EE-527: MicroFabrication

Toxicity of Materials

Toxicity

- A toxic substance or poison is a material that will produce serious disease of death upon introduction into a normal healthy person's bloodstream.
- Unique susceptibilities or allergies are not included.
- Acids and bases are not strictly poisons, even though they can cause local destructive effects on tissue severe enough to be fatal.

Types of Poisons

- Cytotoxins: injure all cells that they contact, usually by destroying the ion permeability of the cell membrane
- Neurotoxins: injure the central nervous system, usually the ability of neurotransmitters to regulate the Na^+ and K^+ membrane channels
- Hemotoxins: injure the circulatory system, usually the ability of hemoglobin to carry oxygen

Factors Affecting Toxicity

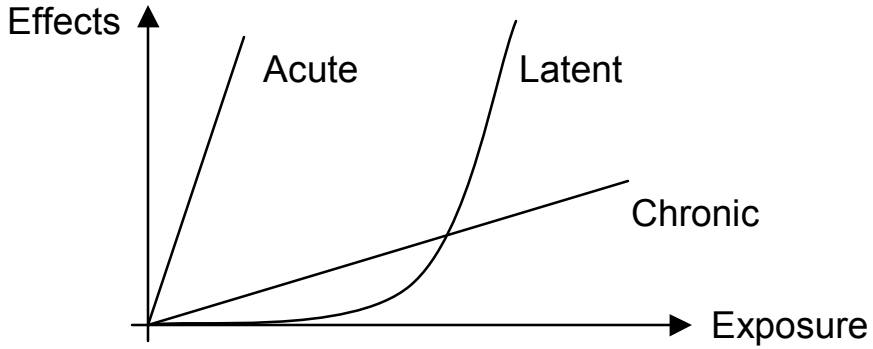
- Quantity of material: generally less than 1/8 ounce
- Rate and extent of absorption into the bloodstream
  - routes of exposure:
    - (1) inhalation-- most common for adults
    - (2) oral-ingestion-- most common for children
    - (3) cutaneous
    - (4) subcutaneous
    - (5) intravenous
    - (6) intramuscular
    - (7) intraperitonial-- puncture wounds to the gut sac
- Rate and extent the material is broken down by the body
- Rate and extent the material is excreted by the body

Exposure by Inhalation

- Respiratory system is most potentially hazardous route of intake of poisoning
  - asphyxiants- reduce or eliminate oxygen uptake
  - irritants- mucus, nasal, skin
  - anesthetics- loss of consciousness
  - lacrymators- cause tearing, gagging
- Small volumes within the aveoli and bronchi tend to trap aerosol particles in the micron size range
- Tidal volume of lungs is small compared to stagnant volume- a long time is required to fully exchange
- Strong irritants can cause swelling which closes passageways and produces asphyxiation

Types of Poisoning Effects

- All materials are toxic in sufficient quantity:
  - 5g of caffiene in a single dose is usually fatal to an adult
  - many people drown in water
- Effects versus exposure:
  - acute: short term; immediately obvious
  - chronic: long term; requires repeated exposures
  - latent: requires an incubation period
    - Example: benzene poisoning: delayed onset of aplastic anemia



Measures of Toxicity

- Lethal Dose, 50 % Kill (LD_{50})
  - amount of material which kills 50 % of laboratory animals
  - expressed as mg of poison per kg of animal weight
  - Example: asprin: LD_{50} = 1750 mg/kg
    - 100 kg person will have 50 % chance of death consuming 175 grams
- Lethal Concentration, 50 % Kill (LC_{50})
  - concentration of material in ppm by volume that kills 50 % of laboratory animals during exposure period
- Lethal Dose, Low (LD_{LO})
  - smallest dose ever reported to have caused a fatality
- Lethal Concentration, Low (LC_{LO})
  - smallest concentration ever reported to have caused a fatality

Measures of Toxicity

- Threshold Limit Value, (TLV)
  - upper limit of material concentration that an average healthy person can be exposed to on a continual every day basis without adverse effects
  - expressed as ppm for gases in air
  - expressed as mg/m^3 or $\mu g/m^3$ for fumes or mists in air
  - recommendations set by American Conference of Governmental Industrial Hygienists (ACGIH)

Measures of Toxicity

- Example: carbon monoxide, CO
  - hemotoxin; combines with hemoglobin 300X more readily than O_2
  - TLV = 100 ppm; body can tolerate 0.01 % in air
  - @ 1000 ppm (0.1 %) causes headache and nausea
  - @ 10,000 ppm (1.0 %) fatal to adults in 1 min.
- Example: carbon dioxide, CO_2
  - TLV = 5,000 ppm (0.5 %); present atmosphere is 320 ppm
- Example: hydrogen cyanide, HCN
  - TLV = 10 ppm; 0.2-5.0 ppm is the odor threshold (almond smell)
  - @ 100 ppm, causes death in 1 hr.
  - @ 180 ppm, causes death in 10 mins.
  - @ 280 ppm, immediately fatal

Measures of Toxicity

- Time-Weighted Average TLV, (TWA-TLV)
  - This is a TLV for an 8 hour day, 40 hour work week exposure
- Immediately Dangerous to Life and Health, (IDLH)
  - Defined by OSHA and NIOSH
  - Maximum concentration from which one could escape within 30 minutes without adverse health effects

Notorious Poisons

- carbon monoxide CO TLV = 100 ppm
- carbon dioxide CO_2 TLV = 5000 ppm
- hydrogen cyanide HCN TLV = 10 ppm
- hydrogen sulfide H_2S TLV = 10 ppm
- sulfur dioxide SO_2 TLV = 5 ppm
- nitrous oxide N_2O used for anesthetic purposes
- nitric oxide NO TLV = 25 ppm
- nitrogen dioxide NO_2 TLV = 5 ppm
- ammonia NH_3 TLV = 50 ppm
- arsenic trioxide As_2O_3 0.1 g usually fatal
- tetraethyl lead $Pb(C_2H_5)_4$ 0.075 mg/m^3 via skin
- liquid mercury Hg TLV = 0.1 ppm via skin contact

Changes in Attitudes

- 1970s - 1980s: "Solution to polution is dilution"
- 1990s: "Reduce, reuse, recycle"
- Minimata Bay, Japan: methyl mercury poisoning
  - thousands of people affected: poor health, shortened lifespans, serious birth defects
  - dilution rendered ineffective because marine life re-concentrates the waste materials