Classroom notes for: Radiation and Life

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Types of Irradiation

It is important to distinguish between the different ways of being irradiated.

– **Irradiation by a Source External to Your Body**
You can be irradiated by a source external to your body (remember the six sources of ionizing radiation?). Once you leave the area, you are no longer being irradiated, so the radiation can no longer injure you (remember, the ionizing radiation that irradiated you does not still somehow exist inside you after you’ve been irradiated; it eventually loses its energy by one of the mechanisms previously discussed)

– **Irradiation by a Source Internal to Your Body**
You can ingest or inhale radioactive materials (or have them injected directly into your bloodstream), creating a source internal to your body.
In this instance, you will suffer continuous irradiation, because the source is inside you and continues to emit radiation.

The irradiation will continue until either your body expels the material, or it decays away naturally; thus you may be irradiated over your entire lifetime if your body keeps it (due to its chemical properties) and it has a very long half-life.

- **Irradiation by Contamination on Your Body**

This is a special circumstance, because the source is outside your body, but will continue to irradiate you until washed or wiped off (or it sloughs off).

Contamination events are fairly common, but typically result in small doses (<1 mrem).
Radiation Biology

From USNRC Regulatory Guide 8.29, “Instruction Concerning Risks from Occupational Radiation Exposure”

The potential health effects can be divided into three main categories:

- somatic effects, which are physical effects occurring in the exposed person;
- genetic (“heritable”) effects, which are abnormalities that may occur in the future children of exposed individuals and in subsequent generations (genetic effects exceeding normal incidence have not been observed in any of the studies of human populations); and
- teratogenic effects, which are observed in children who were exposed during the fetal and embryonic stages of development (these effects have been observed at exposures greater than 20 rems)

Many speak of “genetic effects” of radiation when the more precise term is “heritable ill-health”. (Heath Physics, March 2002, p. 383)
Somatic effects can be divided into early effects and delayed effects.

Early effects are observable after receiving a very large dose in a short period of time (an acute dose). A dose to the whole body of about 300-500 rads received over a few hours will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death if medical treatment is not provided. These effects would not occur if the same dose were accumulated gradually over many weeks or months. Thus, one of the justifications for establishing annual dose limits is to ensure that occupational dose is spread out in time.
Delayed effects may occur years after exposure.

- These effects are caused indirectly when the radiation changes parts of the cells in the body, which causes the normal function of the cell to change, for example, normal healthy cells turn into cancer cells. The potential for these delayed health effects is one of the main concerns addressed when setting limits on occupational doses.

- From currently available data, the NRC has adopted a risk value for an occupational dose of 1 rem TEDE of 4 in 10,000 of developing a fatal cancer (one in five adults would normally will die from cancer from all possible causes).

In the absence of scientific certainty regarding the relationship between low doses and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing can cause biological effects that may be harmful to the exposed person and that the magnitude or probability of these effects is directly proportional to the dose (LNT model).
Doses from Manmade and Natural Sources of Ionizing Radiation

Each year, all members of the U.S. population receive a radiation dose.

This dose has two components: natural and manmade.

On average, the total is about 360 mrem.

- 300 mrem (about 82% of total) is from irradiation by natural sources of ionizing radiation.
- 60 mrem (about 18% of total) is from irradiation by manmade sources of ionizing radiation.
Radon 55%

Other (<1%)
- Occupational 0.3%
- Fallout <0.3%
- Nuclear Fuel Cycle 0.1%
- Miscellaneous 0.1%

Cosmic 8%

Terrestrial 8%

Internal 11%

Medical X-Rays 11%

Nuclear Medicine 4%

Consumer Products (3%)
A reasonable question to pose would be: what is the difference between manmade and natural radiation?

The answer is that ionizing radiation of a particular energy will produce a given biological effect regardless of whether it is emitted by a natural or a manmade source. It doesn’t “know” how it was created; there’s no difference between an alpha particle emitted by uranium in rock and an alpha particle emitted by uranium in a nuclear reactor. “A rem is a rem”, whether the radiation source is natural or manmade.

All dose figures in this (and subsequent) sections are stated as if the dose is received over the entire body. In instances where the dose is obviously only received by an individual organ, the dose to that organ is converted and stated as if the dose is received over the entire body. This is essentially a technique that allows for better comparison of doses that may be received by different people to different parts of the body.
Natural Sources of Ionizing Radiation

– Natural ("background") radiation levels have a strong dependence on locality.
– Natural ("background") radiation has four main components.

Radon Gas (200 mrem/yr - 55% of total) (NCRP 93)

Properties

Radon-222 is a colorless and odorless radioactive gas produced in soil by the decay of radium-226, a natural component of all soil. (Radon Public Education and Screening Program, French and Skrable)

– It is odorless and colorless because as a member of the noble gases it is inert (remember that the noble gases have full valence shells).
– The radium in the soil is produced as part of the uranium-238 decay series that we discussed earlier.
Pathways into Homes

Houses (and other buildings) may have cracks in their foundations and basement floors that permit radon gas to seep into them. (Chemistry in the Community 4th Ed., American Chemical Society, p. 442)

In older homes, outdoor air enters through doors, windows, and the gaps around them and thus dilutes the radon or removes it from the house. (Chemistry in the Community 4th Ed., American Chemical Society, p. 442)

However, to conserve energy, new homes are built more air-tight than older homes. In a tightly sealed house, radon gas does not have as many opportunities to escape. Since indoor air cannot mix freely with outdoor air, radon concentrations may reach high levels. As a result, radon poses a problem in some areas because of changes in how homes are built and used. (Chemistry in the Community 4th Ed., American Chemical Society, p. 443)
Some factors that influence the amount of radon in a home are:

- the radium content of the soil;
- the permeability of the soil to radon gas;
- the pathways for entry of radon gas into a home; and
- the type and amount of ventilation in a home

Radon released from well water is usually a minor contributor to the airborne radon level in a home.

*(Radon Public Education and Screening Program, French and Skrable)*
Damage to Tissue

♦ Radon is a noble gas, however, so it poses little danger itself; it will be inhaled and then exhaled without being retained by the body.

♦ However, while in the home, radon will undergo radioactive decay and transform into polonium-218, which itself will decay (Radon Public Education and Screening Program, French and Skrable)

♦ These decay products, or progeny, are not noble gases. They can adhere to particulate matter, and when breathed in, deposit in the lungs (Radon Public Education and Screening Program, French and Skrable)
  – Polonium-218, bismuth-214, and polonium-214 are alpha-emitters.

♦ Remember, alpha particles can’t penetrate the layer of dead skin on the exterior of your body, but the interior of your lungs has no such protection.
The damage that the radon progeny can cause to lung tissue was first observed in uranium miners, who had unusually high levels of lung cancer. (Radon Public Education and Screening Program, French and Skrable)

By the early 1980’s, it was discovered that radon gas can accumulate in homes, as mentioned.

In 1998, the results of the National Academy of Science Biological Effects of Ionizing Radiation (BEIR) VI report were released. The BEIR VI committee identified radon as the second leading cause of lung cancer. (Radon Bulletin, Spring 1998, p. 1)

The committee estimated that 12% of lung cancer deaths in this nation (15,000-22,000/year) are linked to radon. (Radon Bulletin, Spring 1998, p. 1)

These figures, although sobering, should be kept in perspective, however. About 80% of all U.S. lung-cancer deaths annually are attributed to cigarette smoking. (Chemistry in the Community 4th Ed., American Chemical Society, p. 443)
**EPA Corrective Action Guide**

- Based on the studies of lung cancer in uranium miners, and on the practical difficulty and cost of reducing home radon levels to the average outdoor level of 0.5 pCi/L, the U.S. Environmental Protection Agency (EPA) established a Corrective Action Guide for radon. *(Radon Public Education and Screening Program, French and Skrable)*

- The EPA Corrective Action Guide is a yearly average concentration in living areas of 4 picocuries per liter of air (4 pCi/L).

- 1 picocurie (pCi) = 2.22 decays per minute (dpm)
  A concentration of 4 pCi/L over one year translates to a dose equivalent of 1,000 mrem to the whole body. *(Radon Public Education and Screening Program, French and Skrable)*
Testing for Radon

- Passive radon testing devices do not need power to function. They include radon detectors such as charcoal canisters, alpha-track detectors, and charcoal liquid scintillation devices that are available in hardware stores, drug stores, other stores, and by mail, and electret ion chamber detectors generally only available through laboratories. (http://radon-info.com)

  - The Professional Radon Gas Test Kit by PRO-LAB can be used to test for home radon. (http://www.prolabinc.com)

- The Pro–Lab Professional Radon Gas Test Kit utilizes the most advanced liquid scintillation, short–term detectors, which contain silica gel desiccants (patented) necessary to remove all moisture in order to make your test results accurate and reliable. (http://www.prolabinc.com)
The construction is simple:

– plastic bottle and cap; and
– roughing filter to keep out large particulate matter and admit radon; and
– charcoal that admits radon and adsorbs it; and

This method employs a small vial containing activated charcoal for sampling the radon. After an exposure period of 2 to 7 days (depending on design) the vial is sealed and returned to a laboratory for analysis. While the adsorption of radon onto the charcoal is the same as for the AC method, analysis is accomplished by treating the charcoal with a scintillation fluid, then analyzing the fluid using a scintillation counter. The radon concentration of the sample site is determined by converting from counts per minute.

(http://www.nrsb.org/measurement_method_definition.htm)
At the laboratory, the devices are prepared for analysis by radon desorption techniques. This technique transfers reproducibly a major fraction of the radon adsorbed on the charcoal into a vial of liquid scintillation fluid. The vials of liquid scintillation fluid containing the dissolved radon are placed in a liquid scintillation counter and counted for a specified number of minutes (e.g., 10 minutes) or until the standard deviation of the count is acceptable (e.g., less than 10 percent).

Silica gel is silicon dioxide (SiO₂). It is a naturally occurring mineral that is purified and processed into either granular or beaded form. As a desiccant, it has an average pore size of 24 angstroms and has a strong affinity for moisture molecules. The silica gel will pull in moisture at temperatures up to 220°F (105°C). As temperature goes above 100°F, the rate of moisture pick-up will slow down but the silica gel will still work. Silica gel performs best at room temperatures (70° to 90°F) and high humidity (60 to 90% Rh) and will drop the relative humidity in a container down to around 40% Rh. In the United States, silica gel is commonly used in food and pharmaceutical applications as only silica gel has been approved by the FDA for direct contact with these items.
♦ Adsorption and absorption are two different things. Absorption is when a substance is chemically integrated into another. When you drink a glass of water, you are absorbing it, as the water becomes part of you. Adsorption is when one substance is being held inside another by physical bonds. If you spill a glass of water on your shirt, it is adsorbed as the fibers will hold the water until heat dries out the shirt. (http://www.multisorb.com/faqs)

♦ First Alert makes the Radon Test Kit Model RD1, a charcoal test kit which includes lab analysis by an EPA listed lab as part of the price. B.J.’s, Costco, Home Depot, Lowe’s, Sears, Target, and Walmart are some of the stores that carry First Alert products. (http://www.firstalert.com)

♦ If you are interested to learn more information, contact the State of Massachusetts Department of Public Health at 1-800-445-1255.