Industrial Hygiene

- Methods to prevent or reduce the intrusion of toxicants into humans
  - Identification: *presence*
  - Evaluation: *magnitude*
  - Control: *reduction* to acceptable levels
- Institute Concerned
  - NIOSH: How much hazardous
  - OSAH: How to protect employees

3.2 Identification of Toxins

- Exposure to hazards
  - chemicals, aerosols, dusts, fibers, noise, radiation, Tab 3-5, p. 75.
- Information for health identification
  - hazards due to agents in workplace, e.g., TLV, reactivity, flammable concentrations, Tab 3-6, p. 75.
  - Information is part of the process safety information (PSI) that is needed for a process hazards analysis (PHA).

Material Safety Data Sheets

- Available from internet, chemical manufacturers, libraries. Part of information required by PSM.
- Chemical identity, PEL, TLV
- Physical, fire/explosion, reactivity, health hazard data
- Guidance for handling, use, control
- Ex., Fig. 3-2., pp. 76,77

3.3 Evaluation

- Determine the extent and degree of employee exposure to toxicants and physical hazards
- Immediately acute effect
  - Sudden exposures to high conc.
  - Unconsciousness, burning eyes, coughing
  - Ready access to clean environment
- Chronic effect
  - Repeated exposures to low conc.
  - Might not obvious for months or years

TVL-TWA Model

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

where t_w is the worker shift in hours.
C(t) is the concentration of the toxin in air.

The integral is divided by 8 hours regardless of the time worked in the shift.

TLV-TWA Determination

- TWA from intermittent measurements

$$TWA = \frac{C_1 T_1 + C_1 T_2 + \cdots C_n T_n}{8\ hr}$$

where C_i is the concentration estimated to be the average concentration over the time interval T_i.

Multiple Exposure Model

- Assume that the effects of the chemicals together are additive
- Additive models assume that total effect varies in magnitude, not in type of effect, with the concentration.
- Suitable for chemicals that cause similar effects
- Effects could be synergistic

  → not additive

Total Exposure Factor, TEF

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

- C_i is average concentration of *i* and $(TLV\text{-}TWA)_i$ is the threshold limit value for *i*.
- If TEF = 1, the total effect is assumed the same as one of the chemicals at its TLV-TWA value.
- If TEF > 1, personnel are overexposed.

TLV-TWA for Mixture

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

- If TEF = 1, then $(TLV\text{-}TWA)_{mix}$ = sum of concentrations
- If TEF > 1, the mixture threshold level is less than the sum of concentrations.
- If conc. > $(TLV\text{-}TWA)_{mix}$, people overexposed

Exposure to Dust

- Greatest hazard
  - Size of 2 - 5 micron, which settle in the lungs
- Less than 2 micron, mostly exhaled
- Greater than 5 micron, not penetrate the lungs.
- Another hazard of dusts
  - Combustible dusts can explode
- Hazard level based on particle sizes, concentration in air

Noise Exposure

- Intensity (db) = $10 \log_{10}(I_2/I_1)$
- Human hearing threshold of 0 dB = dBA (absolute)
- For TEF evaluation
  - Sound durations ~ concentrations
  - Permissible durations ~ values of TLV-TWA concentrations.
  - Tab 3-8, P. 85

Toxic Vapor Exposure

- Measure toxic levels when possible, but estimations are often needed.
- Mass balance: $$V\frac{dC}{dt} = Q_m - kQ_v C$$

  where Q_m, source; Q_v, ventilation rate (vol/time); k, mixing factor (variable)
- Steady state: $$C = \frac{Q_m}{kQ_v}$$

Toxic Vapor Exposure

- Convert C to ppm in air, C_{ppm}, to estimate *average* conc. of a gas in a volume V with a source term Q_m and a Q_v.

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

where the ideal gas law is assumed. Eqn. 3-9, p. 87. Local C can range widely.

Toxic Vapor C Below TLV

- Mixing factor, k, varies from 0.1 - 0.5, (= 1 for perfect mixing). If not known, use the worst practical mixing case or use 0.1.
- Use this model to determine the minimum ventilation rate to achieve avg. C < TLV. Do vapor sampling at several locations.
- Ventilation: not too high (expensive) or too low (insufficient margin for upsets)

Vaporization of Pure Liquids

- Vaporization rate often not known. Use correlation that assumes rate is $\propto (P^{sat} - p) \sim P^{sat}$ due to moving air.

$$Q_m = \frac{MKAP^{sat}}{R_g T_L} \quad \text{pure liquid}$$

- M is MW, K is a mass transfer coefficient (length/time), A is area of liquid surface, and T_L is liquid temperature.

Vaporization of Liquid Mixtures

- Vapor pressure of each mixture component is given by Raoult's Law (ideal mixture)
- $P_i = x_i P_i^{sat}$, x_i = mole fraction of i in liquid
- Evaporation rate of component i is

$$Q_{m_i} = \frac{M K A x_i P_i^{sat}}{R_g T_L}$$

Vapor Concentration from Liquids

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

- Use vaporization rate as the source term to estimate C_{ppm} in an enclosure with T (air) = T_L (liquid).

$$C_{ppm} = \frac{K A P^{sat}}{k Q_v P} 10^6$$

Vapor Concentration, Unenclosed

- For exposures that are not in enclosed space, the ventilation rate is often variable and unknown.
- For approximate vapor concentrations, an effective ventilation rate for Q_v can be used.

Mass Transfer Coefficient, K

- $K = aD^{2/3}$; D = gas diffusion coefficient
- D estimated from MW, $D = b/M^{1/2}$
- Use water as reference species: $K_o = 0.83$ cm/s

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

3.4 Control of Toxic Levels

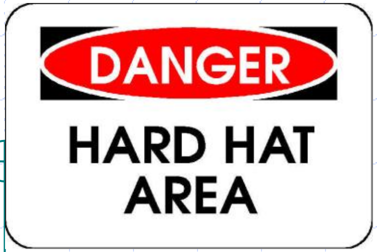
- Estimated level of ventilation required for C_{ppm} < TLV or PEL.
- Safety/costs: consider other factors
- Amount of material needed on site
- Methods to reduce levels
- Local *vs.* normal ventilation
- Containment system

Control of Health Hazards

- Environmental: reduce concentrations in the workplace environment.
- Enclosure, local ventilation: containment
- Dilution ventilation, wet methods (H_2O sprays)
- Dikes (pipes & pumps) and other control methods, Tab. 3-9, p. 95

Personal Protection

- Protection for individuals: summarized in Tab. 3-10, p. 96
- Respirators, cartridges, canisters: short time use, emergency. Listed in Tab. 3-11, p. 97
- Self-contained breathing apparatus (SCBA): not dependent on environment for oxygen.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HARD HAT
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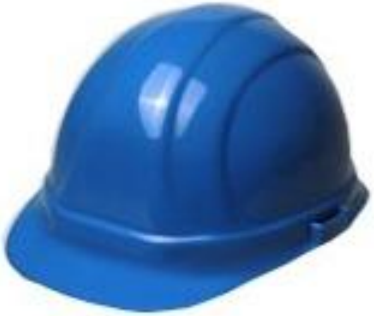
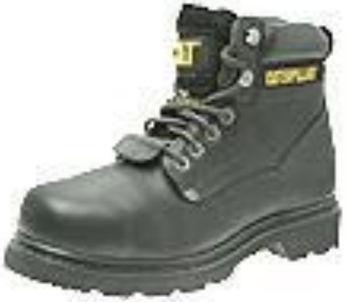
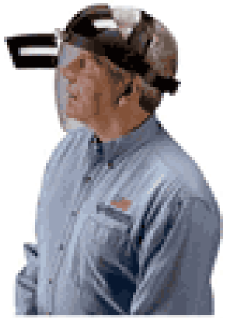
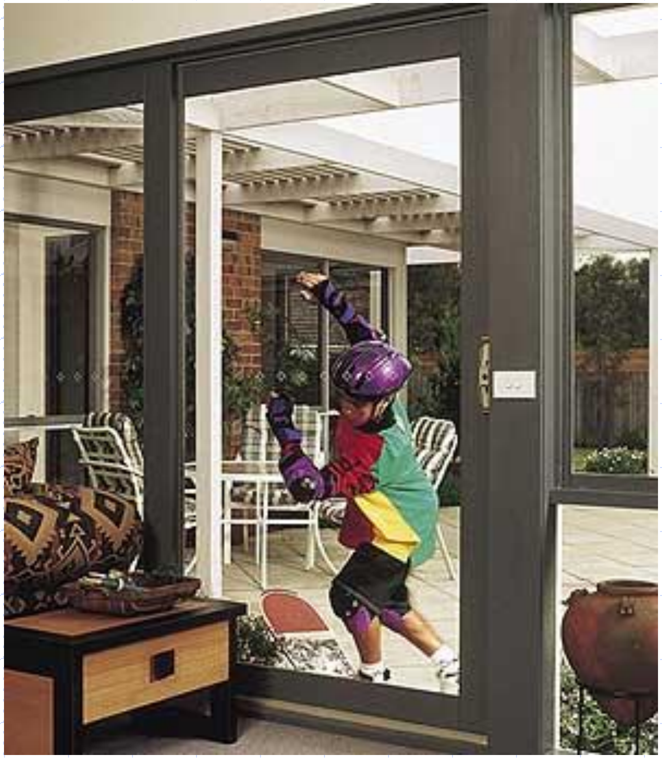
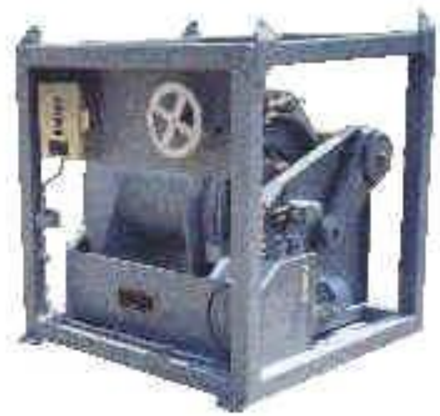
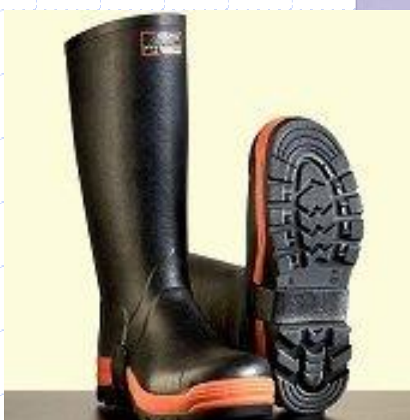


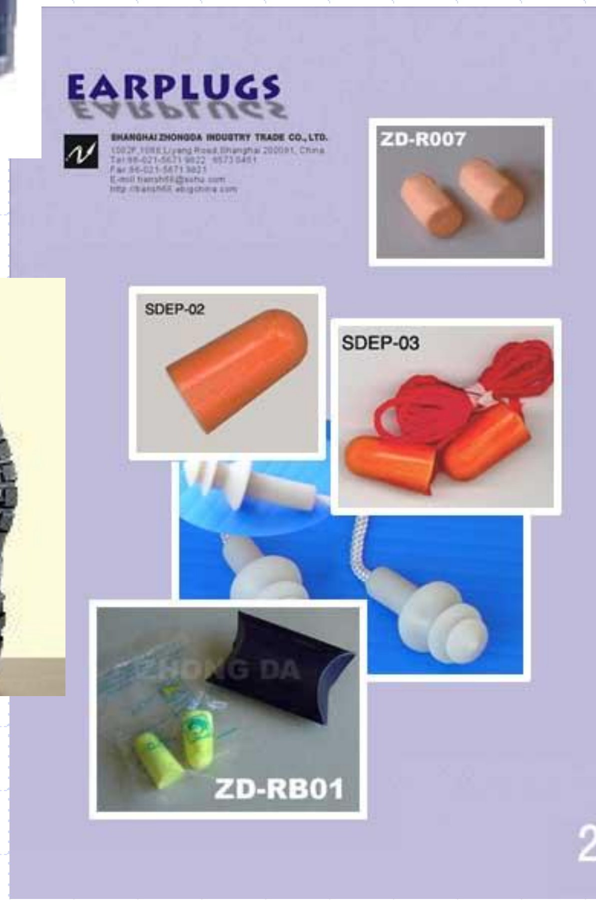


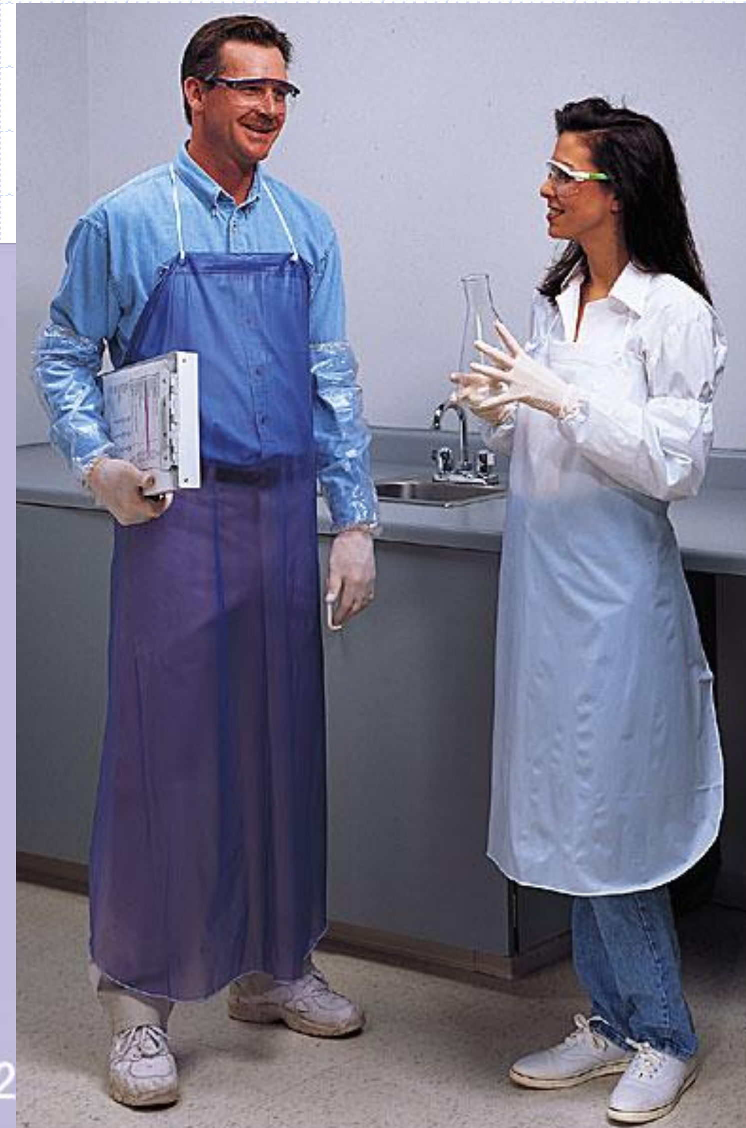


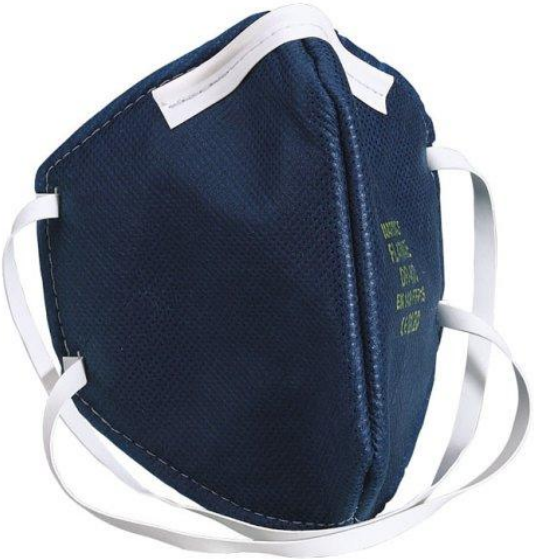


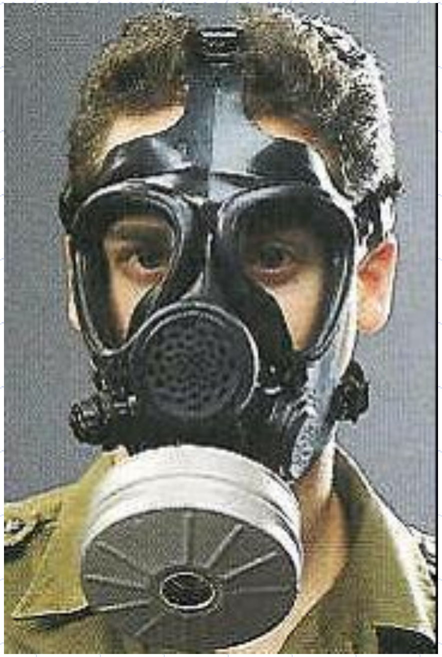


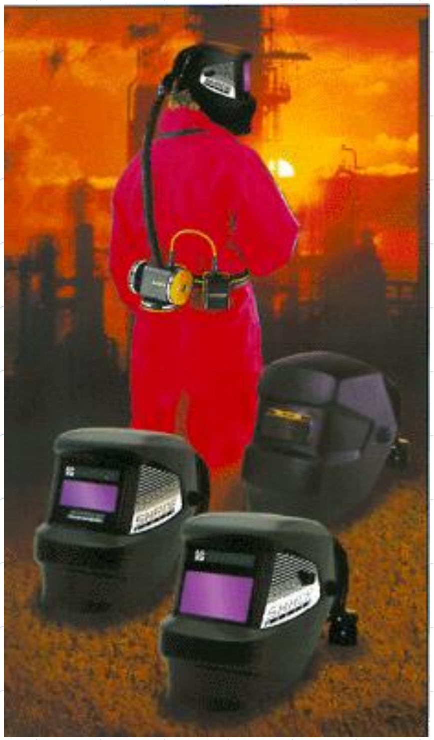



EARPLUGS
SHANGHAI ZHONGDA INDUSTRY TRADE CO., LTD.
ZD-R007
SDEP-02
SDEP-03
ZD-RB01









Ventilation

- Reduce or remove contaminants; dilute below TLV by mixing with air
- Negative pressure with fan on exhaust is best approach: leaks only into ducts
- Disadvantage: high operating cost due to electricity for fans and heating or cooling of the fresh air

Ventilation in Hoods

- **Negative pressure to remove contaminants**
- **Eliminate or reduce greatly the exposure**
- **Minimal airflow required**
- **Visibility plus protection from fire, explosion**
- **Plug flow, rectangular, A = LW, *u* = air velocity:**

$$Q_v = A\,\overline{u} = L\,W\,\overline{u}$$

Dilution Ventilation

- Contaminant in open area and not highly toxic
- Air is used as a diluent to reduce levels.
- Personnel exposed but < TLV, PEL
- Calculate needed ventilation rate

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

Ex 3.3(p.81), 3.2(p. 80), 3.5(p.83), 3.6(p.85), 3.7(p.88), 3.8(p.90), 3.10(p.102)