Radiation Detection Overview

[alpha, beta and gamma particles]

Types of Radiation Decay

Radioactive materials decay via three means, alpha particle emission (alpha decay), beta particle emission (beta decay) and gamma photon emission (gamma decay). A given isotope will always decay via the same means, and may produce "daughter" products as a result of that decay which themselves may be radioactive, and which will decay by the same or a different means than the parent isotope.

The three main types of nuclear radiation emitted from radioactive atoms are alpha, beta and gamma particles.

- Alpha particles are electrically-charged particles and are the least penetrating of the three primary forms of radiation, as they cannot travel more than four to seven inches in air and a single sheet of paper or the outermost layer of dead skin that covers the body will stop them. However, if alpha particle emitting radioactive material is inhaled or ingested, they can be a very damaging source of radiation with their short range being concentrated internally in a very localized area.
- Beta particles are electrically-charged particles and travel faster and penetrate further than alpha particles. They can travel from a few millimeters up to about ten yards in open air depending on the particular isotope and they can penetrate several millimeters through tissue. Beta particle radiation is generally a slight external exposure hazard, although prolonged exposure to large amounts can cause skin burns and it is also a major hazard when interacting with the lens of the eye. However, like alpha particles, the greatest threat is if beta particle emitting radioactive material is inhaled or ingested as it can also do grave internal damage.
- Gamma rays are similar to x-rays; they are a form of electromagnetic radiation. Gamma rays are the most hazardous type of external radiation as they can travel up to a mile in open air and penetrate all types of materials. Since gamma rays penetrate more deeply through the body than alpha or beta particles, all tissues and organs can be damaged by sources from outside of the body. Only sufficiently dense shielding and/or distance from gamma ray emitting radioactive material can provide protection.

Based on the dangers to life and health of gamma emissions, gamma emitting radioactive substances are a likely choice to be used in a "dirty bomb". The remainder of this white paper will focus on gamma emissions.

Gamma Radiation Protection

The only method of reducing effects of gamma radiation is through shielding and/or distance from the gamma radiation source.

Shielding

Shielding of gamma emissions can be accomplished to some extent by using relatively large thicknesses of dense materials. For instance, a 1/2" lead barrier would reduce, by approximately one half, the intensity of gamma radiation from a 1.0MeV source (a source which emits gamma photons with an energy of 1.0MeV). Put another way, a 1/2" thick sheet of lead will prevent the passage of 1/2 of all gamma photons with an energy of 1.0MeV. A 4" concrete wall or 8" of water would be required to provide the same attenuation.

Distance

A homogeneous radiation source will, on average, radiate in all directions equally. For this reason, the intensity of the radiation field will decrease with the square of the distance from the source. For instance, the field intensity 10 meters from a radiation source will be only 1% of the field intensity 1 meter from the source.

Background Radiation

Natural background levels of gamma radiation are present everywhere on earth. This radiation results from naturally occurring radioactive elements found in soil, rocks and even animals and humans, as well as radiation received through the Earth's atmosphere from space.

Measuring Radiation

As in most measurement quantities, certain units are used to properly express the measurement. For radiation measurements they are:

- Roentgen: The roentgen measures the energy produced by gamma radiation in a cubic centimeter of air. It is usually abbreviated with the capital letter "R". A milliroentgen, or "mR", is equal to one one-thousandth of a roentgen. An exposure of 50 roentgens would be written "50 R".
- Rad: Or, Radiation Absorbed Dose recognizes that different materials that receive the same exposure may not absorb the same amount of energy. A rad measures the amount of radiation energy transferred to some mass of material, typically humans. One roentgen of gamma radiation exposure results in about one rad of absorbed dose.
- Rem: Or, Roentgen Equivalent Man is a unit that relates the dose of any radiation to the biological effect of that dose. To relate the absorbed dose of specific types of radiation to their biological effect, a "quality factor" must be multiplied by the dose in rad, which then shows the dose in rems. For gamma rays and beta particles, 1 rad of exposure results in 1 rem of dose.

Other measurement terms include Standard International (SI) units which may be used in place of the rem and the rad are the sievert (Sv) and the gray (Gy). These units are related as follows: 1Sv = 100 rem, 1Gy = 100 rad. Two other terms which refer to the rate of radioactive decay of a radioactive material are curie (Ci) and becquerel (Bq).

MSA

For purposes of practical radiation protection in humans, most experts agree (including FEMA Emergency Management Institute) that Roentgen, Rad and Rem can all be considered equivalent.

Radiation Detection

Instruments that measure **exposure rate**, or the intensity of radiation at a location at some point in time, include survey meters, field survey meters, rate meters, radiac meters, radiation detection meters, low-range meters, high-range meters, airborne meters, fallout meters, remote monitors, and Geiger counters. All of these above 'meters' indicate radiation intensity readings relative to time, such as R/hr or mR/hr. It's also similar to the speedometer of a car, where both measure an accumulation of units over time. If you entered a radioactive area and your meter read 60 R/hr that would mean if you were to stay there for a whole hour you would be exposed to 60 R. Same as driving a car for an hour at 60 mph, you'd be 60 miles down the road after that hour.

Instruments that measure **exposure**, or the total accumulated amount of radiation to which one is exposed, include dosimeters that take the form of a badge, pen/tube type, or even a digital readout. It's also similar to the odometer of a car; where both measure an accumulation of units. The dosimeter will indicate a certain total number of R or mR exposure received, just as the car odometer will register a certain number of miles traveled.

Expected health effects for an adult assuming the cumulative total radiation exposure was all received within a week's time. For children, the effects can be expected at half these dose levels.

Total Exposure	Onset and Duration of Initial Symptoms and Disposition
30 to 70 R	From 6-12 hours: none to slight incidence of transient headache and nausea vomiting in up to 5 percent of personnel in upper part of dose range. Mild lymphocyte depression within 24 hours. Full recovery expected. (Fetus damage possible from 50R and above.)
70 to 150 R	From 2-20 hours: transient mild nausea and vomiting in 5 to 30 percent of personnel. Potential for delayed traumatic and surgical wound healing, minimal clinical effect. Moderate drop in lymphocyte, platelet, and granulocyte counts. Increased susceptibility to opportunistic pathogens. Full recovery expected.
150 to 300 R	From 2 hours to three days: transient to moderate nausea and vomiting in 20 to 70 percent; mild to moderate fatigability and weakness in 25 to 60 percent of personnel. At 3 to 5 weeks: medical care required for 10 to 50%. At high end of range, death may occur to maximum 10%. Anticipated medical problems include infection, bleeding, and fever. Wounding or burns will geometrically increase morbidity and mortality.
300 to 530 R	From 2 hours to three days: transient to moderate nausea and vomiting in 50 to 90 percent; mild to moderate fatigability in 50 to 90 percent of personnel. At 2 to 5 weeks: medical care required for 10 to 80%. At low end of range, less than 10% deaths; at high end, death may occur for more than 50%. Anticipated medical problems include frequent diarrhea stools, anorexia, increased fluid loss, ulceration. Increased infection susceptibility during immune-compromised time-frame. Moderate to severe loss of lymphocytes. Hair loss after 14 days.
530 to 830 R	From 2 hours to two days: moderate to severe nausea and vomiting in 80 to 100 percent of personnel; From 2 hours to six weeks: moderate to severe fatigability and weakness in 90 to 100 percent of personnel. At 10 days to 5 weeks: medical care required for 50 to 100%. At low end of range, death may occur for more than 50% at six weeks. At high end, death may occur for 99% of personnel. Anticipated medical problems include developing pathogenic and opportunistic infections, bleeding, fever, loss of appetite, GI ulcerations, bloody diarrhea, severe fluid and electrolyte shifts, capillary leak, hypotension. Combined with any significant physical trauma, survival rates will approach zero.
830 R Plus	From 30 minutes to 2 days: severe nausea, vomiting, fatigability, weakness, dizziness, and disorientation; moderate to severe fluid imbalance and headache. Bone marrow total depletion within days. CNS symptoms are predominant at higher radiation levels. Few, if any, survivors even with aggressive and immediate medical attention.

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