

EE-527: MicroFabrication

Toxicity of Materials

Toxicity

- A toxic substance or poison is a material that will produce serious disease or 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

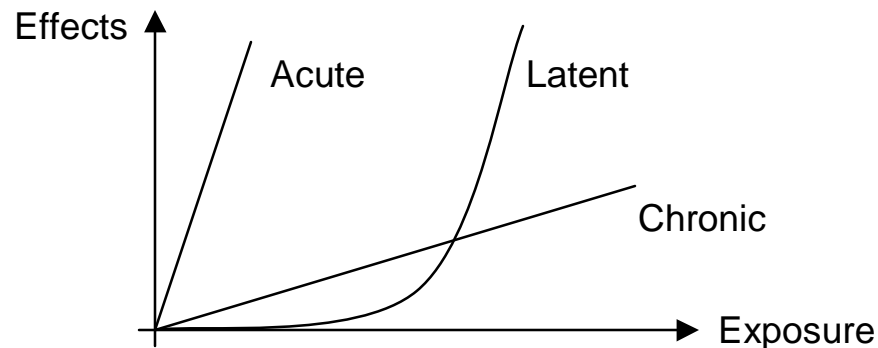
- Quantity of material: generally less than 1/8 ounce
- Rate and extent of absorption into the bloodstream
 - routes of exposure:
 - (1) inhalation-- most common for adults
 - (2) oral-ingestion-- most common for children
 - (3) cutaneous
 - (4) subcutaneous
 - (5) intravenous
 - (6) intramuscular
 - (7) intraperitoneal-- 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 caffeine 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: aspirin: $LD_{50} = 1750$ 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 $\mu\text{g}/\text{m}^3$ 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 O₂
 - 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, CO₂
 - 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 $\text{TLV} = 100 \text{ ppm}$
- carbon dioxide CO_2 $\text{TLV} = 5000 \text{ ppm}$
- hydrogen cyanide HCN $\text{TLV} = 10 \text{ ppm}$
- hydrogen sulfide H_2S $\text{TLV} = 10 \text{ ppm}$
- sulfur dioxide SO_2 $\text{TLV} = 5 \text{ ppm}$
- nitrous oxide N_2O used for anesthetic purposes
- nitric oxide NO $\text{TLV} = 25 \text{ ppm}$
- nitrogen dioxide NO_2 $\text{TLV} = 5 \text{ ppm}$
- ammonia NH_3 $\text{TLV} = 50 \text{ ppm}$
- arsenic trioxide As_2O_3 0.1 g usually fatal
- tetraethyl lead $\text{Pb}(\text{C}_2\text{H}_5)_4$ 0.075 mg/m^3 via skin
- liquid mercury Hg $\text{TLV} = 0.1 \text{ ppm}$ via skin contact

Changes in Attitudes

- 1970s - 1980s: “Solution to pollution 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