended Work Shifts
EL for >8-Hour Work Shifts

- Many workers work longer than eight hours per day and 40 hours per week
- Apply adjustments to ELs with caution
- Should not be used to justify very high exposures as “allowable” where exposure periods are short
EL for >8-Hour Work Shifts

- Adjustments don’t have the benefit of historical use and long term observation
  - Medical supervision during early adjustment use advisable
In simplest form, dose (concentration x time) is held constant and new allowable concentration is calculated:

\[ C_{\text{allowed}} \times T_{8hr} = C_{\text{allowed}} \times T_{Xhr} \]

Other more complicated adjustment calculations can account for pharmacokinetic behavior.
Example EL for >8-Hour Work Shifts

What is the EL for benzene over a 12-hour shift given an 8-hour EL of 1.0ppm?

\[
C_{\text{allowed}}T_{8hr} = C_{\text{allowed}}T_{Xhr}
\]

\[
1.0\text{ppm} \times 8\text{hr} = X\text{ppm} \times 12\text{hr}
\]

\[
8.0\text{ppm/hr} = 12X\text{ppm/hr}
\]

\[
X = 0.67\text{ppm}
\]