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# Industrial Hygiene Concepts

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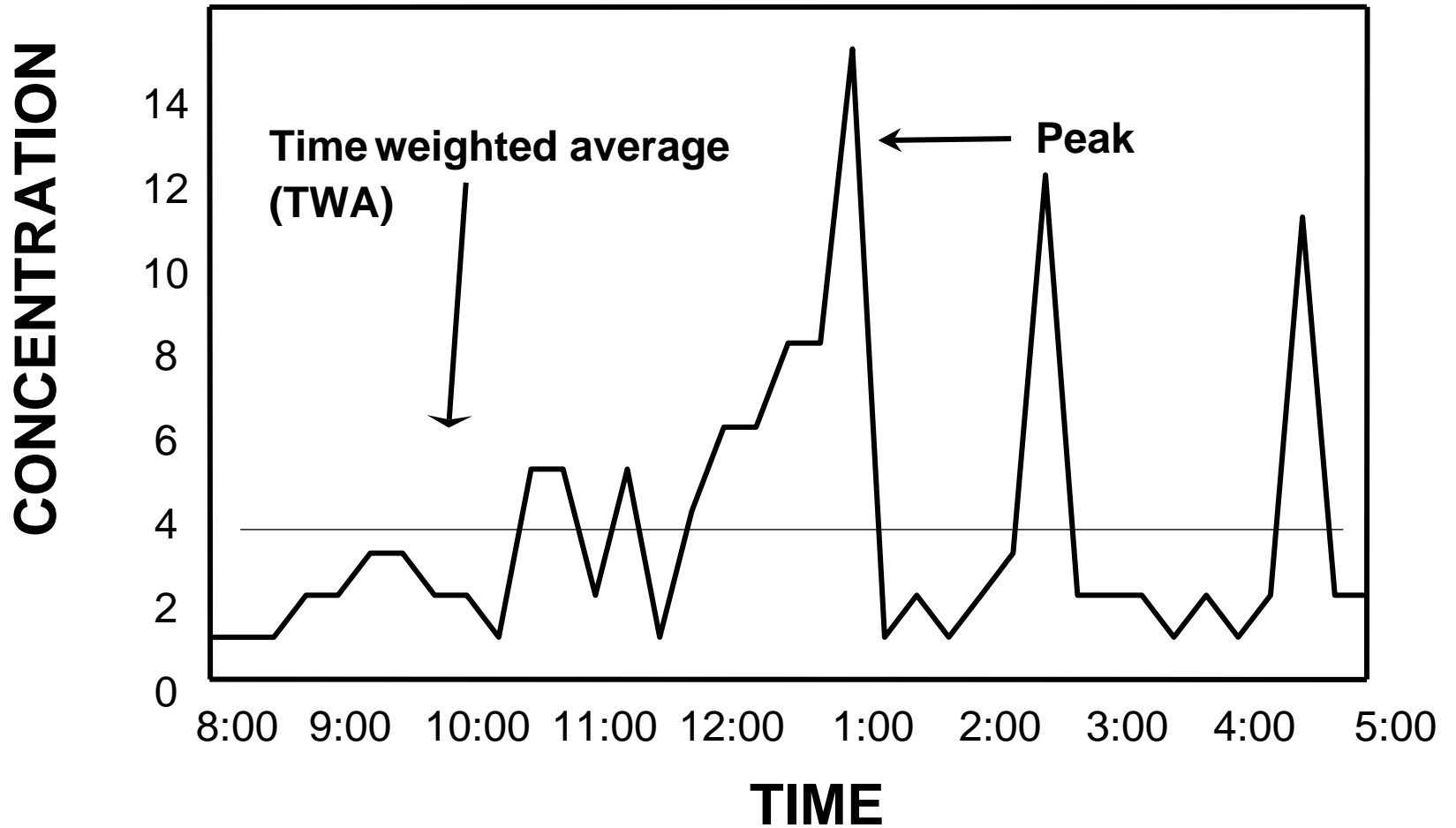


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# Section A

*Time-Weighted Averages*

# Exposure Profile



# 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:

$$\text{TWA} = \frac{\sum_{i=1}^n c_i t_i}{\sum_{i=1}^n t_i}$$

where :

$c_i$  = concentration during the  $i^{\text{th}}$  interval

$t_i$  = duration of the  $i^{\text{th}}$  interval

# Calculation of Time-Weighted Averages

- ◆ Common formula:

$$\text{TWA} = \frac{t_1C_1 + t_2C_2 + \dots + t_nC_n}{t_1 + t_2 + \dots + t_n}$$

- ◆ Compliance formula:

$$8\text{hr TWA} = \frac{t_1C_1 + t_2C_2 + \dots + t_nC_n}{8\text{hr}}$$

# Example of TWA Calculation

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

TWA =

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



# Example of TWA Calculation

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

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

# Example of TWA Calculation

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

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

# Example of TWA Calculation

$$\text{TWA} = \frac{1 \text{ ppmhr} + 28 \text{ ppmhr}}{3 \text{ hr}}$$

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

# Compliance and the 8-Hour TWA

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

TWA =

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

# Compliance and the 8-Hour TWA

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

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



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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:

$$\frac{C_1}{EL_1} + \frac{C_2}{EL_2} + \dots + \frac{C_n}{EL_n} < 1.0$$

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 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

# 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

# EL for > 8-Hour Work Shifts

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

$$C_{\text{allowed}} T_{8\text{hr}} = C_{\text{allowed}} T_{X\text{hr}}$$

- ◆ 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?

$$C_{\text{allowed}} T_{8\text{hr}} = C_{\text{allowed}} T_{X\text{hr}}$$

$$1.0\text{ppm} * 8\text{hr} = X\text{ppm} * 12\text{hr}$$

$$8.0\text{ppmhr} = 12X\text{ppmhr}$$

$$X = 0.67\text{ppm}$$