CE 400 / CE 500

Process Safety Management

Lecture 06 Toxicology

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Toxicology

- Any substance can be toxic with a large enough dose
  - Example: Nitrogen makes up ~79% of the air you breathe but if it rises significantly above that level you will asphyxiate
- The key is to define the level and method of exposure that will lead to serious health effects for a specific substance

Routes of Entry for Toxicants

- Ingestion
  - Through the mouth into the stomach
- Inhalation
  - Through the mouth or nose into the lungs
- Injection
  - Through cuts in the skin
- Dermal Absorption
  - Through the skin membrane

All of these can lead to substance entering blood stream

Elimination of Toxicants

- Excretion – substance physically leaves the body
    - Kidneys – extract material from bloodstream and eliminate via urine
    - Lungs – volatile material is exhaled
    - Also skin eliminates material via sweat
- Detoxification – substance is reacted into something less harmful
    - Liver – material is chemically transformed into something less harmful
    - Other organs also do this to a lesser extent
- Storage – substance is stored, primarily in fatty materials
    - This can be a problem if fatty deposits are metabolized due to lack of food

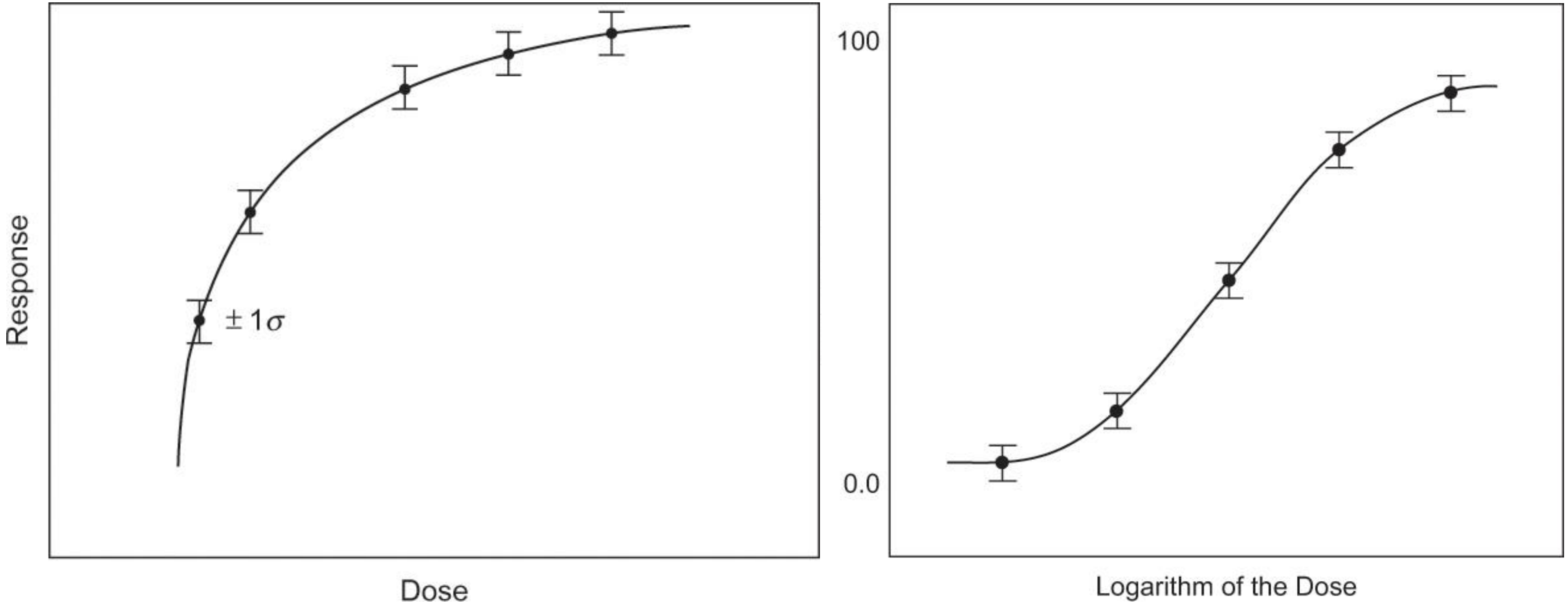
What do Toxicants Do to a Person?

- Irreversible Effects
  - Carcinogen – causes cancer
  - Mutagen – causes chromosomal damage
  - Reproductive hazard – damages reproductive system
  - Teratogen – causes birth defects
- Effects that may or may not be reversible
  - Dermatotoxic – affects skin
  - Hemotoxic – affects blood
  - Hepatotoxic – affects liver
  - Nephrotoxic – affects kidneys
  - Neurotoxic – affects nervous system
  - Pulmonotoxic – affects lungs

Toxicology

- To determine how toxic a material is one must study the response of a number of subjects to various doses
- The test protocol must identify:
  - The toxicant
  - The target or test organism
  - The effect or response to be monitored
  - The dose range
  - The period of the test
    - Long term effects vs short term effects
- Typically subjects exposed to a given set of parameters will exhibit a response that follows a normal distribution
  - Some will show little or no response, some a very large response

The percentage showing a response depends on the dosage



Typical Response versus dose curves. % of Subjects showing response versus dose
The error bars represent +/- 1 standard deviation around the mean response

- Dosage Levels:
  - Effective Dose (ED)
    - Response to agent is minor and reversible
  - Toxic Dose (TD)
    - Response to agent is irreversible
  - Lethal Dose (LD)
    - Response to agent is fatal
  - Subscripts:
    - LD_{50} indicates that this dose leads to a fatal response in 50% of test subjects
    - TD_{10} indicates that this dose leads to a toxic response in 10% of test subjects

Different Individuals Respond Differently to a Given Dose

It often follows a normal distribution

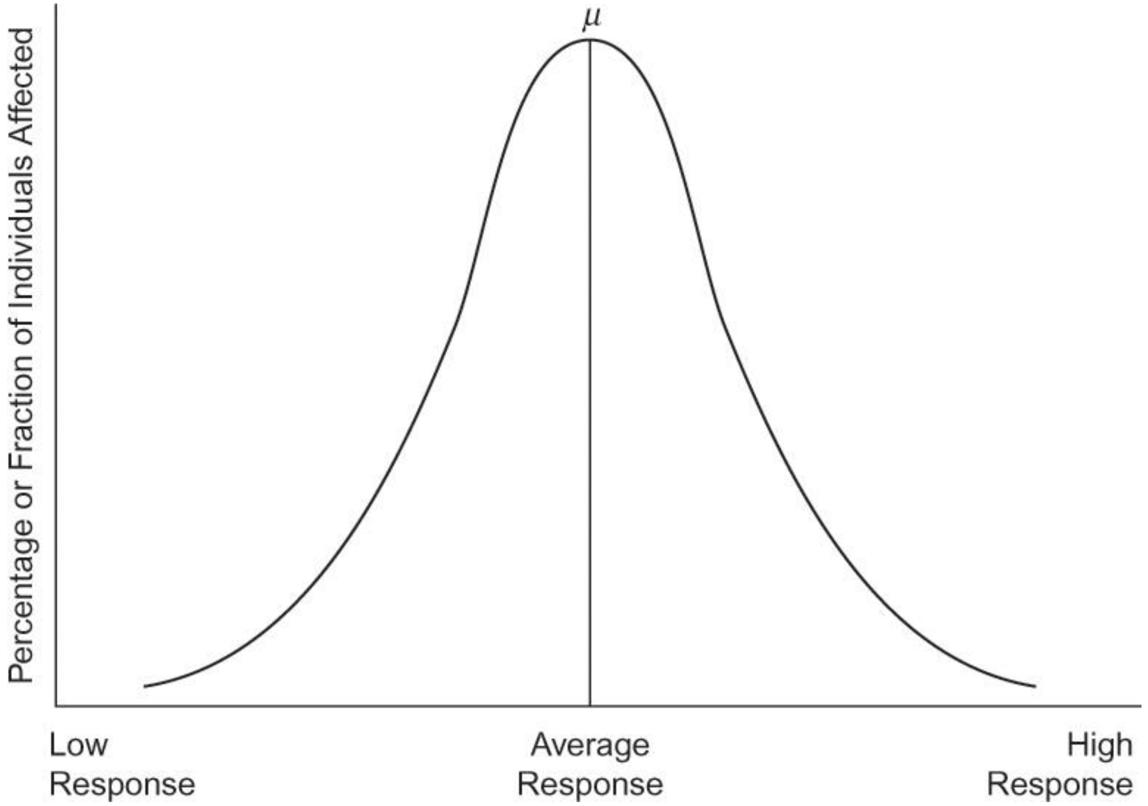


Figure 2-2 A Gaussian or normal distribution representing the biological response to exposure to a toxicant.

Toxicology

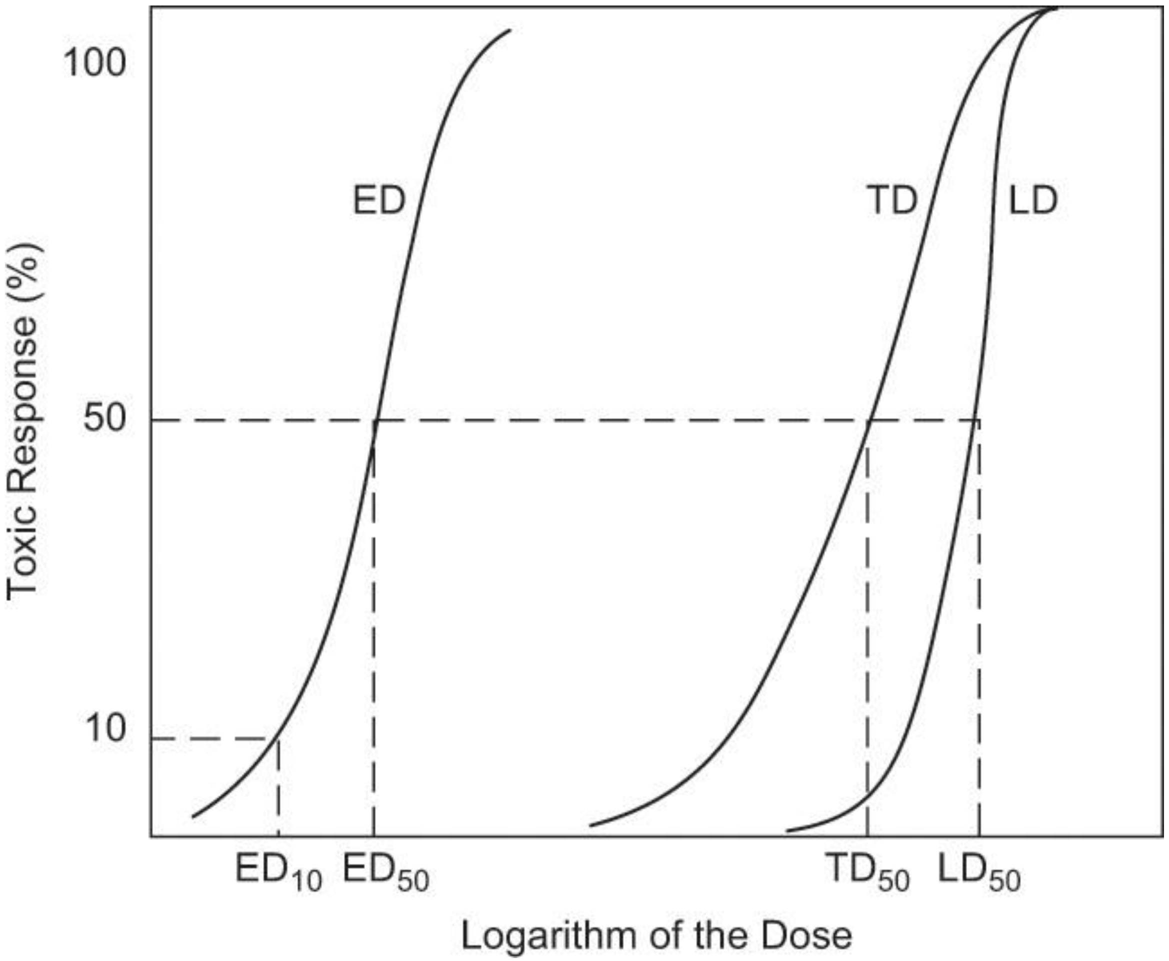


Figure 2-8 The various types of response versus log dose curves are ED for effective dose, TD for toxic dose, and LD for lethal dose. For inhalation exposure, the LC curve expresses the lethal concentration of gases, vapors, or dusts/mists.

Threshold Limit Values (TLV)

- TLV-TWA (Time Weighted Average)
  - Concentration that it is believed that nearly all workers could be exposed to for 8 hours a day, day after day, for a working lifetime and not exhibit adverse effect
- TLV-STEL (Short Term Exposure Limit)
  - 15 minute time weighted average that is deemed safe
  - Exposure should be for less than 15 minutes with at least 60 minutes between exposures and no more than 4 times per day
- TLV-C (Ceiling)
  - This concentration should not be exceeded at any time

Time Weighted Average

- TWA

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

  - Where
    - $C(t)$ is the concentration (in ppm or mg/m^3) of the chemical in the air
    - t_w is the operators shift length in hours
    - The 1/8 factor is to set the expected shift length to 8 hours
    - If the shift is greater than 8 hours then the TWA will be greater than the nominal "average" concentration

Mixtures of Chemicals

- Unless there is evidence to the contrary we assume that the effects of the various chemicals are additive

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

- C_i is the concentration of chemical i with respect to the bulk gas
- $(TLV-TWA)_i$ is the $TLV-TWA$ for chemical species i
- Total mixture concentration is sum of individual concentrations

$$C=\sum_{i=1}^{n} C_i$$

Example of $(TLV - TWA)_{mix}$

Chemical, i =	Concentration, ppm	$(TLV - TWA)_i, ppm$
1	7	8
2	15	25
3	30	35

- $$(TLV - TWA)_{mix} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} \frac{C_i}{(TLV-TWA)_i}} = \frac{7+15+30}{\frac{7}{8}+\frac{15}{25}+\frac{30}{35}} = \frac{52}{2.332} = 22.30$$
- $C = \sum_{i=1}^{n} C_i = 7 + 15 + 30 = 52$ for 8 hours exposure
- Because the cumulative concentration of the mixture exceeds $(TLV - TWA)_{mix}$ the operators' exposure level is unacceptable
  - Note that they were not overexposed to any individual chemical species

Permissible Exposure Level (PEL)

- OSHA defined threshold dose
  - Similar to TLV-TWA
  - Not defined for as many substances, nor updated as often

Immediately Dangerous to Health or Life (IDHL)

- NIOSH (National Institute for Occupational Safety and Health) defined threshold dose
  - "likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment”

NFPA Hazard Identification System

NFPA Hazard Identification System

BLUE Diamond Health Hazard

- **4** Deadly
- **3** Extreme Danger
- **2** Hazardous
- **1** Slightly Hazardous
- **0** Normal Material

RED Diamond Fire Hazard (Flash Point)

- **4** Below 73 °F
- **3** Below 100 °F
- **2** Above 100 °F
  Not Exceeding 200 °F
- **1** Above 200 °F
- **0** Will Not Burn

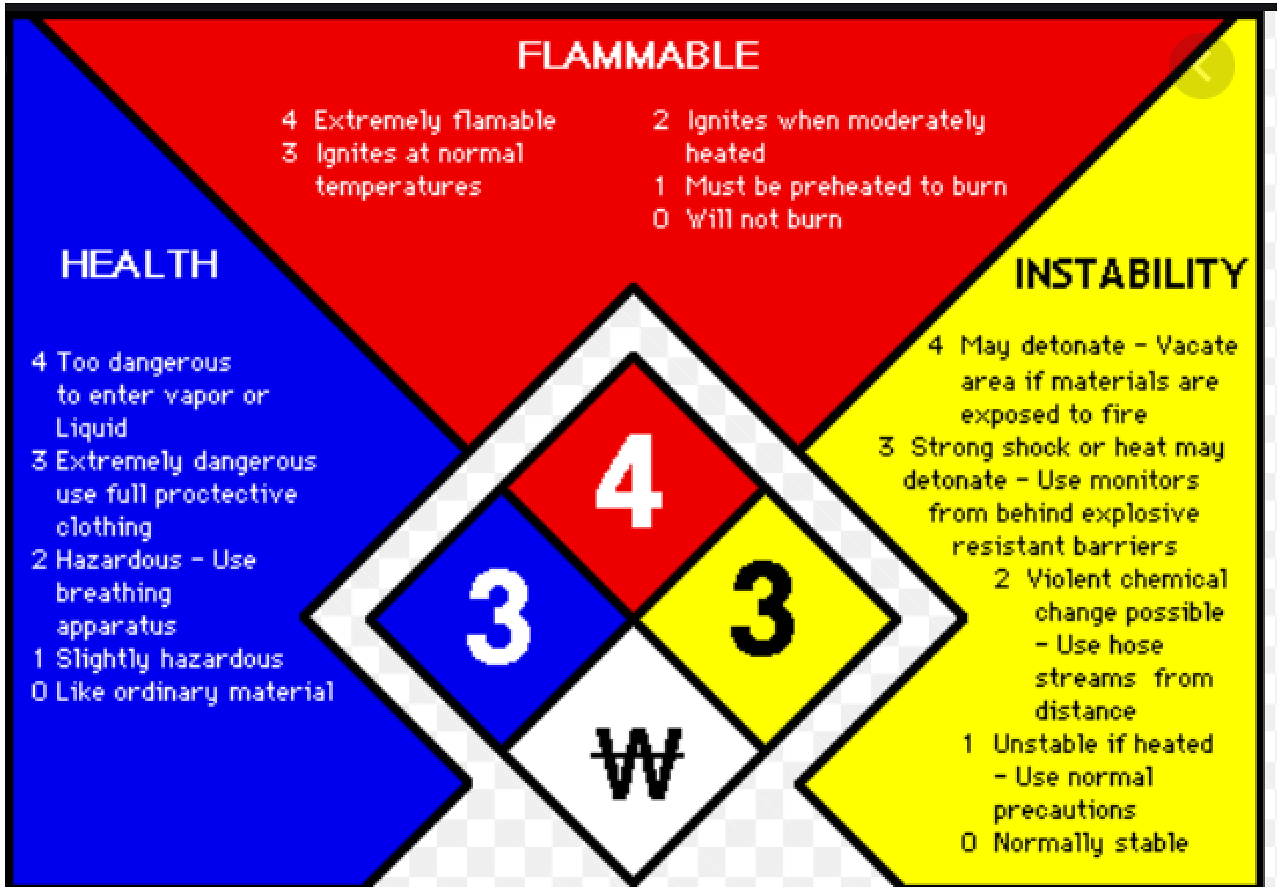
YELLOW Diamond Reactivity

- **4** May Detonate
- **3** Shock and Heat; May Detonate
- **2** Violent Chemical Change
- **1** Unstable if Heated
- **0** Stable

WHITE Diamond Special Hazard

- **ACID** – Acid
- **ALK** – Alkali
- **COR** – Corrosive
- **OXY** – Oxidizer
- ☢ – Radioactive
- **W** – Use No Water

- HMIS – Hazardous Materials Identification System



4. Severe Hazard
3. Serious Hazard
2. Moderate Hazard
1. Slight Hazard
0. Minimal Hazard