# *INTRODUCTION*

## 1. PURPOSE OF THE RADIATION SAFETY HANDBOOK

The University of Colorado Radiation Safety Handbook (RSH) is intended to be a user's guide for anyone working with radioactive materials and/or ionizing radiation. Radioactive materials and ionizing radiation include unsealed sources, sealed sources and x-rays. The RSH is required by the University's Radioactive Materials License. This chapter will address basic radiation safety concepts including some background information for reference use. It will also address the University's Radioactive Materials License, regulations, and inspections.

## 2. FUNDAMENTALS OF RADIATION SAFETY

Radioactivity is defined as the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable atom. Radiation may be particles [alpha ($\alpha$), beta ($\beta$), neutron (n)] or photons [gamma ($\gamma$), x-ray (x)] emitted from an unstable radioactive atom as a result of radioactive decay. All of these types of radiation are represented at the University of Colorado. Each type of radiation has unique safety considerations and handling techniques that will be discussed in this chapter.

**Background Radiation**
Radiation is part of everyday life. There are many sources of natural "background" radiation, both external and internal. External radiation sources include cosmic (beyond the Earth's atmosphere) and terrestrial (the Earth's contribution) radiation. Internal radiation sources include carbon ($^{14}C$), potassium ($^{40}K$), numerous other minerals which make up bones and soft tissues, and radon deposited in the lungs through inhalation. The average radiation dose from exposure to natural and man-made background radiation in the United States is approximately 3.6 mSv (360 mrem) per year (see **common units** below and the glossary for an explanation of these units). As a rough estimate or rule of thumb, this value doubles for each mile of elevation gain. Therefore, living in Boulder, Denver, or Colorado Springs increases the average background dose to approximately 0.5 – 0.6 mSv (500-600 mrem) per year. The increase is due to a higher contribution from cosmic radiation at higher altitudes and terrestrial radiation.

**Common Units**
There are many units used to describe activity, dose, dose equivalent, and exposure. In the United States, conventional units are still being used, although the complete conversion to the Systeme International (SI) units may happen in the future. At the present time, SI units are used in addition to conventional units on packages and radiation sources. At the University of Colorado, subdivisions of units such as millicuries (mCi) and millirem (mrem) are used along with divisions of SI units such as megabecquerel (MBq) and millisievert (mSv). Both conventional and SI are units are acceptable.

The SI unit of radioactivity is the Becquerel (Bq) which is equivalent to one disintegration or decay per second. The SI unit of dose is a Gray (Gy) and the unit of dose equivalent is a Sievert (Sv), both of which are equivalent to 1 Joule per kilogram by definition. As mentioned previously, not all forms of radiation ($\alpha,\beta,\gamma$, n, x) produce the same biological effect. For example, 1 Gray (Gy) of beta radiation <u>is not</u> equivalent to 1 Gray (Gy) of neutron radiation. However, 1 *Sievert (Sv)* of beta radiation <u>is</u> equivalent to 1 *Sievert (Sv)* of neutron radiation.

The conventional unit for radioactivity is the Curie (Ci). One Curie is equal to $3.7 \times 10^{10}$ nuclear disintegrations or decays per second. Other conventional units include the rad for dose and the rem for dose equivalent. Rad is an acronym for Radiation Absorbed Dose and rem is an acronym for Roentgen Equivalent Man. Dose equivalent was developed in an effort to incorporate biology into the physics of radiation exposure. Not all forms of radiation ($\alpha$, $\beta$, $\gamma$, n, x) produce the same biological effect. For example, 1 rad of beta radiation <u>is not</u> equivalent to 1 rad of neutron radiation. However, 1 *rem* of beta radiation <u>is</u> equivalent to 1 *rem* of neutron radiation. Exposure is defined only for gamma or x-rays in air, not tissue. Roentgen (R) is the unit of exposure. Many radiation survey meters use units of milliroentgen (mR). Please refer to the Glossary for additional clarification of these terms.

**Systeme International (SI) Units**

<u>Activity</u>

1 Bq = 1 disintegration / second
1 Bq = $2.7027 \times 10^{-11}$ Curies
1 kBq = 1,000 Bq = $2.7027 \times 10^{-8}$ Ci
= $2.7027 \times 10^{-5}$ mCi
1 MBq = 1000 kBq = 1,000,000 Bq
= 0.027027 mCi

<u>Dose</u>

1 Gy = 1 J / kg = 100 Rad
1 Gy = 100 centigray (cGy)
1 cGy = 1 Rad

<u>Dose Equivalent</u>

1 Sv = 1 J / kg = 100 Rem
1 mSv = 0.1 Rem = 100 mrem

**Conventional Units**

<u>Activity</u>

1 Ci = $3.7 \times 10^{10}$ disintegrations / second
1 Ci = 1000 mCi
1 mCi = 1000 μCi

1 mCi = 37,000 kBq = 37 MBq

<u>Dose</u>

1 Rad = 100 ergs / gram = 0.01 J / kg
1 Rad = 0.01 Gy

<u>Dose Equivalent</u>

1 Rem = 1000 mrem
1 Rem = 0.01 Sv
1 mrem = 0.01 mSv

## ALARA

A common acronym used in radiation safety is ALARA, which stands for <u>A</u>s <u>L</u>ow <u>A</u>s <u>R</u>easonably <u>A</u>chievable. The ALARA philosophy attempts to incorporate physical, social, and economic factors in reducing doses to individuals. The University of Colorado has an ALARA program which is reviewed each year to evaluate efforts at keeping doses and exposures ALARA. It is the responsibility of each radiation worker to keep the dose to themselves and the people around them ALARA. Refer to Appendix A for a copy of the University's ALARA program.

**Time, Distance, Shielding**
Radiation doses may be reduced by taking advantage of time, distance, and shielding. By reducing the **time** spent working with radioactive materials and/or radiation producing machines, the dose received from the radiation is reduced. Increasing the **distance** from a source also will reduce the dose because the intensity of radiation decreases at approximately $1/d^2$, where d is the distance from the source. For example, if the distance (d) is doubled, the intensity is reduced to ¼ ($d^2$) of the original intensity. This is also known as the Inverse Square Law. **Shielding** can be very effective in reducing the dose received. There are different types of shielding for different types of radiation. Use caution when selecting shielding to reduce the radiation dose. The dose may actually increase by selecting the wrong shielding. Verify radiation levels with a survey meter to ensure that appropriate and/or enough shielding has been used. Health Physics normally does not provide shielding to researchers. However, staff members are available to answer general shielding questions and discuss the efficacy of shielding materials.

**Remember: Time, Distance, and Shielding**
Doses can be minimized by taking advantage of the following simple methods:

1. Reduce the amount of **time** spent near the radioactive material/source
2. Increase the **distance** from the source
3. Use appropriate **shielding** whenever possible