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Industrial Hygiene Concepts

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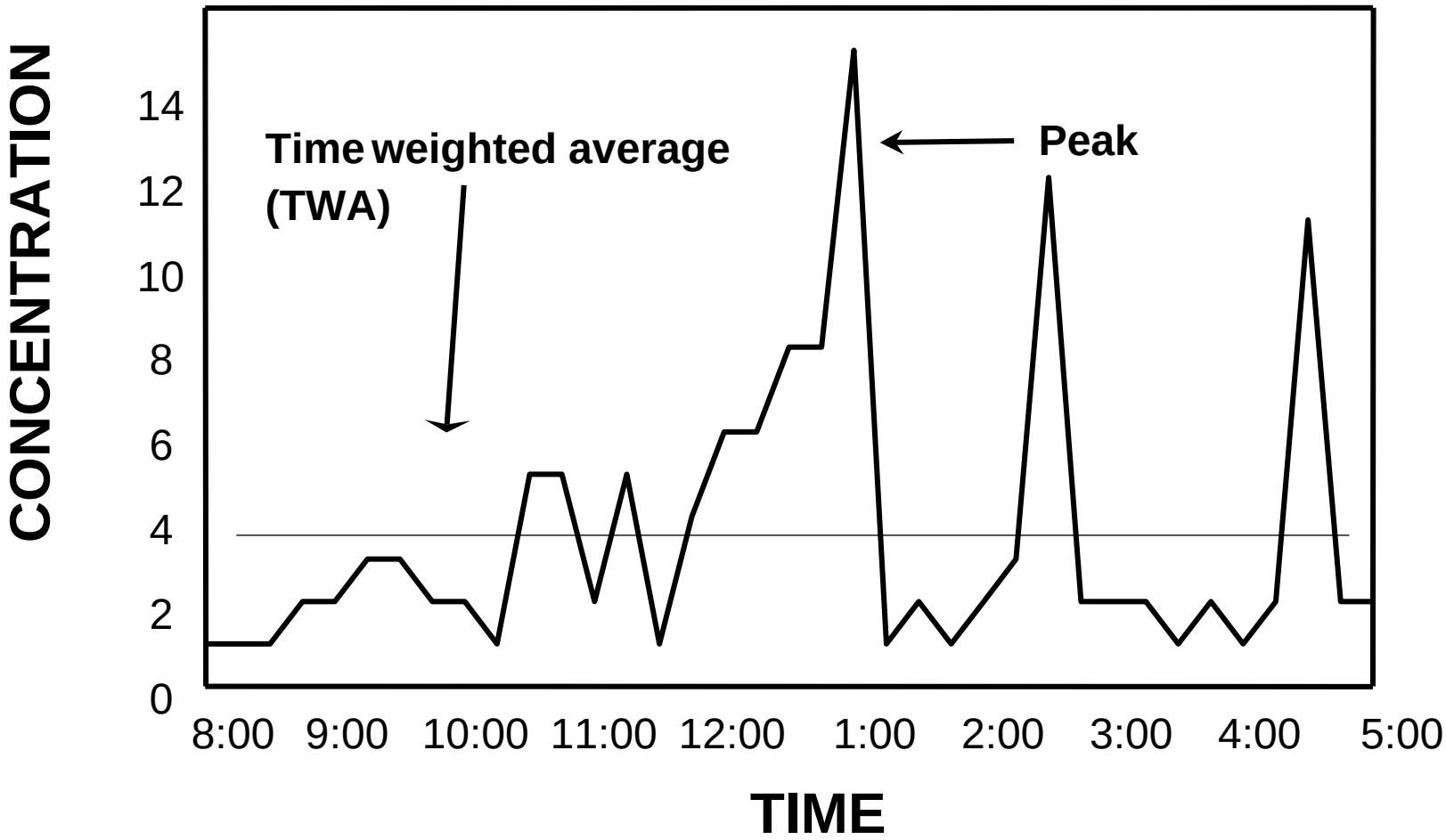
Section A

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:

$$TWA = \frac{\sum_{i=1}^{n} c_1 t_1}{\sum_{i=1}^{n} t_i}$$

where :

c_i = concentration during the i^{th} interval

t_i = duration of the i^{th} interval

Continued

Calculation of Time-Weighted Averages

- Common formula:

$$\text{TWA} = \frac{t_1c_1 + t_2c_2 + \ldots + t_nc_n}{t_1 + t_2 + \ldots + t_n}$$

- Compliance formula:

$$\text{8hr TWA} = \frac{t_1c_1 + t_2c_2 + \ldots + t_nc_n}{8\text{hr}}$$

Example of TWA Calculation

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

$$\text{TWA} = \frac{4\text{hr} * 11\text{ppm} + 2\text{hr} * 14\text{ppm} + 2\text{hr} * 20\text{ppm}}{4\text{hr} + 2\text{hr} + 2\text{hr}}$$

Continued

Example of TWA Calculation

$$TWA = \frac{44ppmhr + 28ppmhr + 40ppmhr}{8hr}$$

$$TWA = \frac{112ppmhr}{8hr} = 14ppm$$

Continued

Example of TWA Calculation

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

$$TWA = \frac{1hr * 11ppm + 2hr * 14ppm}{1hr + 2hr}$$

Continued

Example of TWA Calculation

$$TWA = \frac{11ppmhr + 28ppmhr}{3hr}$$

$$3\text{-}Hour\ TWA = \frac{39ppmhr}{3hr} = 13ppm$$

Compliance and the 8-Hour TWA

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

$$TWA = \frac{4hr * 11ppm + 2hr * 14ppm + 2hr * 0ppm}{4hr + 2hr + 2hr}$$

Continued

Compliance and the 8-Hour TWA

$$TWA = \frac{44ppmhr + 28ppmhr + 0ppmhr}{8hr}$$

$$8\text{-}Hour\ TWA = \frac{72ppmhr}{8hr} = 9ppm$$

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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

Continued

Example of EL for Mixtures

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

$= 1.25$ which is not less than 1.0,

so this mixture is NOT in compliance

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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

Continued

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

Continued

EL for > 8-Hour Work Shifts

- In simplest form, dose (concentration x time) is held constant and new allowable concentration is calculated:

$$C_{allowed} T_{8hr} = C_{allowed} T_{Xhr}$$

- 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?

$$C_{allowed}T_{8hr} = C_{allowed}T_{Xhr}$$

$$1.0ppm * 8hr = Xppm * 12hr$$

$$8.0ppmhr = 12Xppmhr$$

$$X = 0.67ppm$$