Mentoring Advanced placement
Biochemistry

Topic: Toxins

Quick Question:
Against scare of terrorism and nuclear emergency many companies sell readiness kits. These may include iodine tablets to protect against radioactive iodine resultant from nuclear blasts.

Q: If the iodine tablets are exposed to radiation from the blast, same as everything else, what are they preventing?

Challenge:

An old recipe for Snail Killer calls for
20parts Ferrous Sulfate
20parts Ferric Sulfate
45parts Copper Sulfate

- What is the biologic affect of each of these ingredients? Why do they make affective snail control?

A recipe for Grass Killer calls for "strong solution of calcium chloride in water."

- What is the detrimental chemical process involved?

Finally, under Potato Blight Control, "dusting with the following gives good results"
1parts Anhydrous Copper Sulfate
8parts Slaked Lime (calcium hydroxide)

- After researching the affects of snail killer, why might this recipe be an unfortunate choice?

QQ Solution:

Iodine prophylaxis is based on the idea of topping out the body's supply of Iodine before contacting radioactive iodine in fallout. This works because the thyroid gland absorbs radioactive iodine and normal iodine equally.

- If the body's iodine need is satisfied by tablets, all additional iodine will flush out.
- In general, the most harmful fallout affects come from radioactive forms of elements common to the body, or radioisotopes with size and properties similar to the body's atomic building blocks. Incorporation of radioisotopes into the body leads to prolonged and extensive radiation exposure.

Challenge Solution and discussion:

For demonstration, obtain calcium chloride from the chemistry department.
-Take two samples of outdoor grass, replanted in small containers.
-Give both ample light exposure and any water necessary.
-Apply calcium chloride solution to one plant and observe.

- Check with the teacher on disposal of halogenated waste materials. (Hopefully the amount of chlorine is small enough that the plant can conscionably be disposed of in the trash.)

If calcium chloride is not available, the concoction for snails is similar to one for expelling parasitic worms - (magnesium sulfate, calcium sulfate, nicotine, and carrier agents). So, if a test must be done, opt for worms or snails, hopefully nothing more sentient.

- In snail killer, the sulfate ions have little affect, but the metal ions, once freed from their salt complexes, are quite reactive. Iron reacts with peroxides and forms free radicals. Its electrophilicity gives iron a purpose in normal cell function – allowing it to secure O^2 in oxygen transport of red blood cells. But, Iron is always carried by some other agent which shields it from reacting freely. When pesticides introduce iron faster than organisms can attach it to receptacles, destructive reactions take place.

- Copper salts are similar; in small amounts they assist cell production of regulatory free radicals, in large amounts they cause cell death. For more information on coppers apparent role in iron uptake and energy production, see www.physorg.com/pdf76691960.pdf.

"A significant portion of the toxicity of copper comes from its ability to accept and donate single electrons as it changes oxidation state. This catalyzes the production of very reactive radical ions."

"This catalytic activity of copper is used by the enzymes that it is associated with and is thus only toxic when unsequestered and unmediated."
http://en.wikipedia.org/wiki/Copper#Toxicity

- Chlorine is highly reactive. In aqueous solution it readily oxidizes substrates and interrupts existing molecular bonds. With fatty acids, it easily incorporates into unsaturated double bonds. With carbohydrates, it interacts at exposed hydroxyl groups, breaking glucose rings into pieces.

Since plants store energy in the form of starch - glucose chains, and derive structure from cellulose - glucose chains, disruption of glucose molecules has dire consequences.

Reactions of aqueous chlorine and chlorine dioxide with model food compounds.
M Y Fukayama, H Tan, W B Wheeler, and C I Wei,
http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=1474307
See page 268 for an outline of chemical reactions.

- In humans, excessive levels of copper block red blood cell enzyme signaling pathways, causing cell death and hemolysis.

"The great sensitivity of hexokinase to inhibition by copper may be of considerable significance. Already one of the rate-limiting enzymes in glycolysis, inhibition of HK would result in severe impairment of red cell function and might well cause in vivo hemolysis."
http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=302146&tools=bot

- Lime, more or less, digests the potato and causes no harm when eaten. Some latin American cultures even use it in cooking corn.

Copper sulfate, as seen above, affects humans just as it affects potato blight, snails, and other living organisms. The EPA is seemingly lax in regulating use of CuSO4, but the general shift in herbicides and pesticides for the last century has been away from generally reactive molecules and towards one that target a specific step in the life process of a pest organism. Free radical generation, though efficacious, is not terribly elegant.