Chapter 2: Toxicology

Considers worker exposures

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Learning Objectives:
Chapter 2: Toxicology

1. Understand entry routes for toxicants
2. Understand response vs. dose relationships
3. Understand probit equations
4. Understand exposure limits, TLV and PEL
5. Understand NFPA diamond.
Definitions

- entry of toxicants into organism
- elimination from organism
- effects on organism

**Industrial hygiene:** prevention or reduction of entry

- chemical agents
- physical agents: particulates < 5 \( \mu m \), noise, radiation

**Toxicity:** property related to effect on organism
**Problem:** organisms respond via a distribution of effects

**Toxic hazard:** likelihood of damage based on exposure reduction by appropriate techniques
<table>
<thead>
<tr>
<th>ROUTE</th>
<th>ENTRY</th>
<th>CONTROL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingestion</td>
<td>Mouth, stomach</td>
<td>Rules on eating, drinking, smoking</td>
</tr>
<tr>
<td>Inhalation</td>
<td>Mouth, nose</td>
<td>Ventilation, hoods, protection equipment</td>
</tr>
<tr>
<td>Injection</td>
<td>Cuts in skin</td>
<td>Protective clothing</td>
</tr>
<tr>
<td>Dermal Absorption</td>
<td>Skin</td>
<td>Protective clothing</td>
</tr>
</tbody>
</table>

* industrially most significant
Routes and elimination

- DIGESTIVE TRACK
- BLOOD
- TARGET ORGAN

- LIVER
- KIDNEYS / LUNGS

EXCRETION: kidneys (urine), liver (bile), lungs, skin
DETOXIFICATION: liver
STORAGE: fat tissue
Toxic blood levels

Figure 2-1

WIDE VARIATIONS EXPECTED

Injection
Inhalation
Ingestion
Dermal
Toxicology Experiment with Rabbits!

Start with 50 rabbits.
Expose each to a fixed concentration.
Wait for a period of time.
Get a variety of responses.
**Determine Response Curve**

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Worst</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
</tr>
</tbody>
</table>

Average = \(\frac{1 \times 2 + 2 \times 14 + 3 \times 18 + 4 \times 15 + 5 \times 1}{50}\) = 2.98
Plot Bar Chart

Average

Number

Response

0 5 10 15 20

1 2 3 4 5

Response

Number
Repeat experiment at different doses.

<table>
<thead>
<tr>
<th>Dose</th>
<th>Average Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_1$</td>
<td>$R_1 = 2.98$</td>
</tr>
<tr>
<td>$D_2$</td>
<td>$R_2$</td>
</tr>
<tr>
<td>$D_3$</td>
<td>$R_3$</td>
</tr>
<tr>
<td>$D_4$</td>
<td>$R_4$</td>
</tr>
</tbody>
</table>
This form not very useful, particularly at low doses.
Take the log of the dose.

Get S-shaped curve - better at low dose values
Change S-shape into straight line using a mathematical transformation called a probit.

See Table 2-4 in text for numerical conversion.
The Threshold Limit Value (TLV) is the maximum exposure limit to humans for 8 hours a day, 40 hours per week, that does not cause any noticeable effect.

The TWA is the time weighted average.

The TLVs are promulgated by the American Conference of Governmental Industrial Hygienists (ACGIH), a professional society.

The Permissible Exposure Limit is the same thing, but is promulgated by OSHA, a government organization.
Threshold Limit Values

**THRESHOLD DOSE: NO DETECTABLE EFFECT**

Threshold Limit Value TLV: worker’s lifetime
This is for ___ hours per day, ___ hours per week.
**NOT CONTINUOUS EXPOSURE!**

<table>
<thead>
<tr>
<th>TLV - TWA *</th>
<th>Time weighed average</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV - STEL</td>
<td>Short term exposure limit</td>
</tr>
<tr>
<td>TLV - C</td>
<td>Ceiling limit</td>
</tr>
</tbody>
</table>

See Table 2-7 for detailed definitions of these.

See Appendix G for specific values for a number of chemicals. More values are available for TWAs than for STEL or C.
Threshold Limit Values - 2

Published by ACGIH: American Conference of Governmental Industrial Hygienists, a professional organization without legal authority.

Cannot be used as indication of relative toxicity.

Cannot be used for air pollution exposures.

Some toxicants have zero thresholds
## TLV – Example Values

<table>
<thead>
<tr>
<th>Substance</th>
<th>TLV (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>500</td>
</tr>
<tr>
<td>Ammonia</td>
<td>25</td>
</tr>
<tr>
<td>CO</td>
<td>25</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.5</td>
</tr>
<tr>
<td>Gasoline</td>
<td>300</td>
</tr>
<tr>
<td>Hexane</td>
<td>50</td>
</tr>
<tr>
<td>Phosgene</td>
<td>0.1</td>
</tr>
</tbody>
</table>

For flammables, TLV is $\frac{1}{4}$ of lower flammable limit.
Conversion from mg/m$^3$ to ppm

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

$$= \left( \frac{R_g T}{PM} \right) \left( \frac{m_v}{V_b} \right) \times 10^6 \quad \left( \frac{m_v}{V_b} \right) = \text{kg/m}^3 = (\text{mg/m}^3) \times 10^6$$

$$C_{ppm} = \left( \frac{R_g T}{PM} \right) (\text{mg/m}^3) = 0.08205 \left( \frac{T}{PM} \right) (\text{mg/m}^3)$$

Equation (2-7)

For liquid mixtures ppm = mg/m$^3$, but this is not true for vapors!
Problem with Relative Toxicity

Log (Dose)

Average Response

Chemical A

Chemical B
PEL - Permissible Exposure Level

Published by OSHA, and have legal authority.

Defined the same as TLV.

Most PELs are same as TLVs.

Not updated as regularly as TLVs.

Most companies use lowest of the two values.

For some chemicals, i.e. benzene, vinyl chloride, a specific OSHA regulation has been published. Each regulation is unique, but most require EXPLICIT data that workers are not exposed.

See OSHA.gov web site for regulations.
NFPA Diamond

Ratings: 0-4
0: no hazard
4: max. haz.

Used for firefighters

Health Hazard
- 4: Deadly
- 3: Extreme danger
- 2: Hazardous
- 1: Slightly hazardous
- 0: Normal material

Fire Hazard
- Flash Point
  - 4: Below 73°F
  - 3: Below 100°F
  - 2: Below 200°F
  - 1: Above 200°F
  - 0: Will not burn

Specific Hazard
- Oxidizer
- Acid
- Alkali
- Corrosive
- Use NO WATER
- Radiation Hazard

Reactivity
- 4: May detonate
- 3: Shock and heat may detonate
- 2: Violent Chemical change
- 1: Unstable if heated
- 0: Stable
Acetone

NFPA Diamond

See Appendix G
THE END