Allen, Pam, NMENV

ENTERED

From: Maestas, Ricardo, NMENV
Sent: Wednesday, June 25, 2014 3:49 PM
To: Allen, Pam, NMENV
Subject: FW: WIPP Information - for call today
Attachments: Radiation and Radioactivity WIPP Release 2014.docx

March

From: Skibitski, Thomas, NMENV
Sent: Wednesday, March 12, 2014 4:20 PM
To: Kliphuis, Trais, NMENV; Flynn, Ryan, NMENV; Kendall, Jeff, NMENV
Cc: Tongate, Butch, NMENV; Winchester, Jim, NMENV; Blaine, Tom, NMENV; Schwender, Erika, NMENV; Kieling, John, NMENV; Maestas, Ricardo, NMENV; Holmes, Steve, NMENV; LucasKamat, Susan, NMENV; Nelson, Morgan, NMENV
Subject: RE: WIPP Information - for call today

Aloha,
Discussions about radiation include a bewildering system of units and terms. Please see the attached for a cheat sheet on the differences between radiation and radioactivity; the various units used in measurement; what dose and dose rates mean; and SI prefixes to the units used.

Hope you find it useful...
TS

Radiation and Radioactivity

A number of special terms are used when radiation and radioactivity are discussed. Different terms are used to describe the same properties depending upon the setting or source of information. The term **Sievert (Sv)** or **millisievert (mSv)** will often be encountered in scientific settings where the International System (SI) of units is used where the term **rem (Roentogen Equivalent Man)** or **millrem (mrem)** was otherwise encountered. They both account for the biological effects of radiation on tissue but use a different scale. Equivalencies between the two units are possible by moving the decimal point (100 rem equal 1 Sv).

Radiation is energy released from unstable atoms and some devices in the form of rays or particles. Ionizing radiation (alpha, beta, gamma/x-ray, and neutron) possesses enough energy to cause ionization in the atoms in which it interacts by removing electrons from neutral atoms. Non-ionizing radiation (radio waves, infrared, visible light, radar waves, microwaves) does not have enough energy to ionize atoms with which it interacts.

Radioactivity is the process of unstable (or radioactive) atoms becoming stable by emitting radiation (energy). This event over time is called radioactive decay. Radioactive material is the physical material emitting the radiation and radioactive contamination occurs when that material is uncontained and in an unwanted place. Exposure to radiation will not cause contamination nor will it make something radioactive – with one exception. Neutron radiation will cause certain metals to become radioactive.

Alpha Particles (α)

An alpha particle consists of two neutrons and two protons. This gives the alpha particle a positive charge of two and a relatively large mass. The alpha particle has a very short range of about 1 to 2 inches in air. A single piece of paper or even the outer layer of your skin is enough shielding to stop an alpha particle. Therefore, external alpha particles are not considered to be dangerous. There are, however, serious health hazards if inhaled, ingested, or absorption through an open wound. Some alpha sources include uranium-238, radium-226, and thorium-232. Naturally occurring uranium generally consists of 99.27% uranium-238 and decays by way of alpha emission and has a very long half-life of 4.5 billion years. Uranium-235 makes up about 0.72% of naturally occurring uranium and has a half-life of approximately one billion years and decays by both alpha and gamma emission. The average human intake of uranium is due primarily to food ingestion.

Beta Particles (β)

Beta particles have a charge of negative one and are very small in size, 1/3600 the mass of a proton or neutron. Negative beta particles are also known as electrons. Compared to an alpha particle, a beta particle's range is much greater. The range a beta particle can travel depends upon the energy level of the specific beta emitter. Beta particles can penetrate soft tissues like your eyes and the outer layer of skin. Generally, beta particles can be shielded with plastic, glass, aluminum, or wood. Beta-emitting sources include tritium, lead-214, cesium-137, strontium-90, and potassium-40. Tritium (H^3) is a radioactive isotope of hydrogen consisting of one proton and two neutrons, and has a half-life of 12.3 years. Beta radiation from H^3 has a very low energy and can travel just a few inches in air. However, tritium is a pure beta emitter, and can easily be absorbed through a person's skin. Proper shielding, such as glass or wood, should be used to prevent this absorption.

Gamma-Emitting Radionuclides

Gamma radiation and X-rays originate in the nucleus of the atom and travel by way of electromagnetic waves, similar to light. (Alpha and beta are examples of particle radiation.) Gamma rays have neither charge nor mass and are produced succeeding spontaneous decay of radioactive substances such as cobalt-60 or cesium-137. A gamma ray can travel through the air at long ranges, as much as several hundred feet. Gamma rays, such as from cobalt-60, can penetrate deep into the human body and can therefore be used as the radiation in cancer treatment. Thick shielding is needed for gamma ray protection, for example: lead, steel, or concrete.

Neutron Radiation

Neutron radiation is a kind of ionizing radiation which consists of free neutrons. A result of nuclear fission or nuclear fusion, it consists of the release of free neutrons from atoms, and these free neutrons react with nuclei of other atoms to form new isotopes, which, in turn, may produce radiation.

Neutrons may be emitted from nuclear fusion or fission, or from any number of different nuclear reactions such as from radioactive decay or reactions from particle interactions (such as from cosmic rays or particle accelerators). Large neutron sources are rare, and are usually limited to large-sized devices like nuclear reactors or particle accelerators.

Radiation Units of Measure

Radiation is energy and units associated with radiation include Roentgen, Rad, Rem, Gray and Sievert.

Roentgen (R) (generally pronounced "rent guh n") is an obsolete unit of radiation dosage. It is a unit for measuring exposure, is defined for only ionizing radiation in air, applies only to gamma and x-rays, and is not related to biological effects.

Rad, or "**Radiation Absorbed Dose**," is a unit for measuring absorbed dose in any material and applies to all types of radiation. It does not take into account the potential effect that different types of radiation have on the body (tissue).

The SI equivalent of the rad is the **Gray (Gy)** which also measures radiation absorbed into any material. One gray is the absorption of one joule of energy, in the form of ionizing radiation, divided by one kilogram of matter.

Rem, or "**Roentgen Equivalent Man**," is a unit for measuring dose equivalence. Rem is the most commonly used unit in the United States and takes into account the biological effect on the human body of different types of radiation. Millirem (mrem) is 1/1000 of a rem as microrem (μrem) is one millionth of a rem.

Sievert (Sv) is the SI derived unit of dose equivalent radiation. One rem is equal to 0.01 Sv or 10 millisieverts (10 mSv). One mrem is equal to 0.00001 Sv is equal to 0.01 mSv is equal to 10 μSv.

Radioactivity Units of Measure

Radioactivity is rate of decay and units associated with radioactivity include dpm or dps (disintegrations or decays per minute or second), Curie, and Becquerel.

The basic unit of radioactivity is **disintegrations per minute (dpm)** and is derived from the number of counts measured by an instrument and the instrument efficiency.

The **Curie (Ci)** is a unit of radioactivity and is equal to 2.22×10^{12} dpm or 3.7×10^{10} dps. Because the Curie is a larger unit of measure it will commonly be encountered with a prefix such as milli (mCi), micro (μCi), pico (pCi), and atto (aCi) and often with a unit of mass (/g, /kg) or volume (/ml, $/m^3$).

The SI derived unit of the Curie is the **Becquerel (Bq)** which equals one-decay per second. One Ci is equal to 3.7×10^{10} Bq is equal to 37 GBq (gigabecquerels). One Bq equals 2.7×10^{-11} Ci.

These conversions are easier to grasp when displayed on a spreadsheet.

Dose and Dose Rates

Dose is the amount of radiation you receive.

Dose Rate is the rate at which you receive the dose.

Absorbed dose is the energy absorbed by matter from ionizing radiation expressed in units of rad or gray (1 rad = 0.01 gray).

Dose equivalent is the product of absorbed dose (in rad or gray) in tissue, multiplied by a quality factor (and other modifying factors) and is expressed in units of rem or Sievert. A quality factor (QF) is used as a multiplier to reflect the relative amount of biological damage caused by the same amount of energy deposited in cells by the different types of ionizing radiation. (QF for alpha = 20; for neutrons 2 to 11; betas = 1, gamma and x-rays = 1)

Other terms related to dose:

- **Effective dose equivalent** includes the dose from radiation sources internal and external to the body, expressed in units of rem or Sievert.
- **Committed dose equivalent** is calculated to be received by a tissue or organ in the body over a 50-year period after the intake of the radionuclide into the body, expressed in units of rem or Sievert.
- **Committed effective dose equivalent** is the sum of the committed dose equivalents to various tissues in the body each multiplied by the appropriate weighting factor, expressed in units of rem or Sievert.
- **Total effective dose equivalent (TEDE)** is the sum of the effective dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposures).

What it means

The average exposure or dose received in the United States is about 360 mrem/year or 3.6 mSv/yr. For perspective, the average dose to the mouth from a dental x-ray (panoramic) is between 55 mrem and 70 mrem or 0.55 mSv to 0.7 mSv. A CAT scan of the head will deliver an average dose of about 3 to 5 rem (3,000 mrem to 5,000 mrem) or 0.03 to 0.05 Sv (30 mSv to 50 mSv) and a pack and a half per day cigarette habit will deliver a dose of about 8,000 mrem or 80 mSv per year to the lungs.

Acute exposure effects include slight changes to blood chemistry at 25 to 50 rem (50,000 mrem) or 250 to 500 mSv. Radiation sickness occurs at 100 to 200 rem or 1,000 to 2,000 mSv (1 Sv to 2 Sv). Blood system damage occurs at 200 to 500 rem or 2 to 5 Sv and gastrointestinal damage occurs at levels over 500 rem or 5 Sv (5,000 mSv).

The LD 50-60 (lethal dose to 50% of the exposed population in 60 days) occurs with an exposure of 450 to 600 rem or 4,500 to 6,000 mSv (4.5 Sv to 6 Sv). Death within 2 to 3 days occurs after an exposure of greater than 5,000 rem or greater than 50,000 mSv (50 Sv).

Acute effects from short-term, high-level (activity) exposure to radiation usually appear quickly, causing what is known as radiation sickness, which includes symptoms like nausea (at 500 mSv), vomiting (700 mSv), hair loss within two weeks (750 mSv), and skin burns. If the dose is fatal, death usually occurs within 2 months.

As an example, while radioactive contamination from the excursion at the Fukushima Daiichi nuclear power plant in Japan is measureable, effects in the U.S. are lost in the variability of the amount of ambient radiation to which we are routinely exposed on a daily basis. The same is likely true locally for the recent release at WIPP. In most cases and for most people, the greatest exposure over a life time is due to radon gas.

Metric (SI) Prefixes

Decimal	Scientific Notation	Name	Factor	Prefix	Symbol
10	1.00E+01	Ten	E01	deka	da
100	1.00E+02	Hundred	E02	hecto	h
1,000	1.00E+03	Thousand	E03	kilo	k
1,000,000	1.00E+06	Million	E06	mega	m
1,000,000,000	1.00E+09	Billion	E09	giga	g
1,000,000,000,000	1.00E+12	Trillion	E12	tera	t
1,000,000,000,000,000	1.00E+15	Quadrillion	E15	peta	p
1,000,000,000,000,000,000	1.00E+18	Quintillion	E18	exa	e
0.1	1.00E-01	Tenths	E-01	deci	d
0.01	1.00E-02	Hundredths	E-02	centi	c
0.001	1.00E-03	Thousandths	E-03	milli	m
0.000001	1.00E-06	Millionths	E-06	micro	μ
0.000000001	1.00E-09	Billionths	E-09	nano	n
0.000000000001	1.00E-12	Trillionths	E-12	pico	p
0.000000000000001	1.00E-15	Quadrillionths	E-15	femto	f
0.000000000000000001	1.00E-18	Quintillionths	E-18	atto	a