Units Used When Discussing Radiation and Exposure Limits

When discussing radiation safety, it is necessary to know how radiation is measured. That is basically a discussion of units.

Number of particles

The *curie* (abbreviated Ci) is a measure of the activity of the sample that is the number of nuclear disintegrations in a given time. Specifically the curie is 3.7×10^{10} disintegrations per second, which is the activity of a gram of radium. In the SI system of units, the curie has been replaced by the *becquerel* (Bq) with 1 curie = 37×10^{9} Bq, so a Bq is one disintegration per second.

The activity of a source (in Ci or Bq) is one way to describe the amount of radiation present. An alternative method is to give the *flux* of radiation. That is the number of quanta (alpha, beta, gamma, protons, chickens . . . or whatever) incident on a unit area per unit of time (for example the number of betas incident on 1 cm^2 /s).

Energy despoited

There is another type of radiation unit that is related to the interaction of radiation with living tissue. As radiation passes through matter, it interacts and in general deposits energy in the matter. A *rad* of radiation will deposit 100 ergs of energy for each gram of tissue it passes through. Starting from the activity of a source or the flux of the radiation and converting to rads is not a simple process. This involves details of the interaction between the specific type of tissue and the specific type and energy of the radiation. Recently SI replaced the rad with the *gray* (Gy). A *gray* of radiation will deposit 10,000 ergs of energy for each gram (or 1 J/kg) of tissue it passes through (100 rad = 1 Gy).

Damage caused

Even when losing the same amount of energy in a given bit of living tissue, different kinds of radiation cause different degrees of damage. This is because for some type of radiation a given particle may interact relatively infrequently, but deposits a relatively large amount of energy during each interaction, while a particle of different type of radiation, may interact frequently, but lose only a small amount of energy in each interaction. The energy deposited per gram of tissue may be the same but the damage is different. Thus a further set of units is needed.

The *rem* (roentgen equivalent unit (a roentgen is basically 1 rad of gamma's)) is the standard old unit for radiation damage and the sievert (Sv) is the new SI unit. 100 rem = 1 Sv. The amount of radiation present in Gy, is multiplied by an RBE (relative biological effectiveness) factor to yield the amount of radiation damage in sieverts. The RBE for x rays, gammas and betas is 1, protons it is 10 and for alpha it is 20. Thus the same number of rads or grays of alphas in much more damaging the equivalent amount of gammas.

Note the rem or the sievert do not indicate how quickly the damage was done. So often the radiation field is reported in rem/hr or mrem/ year or Sv/year. Acceptable limits of radiation exposure have decreased over the years as more information on the long term effects of radiation have become available.

Typical Exposures

Typical exposures **per year** to a member of the public may include:

- 35-60 mrem (~0.0005 mrem/hr) from cosmic rays (strong altitude dependance)
- 35-70 mrem (~0.0005 mrem/hr) from natural radioactive sources
- 30-350 mrem (~0.0005 - 0.005 mrem/hr) from all natural radioactivity that includes sources within the body
  - (25 mrem from K^{40},
  - 1 mrem from C^{14},
  - remainder from Ra^{226})
- 100 mrem from medical x-rays.
- 4 to 8 mrem (0.0005 to 0.001 mrem / hr) estimate of exposure in the Physics and Atomospheric Science Building at the University of Arizona.

- 0.001 **mrem/hr** typical poker chip source at one meter.

Legal Limits of Exposure

These limits are set by various government agencies and are subject to change.
For the general public **(Or Students)** the acceptable whole body exposure is:

100 mrem/yr = 1 mSv/yr,

For radiation workers the limit is

5000 mrem / yr.

If the radiation exposure is limited to the skin or extremities, the limit is even higher.

One of our typical "poker chip" sources will produce a radiation field a one meter of about 0.001 mrem/hr. A student working with one of the "poker chip" sealed source would reach their annual full body radiation exposure in about 100 hours. This assumes a distance of one meter and no shielding. Note that there are about 75 hours of advanced lab per semester. Double the distance to two meters and the time increases to 400 hour.