Learning Objectives

1. How government regulations affect chemical plant operations.
2. The steps in an industrial hygiene study.
3. Determining volatile concentrations in air.
4. Ventilation.
5. Noise exposure.
6. Chemical plant industrial hygiene control methods.
1. Laws are enacted by Congress and signed by the President. They are published in the United States Code (USC). The laws do not have details on implementation.

2. The applicable government agency develops and proposes a regulation. The regulation contains the details on implementation. It is published in the Federal Register and a comment period and hearing is normally held.

Government Regulations

- Occupational Safety and Health Administration (OSHA):

- Environmental Protection Agency (EPA):
  40 CFR Part 68 “Risk Management Programs”

- Department of Homeland Security (DHS)
  6 CFR 27 “Chemical Facility Anti-Terrorism Standards (CFATS)
OSHA: Occupational Safety and Health Administration

- Management Systems
- Employee Participation
- Process Safety Information
- Process Hazard Analysis
- Operating Procedures
- Training
- Contractor Safety
- Pre-Startup Safety Reviews
- Mechanical Integrity
- Safe Work Practices
- Management of Change
- Emergency Planning and Response
- Incident Investigation
- Compliance Audits

See Table 3-5
EPA

EPA - Environmental Protection Agency
Risk Management Plan:

• Considers offsite impacts due to fires / explosions / toxic release

• Must identify hazards

• Must perform consequence analysis

See Table 3-5

40 CFR Part 68 “Risk Management Programs”
DHS

DHS – Dept. of Homeland Security

“Secures the nation from the threats we face.”
Large inventories of chemicals in a chemical plant represents an asset that terrorists can use by:

1. Intentional loss of containment
2. Theft of chemicals
3. Contamination or spoilage of product or process
4. Acquisition of chemicals under false pretense
6 CFR 27 “Chemical Facility Anti-Terrorism Standards”

- 6 CFR 27 contains a list of chemicals and threshold quantities
- If your company has this chemical and exceeds the threshold, you need to fill out an on-line report
- DHS evaluates the information and provides a preliminary classification of your plant in four tier groups, with Tier 1 having the highest risk
- Detailed Security Vulnerability Assessment (SVA) is then completed and sent to DHS for final classification
- All tier groups must complete a Site Security Plan (SSP)
- DHS will do on-site inspections of some sites
6 CFR 27 “Chemical Facility Anti-Terrorism Standards”

- **Deterrence** – discourages by means of fear or doubt
- **Detection** – by cameras, alarms and patrols
- **Delay** – slow progress of adversary
- **Response** – on-site and off-site
- **Awareness** – employee awareness of customers and intended use for products
Industrial hygiene

Concerns conditions related to workplace injury and sickness
e.g.: exposures to toxic vapors, dust, noise, heat, cold, radiation,
physical factors, etc.

- **ANTICIPATION**: Expectation of hazard existence
- **IDENTIFICATION**: Presence of workplace exposure
- **EVALUATION**: Magnitude of exposure
- **CONTROL**: Reduction to acceptable levels

**Chemical plants and labs**: requires co-operation from industrial
hygiene, safety and plant operations people
Identification

Requires study of

- Chemical process
- Operating conditions
- Operating procedures

Potential hazards:
- Liquids
- Vapors
- Dusts
- Noise
- Radiation
- Temperature
- Mechanical

Hazard data:
- Physical state / vapor pressure
- TLV’s
- Temperature sensitivity
- Rate and heat of reaction
- By-products
- Reactivity with other chemicals
- Explosion limits

Risk assessment: potential for hazard to result in an accident
Odor Threshold

Concentration at which most people detect an odor.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Odor Threshold</th>
<th>TLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>5.75</td>
<td>25</td>
</tr>
<tr>
<td>Butyraldehyde</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Chloroform</td>
<td>11.7</td>
<td>10</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.05</td>
<td>0.5</td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>851</td>
<td>1</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>0.0005</td>
<td>10</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.051</td>
<td>0.05</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.16</td>
<td>20</td>
</tr>
</tbody>
</table>

See Table 3-9
Evaluating Volatiles

Monitoring air concentrations \rightleftharpoons Variation in time and place

Time Weighted Average

Continuous:

$$TWA = \frac{1}{8} \int_{0}^{t_w} C(t)dt$$  ppm or mg/m$^3$

![Graph showing time weighted average](Image)
Evaluating Volatiles

**Intermittent:**

\[ TWA = \frac{1}{8} \sum_{i} C_i T_i \]

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>Conc. (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>1.9</td>
<td>95</td>
</tr>
<tr>
<td>2.5</td>
<td>90</td>
</tr>
<tr>
<td>3.1</td>
<td>80</td>
</tr>
<tr>
<td>3.8</td>
<td>70</td>
</tr>
</tbody>
</table>
Evaluating Volatiles

Additive effect multiple toxicants: $\sum_{i=1}^{i} \frac{C_i}{(TLV - TWA)_i} < 1$

Mixture: $(TLV - TWA)_{mix} = \sum_{i=1}^{i} \frac{C_i}{\sum_{i=1}^{i} \left(\frac{C_i}{TLV - TWA}\right)_i}$

If $\sum C_i < (TLV - TWA)_{mix}$

Then exposure is OK.

Problem: The presence of an additional chemical reduces the exposure concentrations. If you are not aware of the presence of an additional chemical then you might be overexposed when you think you are OK!
Estimating Volatiles

Relevant for design purposes:

- enclosed spaces
- open containers
- filling of vessels
- spill area

Figure 3-3 in text

Ventilation rate

\[ Q_v \ (\text{m}^3/\text{s}) \]

Volatile rate out

\[ kQ_v C \ (\text{kg}/\text{s}) \]

Physical Facts:

\[ Q_m \ (\text{kg}/\text{s}) \]

Evolution rate
Estimating Volatiles

Ventilation rate
$Q_v$ (m$^3$/s)

Volatile rate out
$kQ_vC$ (kg/s)

Mass Balance:

Evolution rate
$Q_m$ (kg/s)

Steady State:
Estimating Volatiles

Average conc. at steady state

More convenient in terms of ppm:

$$C_{ppm} = \frac{V_v}{V_b} \times 10^6 = \left( \frac{m_v}{\rho_v} \right) \times 10^6 = \left( \frac{m_v}{V_b} \right) \left( \frac{R_g T}{PM} \right) \times 10^6$$

Equation (3-8)

Ideal mixing $k =$

Non-ideal $k =$

Leads to higher concentrations

If evolution rate increases or ventilation decrease, concentration will increase.
Example

During a degreasing operation involving trichloroethylene, 10 gallon of TCE evaporates per 8-hour shift.

Data: $MW = 131.4$, $T = 537^\circ R$, $P = 1$ atm

Specific gravity of liquid = 1.46

Ventilation Rate, $Q_v = 1000$ ft$^3$/min
Step 1: Determine evaporation rate in lb/min

\[ Q_m = \left( \frac{10 \text{ gal}}{8 \text{ hour}} \right) \left( \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) \left( \frac{62.4 \text{ lb}_m}{\text{ft}^3} \right) (1.46) \left( \frac{1 \text{ hour}}{60 \text{ min}} \right) \]

\[ Q_m = 0.254 \]
Step 2: Apply Equation (3-9)

\[ C_{ppm} = \frac{Q_m RT}{kQ_v PM} \times 10^6 \]

\[
C_{ppm} = \left( 0.254 \frac{\text{lb}_m}{\text{min}} \right) \left( 0.7302 \frac{\text{ft}^3 \text{ atm}}{\text{lb-mole} \ ^\circ \text{R}} \right) \left( 537 \ ^\circ \text{R} \right) \times 10^6
\]

\[
C_{ppm} = \frac{760}{k} \quad 0.1 \leq k \leq 0.5
\]

@ \( k = 0.1 \) \( C_{ppm} = 7,600 \) ppm

@ \( k = 0.5 \) \( C_{ppm} = 1,520 \) ppm

TLV is 10 ppm, STEL is 25 ppm

Appendix G
What ventilation rate required to reduce below TLV?

Assume $k = 0.1$ (worst case)

Use Equation 3-9, calculate $Q_v$

$$10 \text{ ppm} = \left(0.254 \text{ lb}_m \frac{\text{min}}{}\right) \left(0.7302 \text{ ft}^3 \frac{\text{atm}}{\text{lb-mole } ^o\text{R}}\right) \left(537 \text{ } ^o\text{R}\right) x 10^6 \frac{\text{lb}_m}{(0.1)(Q_v)(1 \text{ atm}) \left(131 \text{ lb}_m \frac{\text{lb-mole}}{}\right)}$$

$Q_v = 760,000$

Other control methods?
Alternate Control Methods
Vaporization

**SOURCE TERM:**

\[ Q_m = \alpha(P_{Sat} - P) = \frac{MKA}{RT_L}(P_{Sat} - P) \approx \frac{MKA}{RT_L}P_{Sat} \]  

(kg/s)

\[ A = \text{area for mass transfer} \]

\[ C = \frac{Q_m}{kQ_v} \]  

Eqn. 3-7

Enclosure with \( T_L = T \)

\[ C_{ppm} = \frac{KAP_{Sat}}{kQ_vP} \times 10^6 \]  

Eqn. 3-14

**Estimating mass transfer coefficient:**

\[ K = K_0 \left( \frac{M_0}{M} \right)^{1/3} \]  

Eqn. 3-18

**K \(_{\text{water}}\) = 8.3 \times 10^{-3} \text{ m/s}**

\[ M = 18 \]
Filling Vessels

Total Volatiles = Evaporation + Displacement

\[ Q_m = Q_{m1} + Q_{m2} \] (kg/s)

\[ Q_m = (\phi r_f V_c + KA) \frac{MPSat}{RT_L} \]  

if \( T_L = T \):

\[ C_{ppm} = (\phi r_f V_c + KA) \frac{PSat}{kQ_v P} \times 10^6 \]

Splash filling: \( \phi = \)

Subsurface filling: \( \phi = \)

\( KA \) often small compared to displacement
Measuring Volatile Concentrations

Colorimetric Tubes
Measuring Volatile Concentrations

Easy-to-use monitors guide you through testing by displaying prompts that tell you how to calibrate, the battery status and the gas you’re monitoring.

**Specifications:** Gas concentrations are displayed simultaneously for immediate, hassle-free results. Audible and visual alarms let you know when the user-selectable alarm levels are reached. You can select latching or non-latching alarms. Two modes let you select how you want results displayed—in exact gas concentrations or by acceptable levels. Stainless steel case with water-resistant design and RFI protection help the monitors deliver accurate results under tough conditions. Leather case is included. See chart for additional specifications.
Measuring Volatile Concentrations

← Filter unit, usually contains activated charcoal.

This unit goes with the worker and is better at measuring the actual exposure to that person.

← Battery powered air pump.
Ventilation

DILUTION

Dilution below target concentration
Mixing factor $k$ see Table 3-15

Problems: Requires high air flow and energy costs. Workers always exposed

LOCAL

Remove contaminant before exposure workers minimal air flow

$\Delta P \approx 0.01 \text{ atm}$

Target Velocity:

- eliminates exposure
- containment device
- shield
- limited workspace

Bypass laboratory hood

Negative pressure ventilation Positive pressure ventilation
Velometer for Measuring Flow
Hood Operation

← Red liquid level indicates proper hood function.
Evaluating Noise

NOISE PROBLEMS ARE COMMON IN CHEMICAL PLANTS

Relative Noise Intensity \( = -10 \log \frac{I}{I_0} \) (dB) \( I_0 \) = hearing threshold (dBA)

Similar calculations as volatiles

Table 3-11
# Exposure to Noise (Table 3-10)

<table>
<thead>
<tr>
<th>Source</th>
<th>Intensity (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riveting (painful)</td>
<td>120</td>
</tr>
<tr>
<td>Passing Truck</td>
<td>100</td>
</tr>
<tr>
<td>Noisy Office</td>
<td>80</td>
</tr>
<tr>
<td>Whisper</td>
<td>20</td>
</tr>
</tbody>
</table>
Noise Reduction Ratio (NRR)

Used for Personal Protective Equipment:

A particular hearing protector has an NRR of 18. If the ambient noise level is 95 dba, what is the worker exposure?

Sound Measuring Device →
Hearing Protection
Safety Showers / Eyewashes

Useful for fires and chemical spills.

For chemical spills, clothing must be removed.

Must be used, with assistance, for 15 min.
Minimum flows: Eyewash: 4 gpm
Shower: 30 gpm

Both must be tested regularly.

Area around unit must be unobstructed.

Required within the lab if chemicals are used.
Safety Showers / Eyewashes

Water must continue to flow once handle is released.

Current OSHA standard requires water temperature control.

Problems with:

- Dirty water
- Rust from pipes
- Water temperature
Flammable Storage Cabinets

Offers protection from external fire.

Must be electrically grounded to prevent static accumulation.

Vent hole is left closed, unless stored materials have an odor, in which case the vent is connected to the ventilation system.

Do not store anything on the top.

Store only flammables, nothing else.
Table 3-12

Control

CHEMICAL PLANT INDUSTRIAL HYGIENE METHODS

- **Inherently Safer Design** – Eliminate or reduce hazard.
- **Enclosures** – Enclose room or equipment.
- **Local Ventilation** – Contain and exhaust
- **Dilution Ventilation** – Ventilation in work area
- **Wet Methods** – Liquid to reduce dusts.
- **Good Housekeeping** – Keep materials contained
- **Personal Protection** – As last line of defense.
Legacy of the Past!
Legacy of the Past!
Promise of the Present!
THE END

“THINK SAFETY”!