APPENDIX A

RADIATION OVERVIEW

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APPENDIX A RADIATION OVERVIEW

A1 GENERAL

Radiation is energy in the form of electromagnetic waves or subatomic particles. Radiation is emitted from the nucleus or electron cloud of atoms or from devices generating electromagnetic waves and particles such as x-ray machines, neutron generators, and cyclotrons. Radiation is either *ionizing* or *non-ionizing*.

Radiation that has insufficient energy to remove electrons from atoms is non-ionizing radiation. Examples of non-ionizing radiation include most visible light, infrared light, microwaves, and radio waves. Radiation that has sufficient energy to remove electrons from atoms is ionizing radiation. All radiological investigations at HPS have focused on ionizing radiation, which includes alpha, beta, and gamma radiation.

A2 ALPHA RADIATION

Alpha particles are charged particles containing two protons and two neutrons. Alpha particles are emitted from the nuclei of certain heavy atoms, such as uranium, when they decay. Because of its size and heavy electrical charge, +2, an alpha particle can travel only a few centimeters in air. It can be stopped or shielded by a sheet of paper. Alpha particles cannot penetrate the outer layer of skin but can cause localized damage inside the body if ingested or inhaled.

A3 BETA RADIATION

Beta particles are particles with the mass of an electron and a -1 electrical charge; essentially, they are high-velocity electrons. Radioactive isotopes of many different elements emit beta particles. Even though moderate energy beta particles can travel as far as 10 feet through air, they easily can be stopped by a 1/3-inch-thick sheet of plastic or a 1/8-inch-thick sheet of aluminum. Because beta particles can penetrate the outer layer of skin and affect living tissue, they are a hazard to the body's skin and the eyes.

A4 GAMMA RADIATION

Gamma radiation is electromagnetic radiation with no mass or charge. Gamma rays are emitted from the nucleus of an atom during radioactive decay. Because it has no mass or charge, gamma radiation can penetrate most materials. In air, higher energy gamma radiation can travel several hundred feet. Gamma radiation can penetrate the skin and interact with the dense structures of the body. Dense materials such as lead or concrete are needed for shielding against gamma radiation.

A5 X-RAYS

X-rays are also electromagnetic radiation with no mass or charge. The difference between gamma radiation and x-radiation is the nature of their origin. Gamma radiation originates in the nucleus, while x-rays originate in the electron region of the atom. The penetrating properties are the same; therefore, safety concerns and shielding mechanisms are similar. X-rays are typically produced by machines, and thus are not a hazard if the machine is turned off.

A6 SCIENTIFIC NOTATION

Radiation measurement units are normally reported in scientific notation. Scientific notation is also known as exponential notation or power-of-10 notation. It is a concise method of expressing numbers from very small to very large. Scientific notation is the expression of a number raised to a power of 10. For example, 3,456 can be expressed as 3.456×10^3. For the purpose of this HRA, scientific notation is often used when radiation units are reported.

Here is a listing of common numbers expressed in scientific notation:

10^6 = 1,000,000	10^{-1} = 0.1 (1/10)
10^5 = 100,000	10^{-2} = 0.01 (1/100)
10^4 = 10,000	10^{-3} = 0.001 (1/1000
10^3 = 1000	10^{-4} = 0.0001 (1/10,000)
10^2 = 100	10^{-5} = 0.00001 (1/100,000)
10^1 = 10	10^{-6} = 0.000001 (1/1,000,000)
10^0 = 1	

A7 RADIATION UNITS

For this HRA, radiation measurements are stated in units of curies, roentgens, rads, rems, and reps. These units are defined as:

- **Curie (Ci).** The curie measures radioactivity; 1 curie is that quantity of a radioactive material that will have 37,000,000,000 (3.7×10^{10}) transformations in 1 second. Often radioactivity is expressed in smaller units like thousandths (10^{-3}, millicurie or mCi), millionths (10^{-6}, microcurie or µCi), billionths (10^{-9}, nanocurie or nCi), or trillionths (10^{-12}, picocurie or pCi) of a curie.
- **Roentgen (R)**. The roentgen is a unit used to measure exposure. It describes an amount of gamma and x-rays present in air only. The roentgen is a measure of the ionization of the molecules in a mass of air: one roentgen is equal to depositing in dry air enough energy to cause an electrical charge of 2.58×10^{4} coulombs per kilogram (kg) (1 kg = 2.2 pounds). The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition in air and only for gamma and x-rays.
- **Rad (from radiation absorbed dose).** The rad is a unit used to measure absorbed dose. This relates to the amount of energy actually absorbed in some material. It is used for any type of radiation and any material. One rad is defined as the absorption of 100 ergs per gram of material. The unit rad can be used for any type of radiation, but it does not describe the biological effects of different radiations.
- **Rem (from roentgen equivalent man).** The rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in biological tissue to the biological effect. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or millirem (mrem). To determine equivalent dose in rem, absorbed dose (rad) is multiplied by a quality factor (Q) that is unique to the type of incident radiation and the material in which the energy is deposited.
- **Rep (from roentgen equivalent physical).** A unit of absorbed radiation dose equal to the amount of ionizing radiation that will transfer 93 ergs of energy to 1 gram of water or living tissue.

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