Toxicology and Ecotoxicology

DEFINITIONS

1. Toxic Dose: is the lowest dosage per unit of weight (typically stated in milligrams of poison per kilogram of body weight =mg/kg) of a substance known to have produced signs of toxicity in an animal. **Toxicity** is the degree to which something is able to produce illness or damage to an exposed organism.

Example 1: Experiments have shown that 0.075 g of Tylenol (acetaminophen) has toxic effects on 500 gram rats. What is tylenol's toxic dose?

0.075 g * 1000mg / g = 75 mg

75mg /0.500 kg = 150mg tylenol/kg of body weight

2. Lethal Dose: represents a dose (usually recorded as dose per kilogram of subject body weight) at which a given *percentage* of subjects will die.

3. $LD_{50:}$= a dose at which 50% of subjects will die.

Example 2: 50% of 250 g rats die after ingesting 0.0845g of Tylenol. Calculate LD_{50} for Tylenol.

0.0845g * 1000mg / g = 84.5 mg tylenol

84.5mg /0.250 kg = 338 mg/kg

Example 3: A 36 kg dog arrives at a vet's clinic. Its owner caught him eating rat poison. You see from the box of rat poison that the owner brings with him that **the poison is cholecalciferol 0.075%**, and that each of the 50 place packs weighs 30 grams. The owner found the other 3 place packs he had put out intact, and 46 packs remain in the box. Half of one packet was ingested.

Will the dog start to experience symptoms soon?[1] Will the dog die?

toxic dosage = **2 mg/kg = 0.002 g of poison/kg of body mass**

lethal dosage of cholecalciferol =**13 mg/kg = 0.013 g/kg**

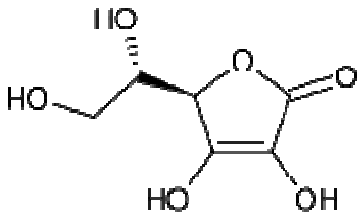
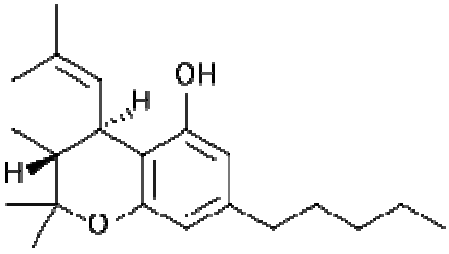
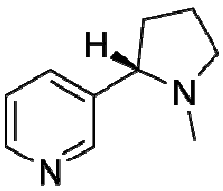
[1] **(It ingested 0.312 mg/kg = 0.000312 g/kg)**

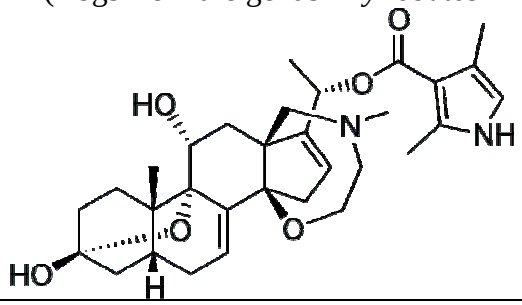
0.5 packet (30 g/packet) = 15 g mixture

0.075% = 0.075/100 = 0.00075(15 g mixture) = 0.01125 g of poison

Concentration of dose received by dog= 0.01125 g of poison/36kg = 0.0003125g/kg < **the toxic dose of 0.002 g**, so the dog should be OK.

Examples of LD 50

Substance	LD_{50} in rats	
	Grams of substance/kg of body mass	Percent of body mass
Vitamin C (ascorbic acid=C_6H_8O6) 	11.9 g/kg	1.19
Grain alcohol (C_2H_6O)	7.06 g/kg	0.706
Table Salt (NaCl)	3 g/kg	0.3
Tetrahydrocannabinol (**C**$_{21}$**H**$_{30}$**O**$_2$) 	1.270 g/kg	0.1270
Nicotine(**C**$_{10}$**H**$_{14}$**N**$_2$) 	0.050 g/kg	0.005

Batrachotoxin($C_{31}H_{42}N_2O_6$) (frogs from the genus *Phyllobates* 	(2 to 7)X 10^{-6} g/kg	0.0000002
Polonium 210 ^{210}Po	1.0 X 10^{-8} g/kg	1.0 X 10^{-9} %
Botulinum toxin ($\mathbf{C_{6760}H_{10447}N_{1743}O_{2010}S_{32}}$)	1.0 X 10^{-9} g/kg	1.0 X 10^{-10} %

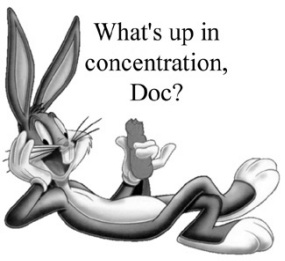
What's interesting about the above table?

- **The poison is the dose. Even salt will become lethal if enough is ingested so that the body's concentration becomes 1/10 of ocean water.**
- **The lower the lethal dose, the more poisonous a substance is. Nicotine is a much more potent poison than THC, and the most dangerous are botulinum and polonium.**

Example 4: Through inhaling smoke, the average smoker takes in 1 to 2 mg of nicotine per cigarette.(Let's use an average of 1.5) How many cigarettes would a 50 kg teenager have to smoke in order to experience a lethal dose?[2] Refer to the LD_{50} table on the previous page.

1.5 mg/cigarette = 0.0015g/cigarette
Amount which will be lethal to teenager= 0.050 g/kg (50kg) = 2.5 g
2.5g (cigarette/0.0015 g) = 1667 cigarettes, which is why cigarettes do not kill immediately. Tobacco companies instead gain from nicotine's addictive properties, leading to very loyal consumers.

4. **Contaminant:** A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful effects to humans or other organisms. For example if **mercury** is above 0.002 mg/L of drinking water it is considered to be a contaminant. Short term exposure to levels above this concentration can lead to kidney damage. Long term effects include damage to the brain and chromosomes.



[2] 1666 cigarettes

Types of contaminants: Microbes ~ Radionuclides ~ Inorganics ~ Volatile Organics ~ Other Gases

Example 5: Give examples of each type:

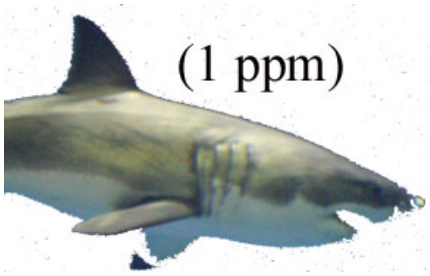
7. **Bioconcentration** refers to the uptake of a chemical from the environment to the organism's tissues so that the concentration in its body tissues is greater than in surrounding environment. The degree to which a contaminant will concentrate in an organism is expressed as a bioconcentration factor (BCF), which is defined as the concentration of a chemical in an organism's tissues divided by the exposure concentration.

Example: **What does a BCF factor of 100 mean?**

The contaminant is 100 times more concentrated in the organism than in the environment.

8. **Bioaccumulation** occurs in the food chain when organisms absorb a toxic substance at a rate greater than that at which the substance is lost. There is subsequently a greater risk of chronic poisoning, even if environmental levels of the toxin are very low. For example, though mercury is only present in small amounts in seawater, it is absorbed by algae(in the form of methyl mercury). It is efficiently absorbed, but only very slowly excreted by organisms. Bioaccumulation results in buildup in the *fatty tissue* of successive trophic levels: zooplankton, small nekton, larger fish etc. Anything which eats these fish also consumes the higher level of mercury the fish have accumulated. This process explains why predatory fish such as swordfish and sharks or birds like osprey and eagles have higher concentrations of mercury in their tissue than could be accounted for by direct exposure alone. For example, herring contains mercury at approximately 0.01 mg/ kg and shark contains mercury at greater than 1 mg/ kg.

(0.01ppm) →



Example 6: a) By what factor did bioaccumulation increase the amount of mercury if we compare herrings to sharks?

1/0.01 = 100

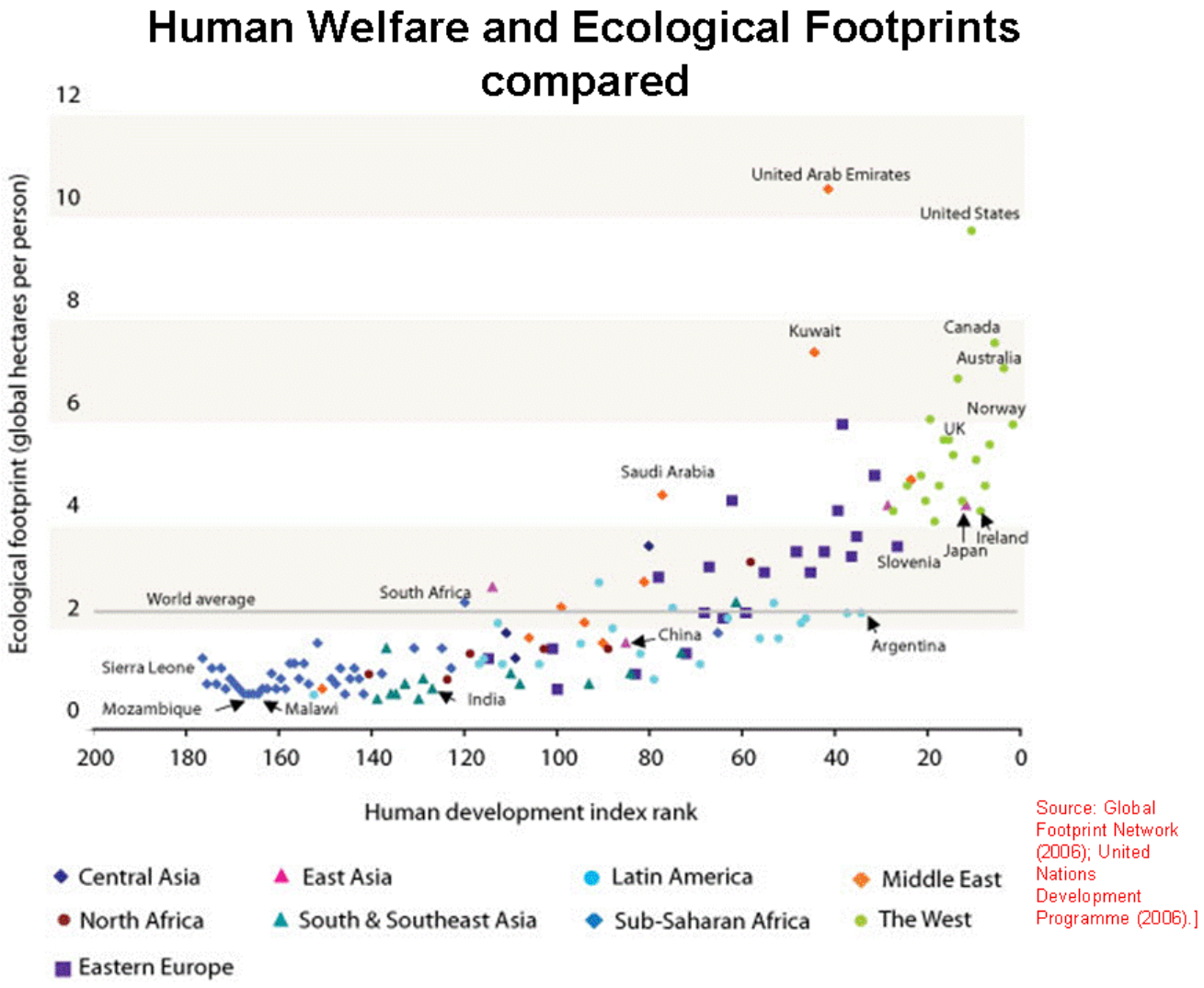
b) Why is 1 ppm = 1 mg/kg ?

1 ppm = 1 part per million
1 mg = 0.001 g
1 kg = 1000g ⟶ **0.001 g/ 1000g = 10^{-6} = $1/10^{6}$**

7. Ecological Footprint

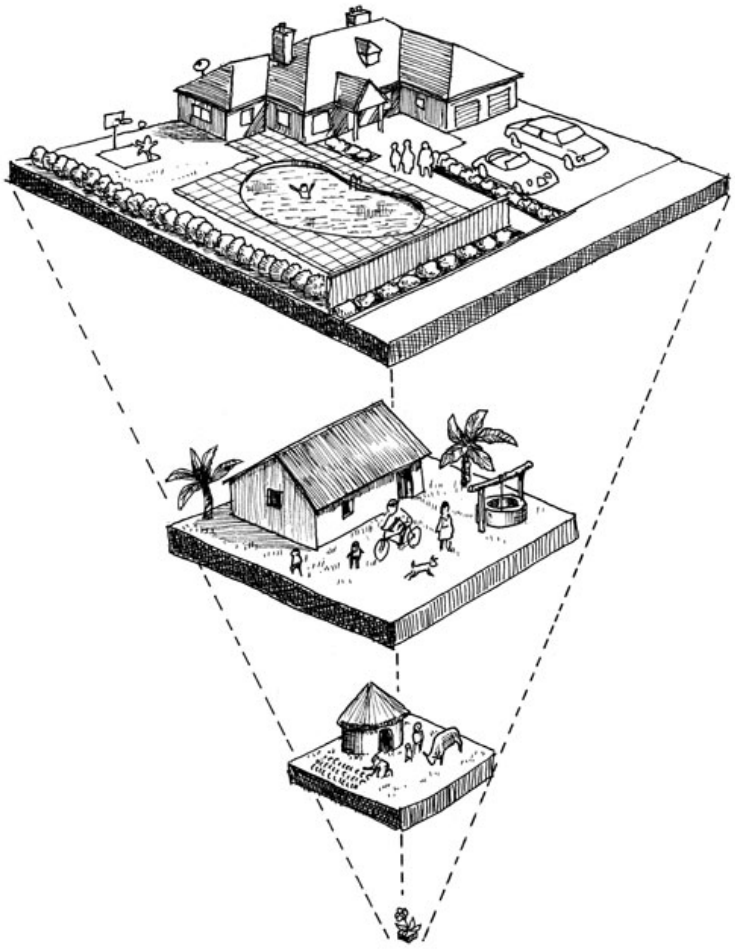
Ecological footprint (*EF*) analysis tries to measure human demand on the Earth's ecosystems and natural resources. Using this assessment, it is possible to estimate how many planet Earths it would take to support humanity if everybody lived a given lifestyle.

In most high-income nations, fossil fuel makes up more than 50 percent of the ecological footprint. This carbon footprint is based on estimating the land area and plants, such as new forests, needed to sequester (recapture) the CO_2 released from burning fossil fuels.



<u>Example 7</u>: Which 5 countries create the largest ecological footprint?

UAE, U.S., Canada, Kuwait, Australia



Example 8 What lifestyles enlarge the ecological footprint?

***Urban living*: commuting, air conditioning, swimming pool, large homes**

Exercises

1. Calculate the toxic dose in mg/kg.

a. 0.15 g of acetaminophen has toxic effects on a 1 kg rat.
b. A minimum of 1 gram of lincomycin (antibacterial drug) has toxic effects a 400 gram mouse.

2. What is the difference between a lethal dose and a toxic dose?

3. What is an LD_{50}?

4. Calculate the LD_{50} for THC, marijuana's active ingredient, if 127 g of THC will kill 50% of men weighing 100 kg

5. Rabbits feeding on lettuce growing above a cadmium dump have become ill. The LD_{50} for cadmium is 75 mg/kg. On average, the rabbits weigh 2 kg. If the lettuce contains 0.01 % cadmium, and each rabbit ate about 125 g of the contaminated lettuce, how close did they come to LD_{50}?

6. Secured bottle caps and locked medicine cabinets in the home can prevent tragic accidents. How many 500mg Advil tablets can be come toxic for a 12 kg toddler? Ibuprofen(Advil) toxic dose = 400mg/kg

7. Do some research and find three water contaminants not mentioned in class.

8. A herring has a concentration of 0.01 mg of mercury per kg of body mass. The water it swims in has a concentration of only 0.0002 mg/kg.

a) Compared to sea water, how much more concentrated is the mercury in the herring? (In other words, what is the BCF factor)?

b) How did it bioaccumulate in the food chain? (Herrings eat small fish and zooplankton. Zooplankton, which are eaten by small fish, eat algae.)

9. How can you create a smaller ecological footprint on a daily basis?

Hint: think of the food you eat, your means of transportation, how you consume energy in your home, how you vacation etc.