PROCESS SAFETY ENGINEERING (0905477)

08- INDUSTRIAL HYGIENE: EVALUATION

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The superior man, when resting in safety, does not forget that danger may come.... When all is orderly, he does not forget that disorder may come. Confucius (551 BC – 479 BC)

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Outline

- Industrial Hygiene: Evaluation
- Evaluating Exposure to Volatile Toxicants by Monitoring
- Exposure to More than One Toxicant
- Evaluation of Worker Exposure to Dusts
- Estimating Worker Exposure to Toxic Vapors
- Estimating the Vaporization Rate of a Liquid
- Evaluating Worker Exposure to Noise

Industrial Hygiene: Evaluation

- The evaluation phase determines the extent and degree of employee exposure to toxicants and physical hazards in the workplace environment.
- The various types of existing control measures and their effectiveness are also studied in the evaluation phase.
- Sudden exposures to high concentrations: ready access to a clean environment is important.
- Chronic effects arise from repeated exposures to low concentrations: preventing and controlling through continuous or frequent and periodic sampling and analysis.
- After the exposure data are obtained, it is necessary to compare actual exposure levels to acceptable occupational health standards to identify the potential hazards requiring better or more control measures.

Evaluating Exposure to Volatile Toxicants by Monitoring

- Continuously monitoring the air concentrations of toxicants on-line in a work environment (the monitoring depends on equipment availability)

$$\text{TWA} = \frac{1}{8}\int_0^{t_w} C(t)\,dt$$

t, is the worker shift time in hr.

$C(t)$ is the concentration in air (ppm or mg/m^3).

- For one chemical, assuming that the concentration C_i is fixed (or averaged) over the period of time t_i, then

$$\text{TWA} = \frac{C_1 t_1 + C_2 t_2 + \cdots + C_n t_n}{8\text{ hr}} = \frac{\sum_i C_i t_i}{8\text{ hr}}$$

Exposure to More than One Toxicant

- The combined exposures from multiple toxicants with different TLV-TWA is determined from the equation:

$$S = \sum_{j=1}^{n} \frac{C_j}{(\mathrm{TLV} - \mathrm{TWA})_j}$$

n, is the number of toxicants.

C_j is the concentration of toxicant j with respect to other toxicants.

$(\mathrm{TLV} - \mathrm{TWA})_j$ is the TLV - TWA for toxicant j.

- If the sum (S) in the above Equation exceeds 1, then the workers are **overexposed.**

- The mixture TLV-TWA can be computed from

$$(\mathrm{TLV} - \mathrm{TWA})_{\mathrm{mix}} = \frac{\sum_{j=1}^{n} C_j}{\sum_{j=1}^{n} \frac{C_j}{(\mathrm{TLV} - \mathrm{TWA})_j}}$$

- The workers are overexposed if the sum of the concentrations of the toxicants in the mixture exceeds

$$(\mathrm{TLV} - \mathrm{TWA})_{\mathrm{mix}} < \sum_{j=1}^{n} C_j$$

Example

Air contains 5 ppm of diethylamine (TLV-TWA of 10 ppm), 20 ppm of cyclohexanol (TLV-TWA of 50 ppm), and 10 ppm of propylene oxide (TLV-TWA of 20 ppm). What is the mixture TLV-TWA and has this level been exceeded?

Solution

From Equation 3-4,

$$(\text{TLV-TWA})_{\text{mix}} = \frac{5 + 20 + 10}{\frac{5}{10} + \frac{20}{50} + \frac{10}{20}} = 25 \text{ ppm.}$$

The total mixture concentration is 5 + 20 + 10 = 35 ppm. The workers are overexposed under these circumstances.

An alternative approach is to use Equation 3-3:

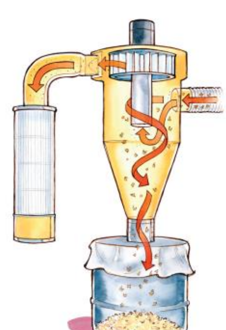
$$\sum_{i=1}^{3} \frac{C_i}{(\text{TLV-TWA})_i} = \frac{5}{10} + \frac{20}{50} + \frac{10}{20} = 1.40.$$

Because this quantity is greater than 1, the TLV-TWA has been exceeded.

Evaluation of Worker Exposure to Dusts

- Dust evaluation calculations are performed in a manner identical to that used for volatile vapors. Instead of using ppm as a concentration unit, **mg/m³** or **mppcf** (**millions of particles per cubic foot**) is more convenient.

$$(\text{TLV} - \text{TWA})_{\text{mix}} = \frac{\sum_{j=1}^{n} C_j}{\sum_{j=1}^{n} \frac{C_j}{(\text{TLV} - \text{TWA})_j}}$$



Example

Example 3-5

Determine the TLV for a uniform mixture of dusts containing the following particles:

Type of dust	Concentration (wt.%)	TLV (mppcf)
Nonasbestiform talc	70	20
Quartz	30	2.7

Solution

From Equation 3-4:

$$\text{TLV of mixture} = \frac{1}{\dfrac{C_1}{\text{TLV}_1} + \dfrac{C_2}{\text{TLV}_2}}$$

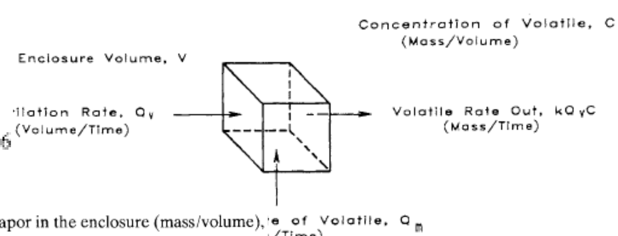
$$= \frac{1}{\dfrac{0.70}{20} + \dfrac{0.30}{2.7}}$$

$$= 6.8 \text{ mppcf.}$$

Special control measures will be required when the actual particle count (of the size range specified in the standards or by an industrial hygienist) exceeds 6.8 mppcf.

Estimating Worker Exposure to Toxic Vapors

$$C_{\text{ppm}} = \frac{Q_m R_g T}{k Q_v P M} \times 10^6$$



C be the concentration of volatile vapor in the enclosure (mass/volume),
V be the volume of the enclosure (volume),
Q_v be the ventilation rate (volume/time),
k be the nonideal mixing factor (unitless), and
Q_m be the evolution rate of volatile material (mass/time).

R_g is the ideal gas constant,
T is the absolute ambient temperature,
P is the absolute pressure, and
M is the molecular weight of the volatile species.

- ✓ A steady-state condition is assumed
- ✓ The K varies from 0.1 to 0.5 for most practical situation. For perfect mixing k = 1.

Example 3-7

An open toluene container in an enclosure is weighed as a function of time, and it is determined that the average evaporation rate is 0.1 g/min. The ventilation rate is 100 ft^3/min. The temperature is 80°F and the pressure is 1 atm. Estimate the concentration of toluene vapor in the enclosure, and compare your answer to the TLV for toluene of 50 ppm.

Solution

Because the value of k is not known directly, it must be used as a parameter. From Equation 3-9

$$kC_{\text{ppm}} = \frac{Q_m R_g T}{Q_v P M} \times 10^6.$$

From the data provided

$Q_m = 0.1$ g/min $= 2.20 \times 10^{-4}$ lb_m/min,
$R_g = 0.7302$ ft^3 atm/lb-mol °R,
$T = 80°F = 540°R$,
$Q_v = 100$ ft^3/min,
$M = 92$ lb_m/lb-mol,
$P = 1$ atm.

Substituting into the equation for kC_{ppm}:

$$kC_{\text{ppm}} = \frac{(2.20 \times 10^{-4}\ \text{lb}_m/\text{min})(0.7302\ \text{ft}^3\ \text{atm/lb-mol°R})(540°\text{R})}{(100\ \text{ft}^3/\text{min})(1\ \text{atm})(92\ \text{lb}_m/\text{lb-mol})} \times 10^6$$

$$= 9.43\ \text{ppm}.$$

Because k varies from 0.1 to 0.5, the concentration is expected to vary from 18.9 ppm to 94.3 ppm. Actual vapor sampling is recommended to ensure that the TLV is not exceeded.

Estimating the Vaporization Rate of a Liquid

- The vaporization rate is proportional to the difference between the saturation vapor pressure and the partial pressure of the vapor in the stagnant air;

$$Q_m \alpha (P^{\text{sat}} - p),$$

Where,

P^{sat} is the saturation vapor pressure of the pure liquid at the temperature of the liquid
p is the partial pressure of the vapor in the bulk stagnant gas above the liquid.

$$Q_m = \frac{MKA(P^{\text{sat}} - p)}{R_g T_L}, \qquad \boxed{Q_m = \frac{MKAP^{\text{sat}}}{R_g T_L}.} \qquad \textit{When } P^{sat} >> p$$

Q_m is the evaporation rate (mass/time),
M is the molecular weight of the volatile substance,
K is a mass transfer coefficient (length/time) for an area A,
R_g is the ideal gas constant, and
T_L is the absolute temperature of the liquid.

- The vaporization rate of volatile from an open vessel or from a spill of liquid

- to estimate the concentration (in ppm) of a volatile in an enclosure resulting from evaporation of a liquid

$$C_{\text{ppm}} = \frac{KATP^{\text{sat}}}{kQ_vPT_L} \times 10^6.$$

- For most situations $T = T_L$

$$C_{\text{ppm}} = \frac{KAP^{\text{sat}}}{kQ_vP} \times 10^6.$$

$$K = K_o\left(\frac{M_o}{M}\right)^{1/3}.$$

- Water is most frequently used as a reference substance; it has a mass transfer coefficient (K_0) of 0.83 cm/s.

Evaluating Worker Exposure to Noise

- Noise evaluation calculations are performed identically to calculations for vapors, except that **dBA** is used instead of ppm and hours of exposure is used instead of concentration

$$\sum_{i=1}^{n} \frac{C_i}{(\text{TLV-TWA})_i},$$

$$(\text{TLV-TWA})_{\text{mix}} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} \frac{C_i}{(\text{TLV-TWA})_i}}.$$

Table 3-8 Permissible Noise Exposures[1]

Sound level (dBA)	Maximum exposure (hr)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
[illegible]	0.5
[illegible]	0.25

Industrial Hygiene, 3d ed. ...l, 1988), p. 176.

Example 3-6

Determine whether the following noise level is permissible with no additional control features:

Noise level (dBA)	Duration (hr)	Maximum allowed (hr)
85	3.6	no limit
95	3.0	4
110	0.5	0.5

Solution

From Equation 3-3:

$$\sum_{i=1}^{3} \frac{C_i}{(\text{TLV-TWA})_i} = \frac{3.6}{\text{no limit}} + \frac{3}{4} + \frac{0.5}{0.5} = 1.75.$$

Because the sum exceeds 1.0, employees in this environment are immediately required to wear ear protection. On a longer-term basis, noise reduction control methods should be developed for the specific pieces of equipment with excessive noise levels.

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