Appendix 4

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RADIOLOGICAL DEFENSE SERIES

A DIGEST OF TECHNICAL INFORMATION

# PROTECTION AGAINST FALLOUT RADIATION

**This technical bulletin, one of a series on radiological defense, describes the phenomena of radioactive fallout, and gives basic precautions to be taken by people caught in the open or required to remain in contaminated areas.**

When an atomic or thermonuclear device is detonated near the ground, great masses of pulverized debris are sucked upward, sometimes to heights of 80,000 feet or more. Radioactive material released by the explosion and vaporized by its heat condenses on the tiny debris particles and is subquently carried back to earth as dust. This is fallout.

Radioactive fallout has a physical behavior and appearance similar to any other dust with the same particle sizes and distribution. The time it takes to fall back to earth after the explosion varies from a few minutes to many hours, depending on the size of the particles and where they were in the cloud. Where it falls depends on the velocity and direction of winds in the altitudes through which it has traveled. The duration of fallout also varies, depending on the same conditions.

In general, fallout descends vertically. However, it will be diffused and if a wind is blowing, will travel in a lateral direction with the wind. Therefore, during fallout, both overhead and side protection are necessary. Since not all dust particles may be visible to the naked eye, the only certain method of determining whether or not fallout is present is detection by radiological instruments. After an atomic attack, dust clouds or unusual dust concentrations in the atmosphere should be assumed to be radioactive until they have been officially surveyed with such instruments.

## COMPONENTS OF RADIOACTIVE FALLOUT

Radioactive material released by an atomic explosion consists of: (1) particles created by the fissioning of the material of the bomb, (2) particles made radioactive by the neutrons released at the time of explosion, and (3) the unfissioned material of the bomb itself. The unfissioned material is generally alpha-emitting, while the fission products and the neutron-induced radioactive products are beta-gamma-emitters.

(1) Alpha radiation cannot penetrate the skin. Consequently the alpha-emitters in fallout present no great danger unless taken into the body by ingestion, inhalation, or through open wounds. The relative proportion of alpha-emitters in fallout to beta-gamma-emitters is small.

(2) Beta radiation can be dangerous both internally and externally. The beta particles emitted by fallout are stopped by moderately thick clothing. They are most hazardous when the radioactive dust carrying them comes into direct contact with the skin or is taken internally.

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(3) Gamma rays, like x-rays, are very penetrating. Fallout gives off gamma rays varying in energy from very soft and easily absorbed, to very hard and penetrating. Therefore, even relatively thin shields afford some protection against gamma rays since they absorb the softer components of the radiation. To provide adequate protection against the more energetic gamma rays, considerable thicknesses of materials are required.

## PROTECTION FROM FALLOUT

Three basic measures give progressively greater protection against fallout radiation.

(1) *Protection from radioactive dust.* Persons caught in fallout should take any cover available. The dust may descend from the atmosphere or be stirred up by the wind, traffic movement, or other means. It should be kept off the skin and from entering the body. Persons caught in the open should cover their mouths with handkerchiefs and protect all parts of their bodies, so far as possible. The dust should be brushed or washed off immediately.

(2) *Additional protection against beta and low energy gamma rays.* Since the most severe dose from the beta radiation occurs if the radioactive particles are in direct contact with the skin, the primary precaution of keeping it off or washing it off as pointed out in (1) above should be followed. Moderate thicknesses of material, such as heavy shoes and clothing, provide additional protection. After the fallout has settled, the dust, although primarily on the ground, will cling to ledges and to a lesser extent to the sides of buildings. Extreme care should be taken to avoid contact with it either by touching or bringing the unprotected face close to it. When it is necessary to walk through or work in a contaminated area, heavy clothing and heavy shoes or boots should be worn. Beta radiation is rapidly absorbed in the air, thus distance provides good protection—four or five feet will stop most of the beta radiation from fallout.

(3) *Protection against gamma radiation;* The basic requirement for protection against any radiation is to get material between you and the source of the radiation so its energy will be absorbed before it gets to you. The greater the thickness and the denser the material, the better. The concept of "half-thicknesses" is useful in understanding the absorption of gamma radiation. If a particular thickness of material, say one-half inch of lead, reduces the gamma intensity by one-half, the next half inch will not reduce the intensity to zero, but will cut it by another half, giving a total reduction of three quarters. The next "half-thickness" would give a reduction to one-eighth, the next to one-sixteenth, etc. Theoretically, the intensity would never go to zero. However, for practical purposes a reduction to zero is not required.

A reduction of about 5000 will give adequate protection from gamma rays from fallout. This would require about 12 "half-thicknesses", for example, about 36 inches of earth, 24 inches of concrete, or 3 inches of lead. Twelve "half-thicknesses" made up of combinations of materials would give the same protection. A "half-thickness" of air is about 200 feet.

Obviously this third measure, which gives the greatest protection, is the most desirable. However, if this is not possible, the other precautions should be rigorously observed. The degree of protection they afford is significant and could provide the margin of safety that would save lives.

Gamma radiation travels in straight lines, but like light it can be scattered around corners. The amount of energy scattered will depend on the angle, size of the opening and distance from the point of scatter. For example, if the opening is the size of an ordinary door, the angle of scatter 90°, and point of measurement about three feet along either side of the opening, the radiation would be reduced to about one or two percent. Another 90° angle of scatter would further reduce the dose rate to two percent of two percent or about 4 ten-thousandths (0.0004). Thus, a winding entrance or one of the maze type into a building or cave, would provide significant protection. Of course, the dust must be kept out, since it is the source of the radiation.

As fallout accumulates, the dose rate builds up, since more of the emitting material will be in the immediate vicinity—in the air and on the ground. After the material has settled, however, the dose rate will begin to decrease through natural decay of the radioactive elements.

Studies made to determine the rate at which this decay occurs have indicated that the following equation is generally applicable:

$I = I_1 t^{-1.2}$ where I is the radiation dose rate at any time t, $I_1$ the dose rate at unit time, and t the time measured from the instant of detonation.

However, this holds only if the fallout radiation is composed of fission products. It will be changed if neutron-induced activity is present. Weathering also will have a pronounced effect. However, the $t^{-1.2}$ calculation can be used for rough planning purposes and provides a basis for predicting dose rates and doses. To facilitate calculations, charts and slide rules have been developed. (Slide rules are available commercially; charts will be contained in a subsequent bulletin in this series.) In an operational situation, it would be necessary to make periodic measurements to follow the rate of decrease and to use dose measuring devices for determining the doses accumulated by people in the area.

If slide rules and charts are not available, very rough predictions of expected radiological situations can be made, using the rule of thumb that dose rate will vary inversely with time. Time may be expressed in any convenient unit—days, hours, minutes.

As examples:

If the dose rate is measured 1 hour after burst as 60 r/hr (the roentgen is the unit of radiation measurement) it would reduce to 1/2 (30 r/hr) at 2 hours after burst; to 1/3 (20 r/hr) at 3 hours; and to 1/4 (15 r/hr) at 4 hours; etc. (*If* $t^{-1.2}$ *is used in the calculation and the dose rate is* 60 *r/hr at* 1 *hour, the dose rate would be* 26 *r/hr at* 2 *hours,* 16 *r/hr at* 3 *hours,* 11.5 *r/hr at* 4 *hours,etc.*).

If the dose rate is measured at 16 hours its value at 17 hours would be 16/17 (0.94) of the measured 16-hour value; at 18 hours, 16/18 (0.89) etc. (*Using* $t^{-1.2}$ *the dose rate would be* 0.93 *at* 17 *hours,* 0.87 *at* 18 *hours, etc.*)

If measured at 3 days, the dose rate would be 1/3 that measured at one day; at 4 days, 3/4 (0.75) the measured 3-day value; at 5 days, 3/5 (0.60) etc. (*Using* $t^{-1.2}$ *the dose rate at* 4 *days would be* 0.71 *that measured at one day, at* 5 *days* 0.54; *etc.*)

Doses may be calculated by using the average intensities between the times in question and multiplying by the time of exposure.

In the first example above, the dose between one and three hours would be $\frac{60 + 20 \text{ r/hr}}{2} \times 2$ hours, or 40 r/hr $\times$ 2 hours = 80 roentgens. (*Using* $t^{-1.2}$ *the dose would be* 60 *roentgens.*)

Greater mathematical accuracy may be obtained by taking more points for the average. However, mathematical refinement is not necessary since this is an approximation.

This rough method gives answers which are on the safe side as compared with those obtained by using the more complicated formula. Any of these equations, no matter how complex, is good only for estimates. Answers must be obtained through actual measurement.

# REFERENCES

The Agency designation "Federal Civil Defense Administration" (FCDA) on publications listed below will be changed to "Office of Civil and Defense Mobilization" (OCDM) as the publications are revised.

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