Radiation Dosage and Natural Radiation

We previously introduced concept of the activity of an isotope, which is a measure of the number of decays/second. The units of activity are 1 Curie = 3.7×10^{10} decays/sec. A more common unit used in our laboratory is a micro-curie, which is equal to 3.7×10^4 = 37,000 decays/sec. Another unit that is used is the Bequerel, 1 Be = 1 decay/sec. Activity is a property of a radioactive isotope, and can be very precisely defined. However, in biology we are also interested in how much damage radiation does to living organisms. We refer to radiation damage as dosage. The more dosage one receives, the more the cells are damaged.

Quantifying dosage is not as straight forward as determining a value for the activity of an isotope. This is because different types of radiation cause damage in cells in different ways. It turns out that a fairly good measure of dosage is the amount of energy the radiation deposits per unit mass of the organism. The more radiation energy absorbed per mass, the more damage is done to the cells, and this is the accepted quantity that one associates with the dosage received. The units of energy absorbption are energy/(mass of tissue), and specifically the most common unit is the Rad:

$$1 \text{ rad} = (100 \text{ ergs of energy absorbed})/(\text{gram of tissue})$$

The rad is a well defined quantity. However, since different types of radiation causes different amounts of damage, the number of rad's do not give a complete picture of how much damage is done to the cells. For example, 1 rad of gamma radiation to an organism will cause less cell damage than 1 rad of alpha radiation. For a more precise description of dosage one multiplies the number of rad received by a factor called the RBE:

$$\text{REM} = (\text{rad})\ (\text{RBE})$$

The acronym REM stands for Roentgen-Equivalent-Man, and is approximately the energy absorbed in tissue equivalent to 1 Roentgen of X or gamma ray radiation. RBE stands for Relative Biological Effectiveness, and is an estimate of the relative damage done by different types of radiation compared to X-rays. We list below the RBE factor for some common types of radiation:

RBE	Type of Radiation
1	for X-rays, gamma, and beta radiation
10	for alpha radiation
3	for slow neutrons
10	for fast neutrons

From the RBE we see that 1 rad of alpha particles does 10 times as much cell damage (10 times the dosage) as 1 rad of gamma radiation. The values of the RBE are not precise well measured quantities. They are estimates, and as our knowledge about radiation damage improves, these numbers might change.

Dosage is a measure of the radiation damage done per gram. So one can talk about dosage received in a certain part of the body, or about whole body dosage. For alpha and beta radiation, which is absorbed near the skin, the dosage is usually localized to a small area near or on the skin. For gamma radiation, which penetrates through the body, one receives dosage throughout the entire body. For medical applications, one wants to deposit the energy of radiation in a very small volume around a cancerous region. For cancer therapy the dosage needs to be very high in a small volume, and zero elsewhere. If an organism absorbs radiation energy, it begins to repair itself. For low dosages, the healing process can be complete. However, if the dosage is too large, permanent damage and even death can occur. Below is a list of dosage levels for a single exposure to radiation in which the whole body absorbs the energy.

One time Whole Body Exposure to Radiation

Dosage	Effects
0 - 25 Rem	No obvious Injury. No detectable clinical effects Probably no delayed effects.
25 - 50 Rem	Possible blood changes, but no serious injury.
50 - 100 Rem	Blood-cell changes, some injury, no disability
100 - 200 Rem	Nausea and fatigue, Injury, possible disability, Shortening of life expectancy
200 - 400 Rem	Injury and disability certain, death possible
400 Rem	50 percent fatal
600 or more Rem	fatal

None of us will hopefully never receive 25 REM, but you might wonder how much radiation we receive in our daily activities. We receive radiation due to natural sources on the earth, cosmic rays, nuclear fallout, and during medical diagnosis (e.g. X-rays). The dosage will vary from place to place, but on the average is it around 250 mRem/year. One mRem = 1 milli-Rem = 0.001 Rem. Specifically, the contribution from the various sources of background radiation are: cosmic rays (around 50 mRem/year), K^{40} (around 100 mRem/year), Uranium and Thorium in the soil (around 40 mRem/year), medical diagnosis (around 50 mRem/year), and nuclear testing fallout (1 or 2 mRem/year). Cosmic ray radiation varies a lot with elevation.

At sea level we are exposed to around 50 mRem/year, and at 20,000 feet elevation, the dosage rate is 560 mRem/year.

For workers in nuclear power plants, nuclear submarines, and other occupations where exposure can be high, the dosage limit set by the U.S. government is 5 Rem/year. If one works 50 hours/week for 50 weeks/year, this dosage comes out to 2 mRem/hour. The 2 mRev/hour is the limit that we have in our laboratory. The radiation safety officer, has to be sure that the sources are properly shielded so that no one is exposed to more than 2 mRem/hour if they work 2500 hours/year or 5 REM/year. Hand held Geiger counters are often calibrated in units of mRem/hour, and can be used used to test work areas. The Geiger counter is, however, usually calibrated for gamma rays from Cs^{137}.

Whenever working with isotopes or nuclear radiation, one should always try to minimize the dosage to be as small as reasonably achievable. An acronym for this safety mentality is *ALARA*: As Low As Reasonably Achievable. The exposure that one receives can be reduced by using as *small of an activity* as possible, by *limiting the time* that one receives exposure, and by keeping yourself as *far away from the sources of radiation* as possible. By minimizing exposure time, maximizing the distance, and minimizing activity used, one can reduce the possibility of radiation damage, and in the laboratory it is important to keep these safety ideas in mind.

Basic Laboratory Safety Rules

1. Eating, drinking and smoking are prohibited in the laboratory.
2. <u>Always</u> wear a monitoring device (your film badge) when working in the lab.
3. Wash your hands immediately after leaving the laboratory. Actually, hands and clothing should be monitored when leaving the laboratory, but since we are using only sealed sources this is probably not necessary.
4. Use tongs or thumb forceps when handling radiosiotopes.
5. All accidents involving personal or work-area contamination are to be reported immediately to the instructor.