Calculations and OELs

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EOH 466A
The Occupational Environment

Definitions

- Particulates: dust, fume, mist
- Vapors
- Gases
- Particle size considerations
  - Inspirable Particulate Mass (IPM)
  - Thoracic Particulate Mass (TPM)
  - Respiratory Particulate Mass (RPM)
OELs

- Concentration
  - Parts per million
    - Maximum vapor concentration = \( \frac{V_p}{V_{atm}} \times 10^6 \)
  - Milligrams per cubic meter
- Normal temperature and pressure
  - 760 mm Hg and 25 C
  - Molar volume = 24.5 Liters per mole

Figure 12.3 — Regions of the respiratory tract. (a) Nasopharyngeal (NP) region
(b) Tracheobronchial (TB) region
(c) Pulmonary (P) region

Inhalable fraction
Thoracic fraction
Respirable fraction

Inhalable fraction

Normal temperature and pressure
- 760 mm Hg and 25 C
- Molar volume = 24.5 Liters per mole
OELs

- Time-weighted average (TWA)
- Ceiling value (C)
- Short-Term Exposure Limit (STEL)
- Immediately Dangerous to Life and Health (IDLH)

OELs

- TLVs for gases and vapors are established in terms of ppm
- mg/M³ values are determined by calculation, conversion based upon an assumption of NTP
- If samples are taken at P and T conditions very different from NTP and results are in mg/M³, results must be corrected.
OELs

• Conversion between ppm and mg/M³

\[ Y \text{ ppm} = \frac{X \frac{mg}{M^3} \times 24.45 \ l}{MW \ \frac{g}{mole}} \]

\[ X \frac{mg}{M^3} = \frac{Y \text{ ppm} \times MW \ \frac{g}{mole}}{24.45 \ l \ \frac{mole}{mole}} \]

OELs

• Time weighted average concentration is measured by taking one or more measurements of concentration over a work shift.

\[ \text{TWA} = \sum_{i=1}^{n} \frac{C_i T_i}{T_{total}} \]
OELs

• 8-hour TWA: average exposure over an eight hour time period (normal work shift)

\[ 8\text{-}\text{hour TWA} = \frac{\sum_{i=1}^{n} C_i T_i}{8\text{ hours}} \]

OELs

• Example: A press cleaner is monitored for exposure to ethanol. The data are:

<table>
<thead>
<tr>
<th>Time Period (number)</th>
<th>Concentration (ppm)</th>
<th>Sample Duration (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>410</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>3.5</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>2</td>
</tr>
</tbody>
</table>
OELs

- Sample TWA calculation

\[
TWA = \frac{410 \text{ ppm} \times 1.5 \text{ hrs} + 250 \text{ ppm} \times 3.5 \text{ hrs} + 75 \text{ ppm} \times 2 \text{ hrs}}{1.5 \text{ hrs} + 3.5 \text{ hrs} + 2 \text{ hrs}}
\]

\[
= \frac{1640 \text{ ppm} \times \text{ hrs}}{7 \text{ hrs}} = 234 \text{ ppm}
\]

\[
8-\text{hr TWA} = \frac{1640 \text{ ppm} \times \text{ hrs}}{8 \text{ hrs}} = 205 \text{ ppm}
\]

OELs

- Short Term Exposure Limit (STEL)
- The concentration to which workers can be exposed continuously for a short period of time without suffering:
  - Irritation
  - Chronic or irreversible tissue damage
  - Narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue or materially reduce work efficiency
OELs

• Short Term Exposure Limits
  – Usually a 15-minute period
  – Should not be exceeded anytime during a workday, even if the 8-hour TWA is below the OEL. (8-hour TWA OEL will be a lower concentration)

OELs

• Short Term Exposure Limits
  – Exposures above 8-hour OEL but below STEL
    • Should not be longer than 15 minutes
    • Should not occur more than 4 times per day
    • There should be at least 60 minutes between exposures in this range.
    • Example: diethylamine, TLV:
      – 8-hour is 5 ppm.
      – STEL is 15 ppm.
OELs

• Ceiling Value
• Concentration that should not be exceeded during any part of the work day.
• Designated by a “C” preceding substance listing.
  – Example, Acetaldehyde, STEL = 25 ppm, and has a ‘C’ designation.

OELs

• Mixtures
• If the biological effects of a group of chemicals are independent, compare each exposure to the individual TLV.
• If the ratio: 8-hour TWA / TLV is
  – < 1 exposure is below TLV
  – > 1 exposure is above TLV
  – Do this for each chemical independently
OELs

• Additive effects
  – Similar toxic effects
  – sum the ratios of 8-hour TLV / TWA
  – K = sum of these ratios
  – If K < 1, combined exposure is below TLV
  – K > 1, combined exposure is above TLV

OELs

• Adjusting OELs to different work shifts
• Allowed exposure should be changed to account for duration of exposure
• OSHA model
• Brief and Scala Model
OELs

• OSHA Model (T > 8 hours)

\[ TWA' = PEL \times \frac{8 \text{ hrs}}{T \text{ hrs}} \]

OELs

• Brief and Scala Model (T is shift in hours)

\[ TLV' = \frac{8 \text{ hrs}}{T \text{ hrs}} \times \frac{24 - T \text{ hrs}}{16 \text{ hrs}} \times TLV \]
OELs

• Example
• 1,2 trichloroethane (a solvent) has a biological half life of 16 hours.
• What modified PEL or TLV would be appropriate for people who work 3 12-hour shifts per week exposed to the compound?
• TLV and PEL are both 10 ppm

Solution

OSHA MODEL

\[
PEL' = \frac{8 \text{ hrs}}{12 \text{ hrs}} \times 10 \text{ ppm} = 6.7 \text{ ppm}
\]

Brief and Scala Model

\[
TLV' = \frac{8 \text{ hrs}}{12 \text{ hrs}} \times \frac{24 - 12 \text{ hrs}}{16 \text{ hrs}} \times 10 = 5 \text{ ppm}
\]
Pre Inspection Research

• Before you visit, research the process.
• Learn some terms before visit.
• Look for records of previous inspections.
• Become aware of hazards you might expect to see.
Initial Walk Through

- Observe work practices and environmental conditions. Look for evidence of potential safety and health hazards: dust, grime in air or on surfaces. Other signs?
- Observe operations: cutting, heating, mixing, bagging.
- Observe controls: engineering, administrative, personal protective equipment.
- Interview Workers: often have important and relevant information
- Make flow diagrams, notes, take photos if possible.

Basic Elements: Qualitative IH Survey

- **List locations covered by the survey.** The elements of this list will depend on the size of the facility being evaluated as well as the level of evaluation.
- **Description of operations.** For each worksite (location) listed, list the operations conducted. This description should include some mention of the operations that may generate hazards.
- **List of hazardous materials.** A list of materials used at each operation should also be listed. This list should be based on the material content, not the manufacturer: so if several suppliers of acetone are used, they can be counted together.
- **List of hazardous physical agents.** Sources of heat, noise, nonionizing radiation (microwaves), ionizing radiation, ergonomic hazards noted should be listed.
- **Existing controls.** Describe ventilation used, personal protection worn and administrative controls in place.
- **Personnel information.** Number and job titles of personnel working in the area should be collected. Comments from interviewed workers should be organized.
Quantitative IH Survey

- OSHA Inspection
- Exposure characterization
- Statistically reliable evaluation requires many measurements
- Sampling strategy is needed
- Design of survey will depend on a qualitative IH survey

Quantitative IH Survey: How are Measurements Taken?

- Integrated over time: minutes to hours
- Grab sampling
- Size-selective sampling
- Direct reading instruments
- Colorimetric tubes
- Sampling media
- OSHA or NIOSH methods
- Accredited laboratory for analysis
Quantitative IH Survey: Record Keeping

• Minimum data elements
  – Plant, location, date, worker ID, job titles, process name, time on/off, inspector name
  – Document calibration and sample handling
  – Provide a sound basis for future reference (legal proceedings?)

• Notify affected workers of monitoring results

Initial Design of Control

• Design Stage: Plan new construction, systems with worker protection in mind.

• Also consider:
  – air pollution
  – water pollution
  – waste minimization
  – hazardous waste control
  – accident/disaster control
Industrial Hygiene Control

- Once a system is constructed, methods to follow in correcting a problem.
- Priority of control
  - substitution, process change
  - ventilation/engineering
  - administrative
  - personal protection

Dilution Ventilation

- Also known as General Exhaust Ventilation
  - substances of low toxicity.
  - contaminant source large or diffuse.
  - prevent buildup of explosive concentrations in a storage area.
  - applies to gaseous hazards, not particulates.
  - when local exhaust ventilation is not feasible.
  - costs of clean air (make up air) not prohibitive.
Local exhaust ventilation

- Preferred with:
  - substances of high toxicity
  - unpredictable or sporadic generation
  - point sources
  - aerosols
  - prevent pollution of air, water, etc.

Dilution Ventilation Theory

- Dilution ventilation may be applied in situations where vapor concentration build-up and decay can be predicted.
- Assumptions when applying equations:
  - perfect mixing in work area
  - constant generation rate
  - clean dilution air is used
  - no other sources of product in air
  - no other removal mechanisms than dilution
General Equation to Predict Concentration

\[ C_2 = \left( \frac{1}{Q} \right) G - (G - QC_1) e^{\left( \frac{Q}{V} \right) (t_2 - t_1)} \]

- Q = Volumetric flow of dilution air
- V = the room volume
- t = time
- C = concentration
- G = generation rate of vapor

Special Cases

• C_1 = 0; t_1 = 0; G > 0

\[ C = \frac{G}{Q} \left( 1 - e^{\left( \frac{Q}{V} t \right)} \right) \]
Special Cases

• If a long time has passed, then exponent drops out (long is more than 3 air changes, Qt / V > 3)

• \( C_m = \frac{G}{Q} \)

Special Cases

• Concentration decay; no more generation.

\[
C = C_1 e^{-\frac{Q}{V}(t_2-t_1)}
\]