Fallout From a Nuclear Explosion

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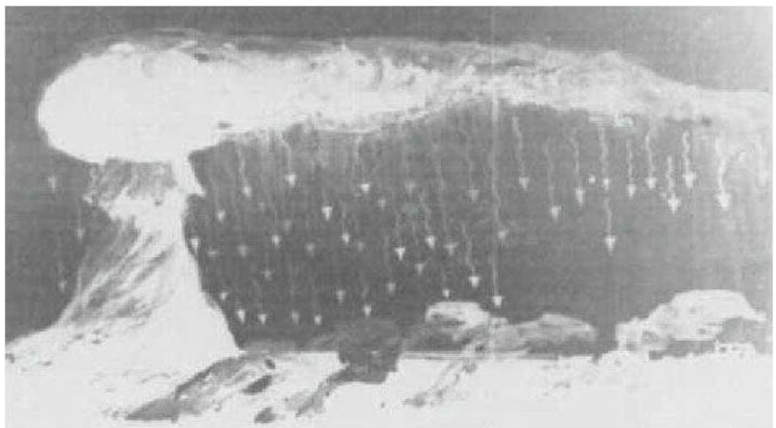

Figure 1. Fallout is distributed downwind from the blast site in a plume-like pattern.

Introduction

This is the third in a series of short articles describing possibilities for a terrorist-initiated attack involving radioactive material or a small nuclear fission weapon. The series includes information about fallout, anticipated post-attack dose rates resulting from various scenarios, suggested individual preparations for such an attack, and many other topics. Much of the information for these articles comes from Civil Defense information published in the 1950s and 1960s and from various Internet sites, but a lot of it is also based on common sense and over 40 years of experience in health physics.

Radioactive Fallout

Fallout is radioactive dust created when a nuclear weapon explodes. A nuclear explosion vaporizes any material within the fireball, including soil, rocks and building materials in the case of a ground burst. When this material condenses in the cloud, it forms dust and light sandy material that resembles ground pumice. This highly radioactive material then falls to earth. The fallout emits gamma rays in all directions. The closer to the ground an atomic bomb is detonated, the more dust and debris is thrown into the air, resulting in greater amounts of fallout. See Figure 1.

The ground track of fallout from a nuclear explosion is a long, fuzzy ellipse downwind of the explosion. It may be a hundred miles long, and up to 30 miles wide from a single explosion. Wind and weather conditions will determine the size and shape of the plume. See Figure 2.

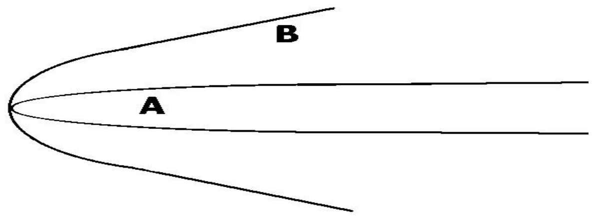

Figure 2. Plume pattern under strong steady wind conditions (A); and with light variable winds (B).

Rain in the area can cause fallout to settle more quickly. This means that a rainstorm can nearly eliminate airborne hazards, but create other significant pathway hazards to those just downwind of a nuclear explosion.

Potential radiation doses caused by fallout radiation and the possible biological consequences of these doses will be covered in a future article in this series.

Constituents of Fallout

Radioactive fallout contains three components:

- Fission products;
- Activation products; and
- Unfissioned weapon material (uranium and/or plutonium).

Fission Products. Each time uranium or plutonium atoms fission they break into two smaller atoms called fission products. These are all radioactive. The main radiation hazard (after the initial 3-minute burst of gammas and neutrons from the detonation) is the fission products produced during the explosion that fall back to earth downwind from the hypocenter. Many of these radionuclides have short half-lives, which means that they decay (i.e., become non-radioactive) quickly. As a general rule, those fission products with the shortest half-lives emit high-energy beta particles and gamma rays. Roughly 90% of the gamma radiation will be gone after the first 7 hours, and 90% of the remaining 10% will be gone after two or three days. There will be so much radioactive fallout in the area of the plume that radiation levels will be very intense during this 2- to 3-day period. After two weeks there would be only $\frac{1}{1000}$ of the gamma radiation remaining.

The longest-lived fission products are Strontium-90 and Cesium-137. Both have half-lives of about 30 years. Since Strontium-90 and its radioactive daughter Yttrium-90 both decay by beta particle emission with no accompanying gamma ray, Cesium-137 (Ba-137m) is usually relied upon as the marker radionuclide since it emits a strong (and easy-to-detect) gamma ray when it decays. These radioisotopes and a handful of others will need to be cleaned up to some extent before contaminated land and structures can be used again. If left alone, these long-lived fission products would decay to 10% of their original activity in 100 years, and to 1% in 200 years.

Activation Products. The initial burst of neutron radiation from the detonation will make a number of materials radioactive. Many metals (e.g., iron, aluminum, copper, gold, etc.) and minerals (e.g., sodium, potassium, calcium, etc.) in structural materials and in the earth can become radioactive in this way.

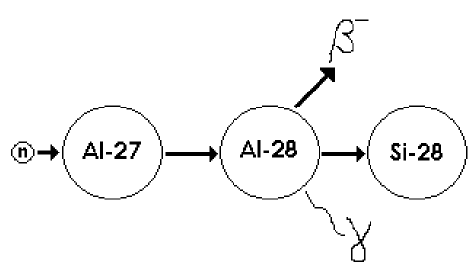

Figure 3. Neutron activation of natural aluminum resulting in radioactive Al-28 (2.24-minute half-life).

Most of these activation products have relatively short half-lives and will therefore contribute significantly to the radiation levels at the blast site and in the fallout plume during the first few days. Radioactive aluminum-28 (Figure 3) decays with a half-life of 2.24 minutes and emits a high-energy beta particle (2.9 MeV) and a high-energy gamma ray 1.8 MeV). As with fission products, those activation products with the shortest half-lives usually emit the highest energy beta particles and gamma rays.

Also, uranium and plutonium from the bomb that is not fissioned might become neutron-activated and form other radioactive transuranic radionuclides of neptunium, plutonium, americium, curium, etc. Since most of these transuranic radionuclides decay by alpha particle emission, they will contribute little to the direct radiation field. Alpha emitters typically produce very little gamma radiation, and what is produced is generally of very low energy. Inhalation and ingestion of these alpha emitters are to be avoided. When these radionuclides are present in a person's body, each alpha particle decay delivers 20 times the dose that either a beta particle or a gamma ray would deliver.

Unfissioned Uranium or Plutonium. Finally, not all of the uranium or plutonium in the bomb will fission or become activated. Some of it will also be present in fallout. Since the half-lives of these radionuclides are very long (i.e., millions of years) they will contribute very little to the direct radiation fields encountered, but their presence will emphasize the need for persons working in and near these areas to wear respirators. During the cleanup and recovery phase, it will be important to minimize the amount of these radionuclides that get into food and drinking water. Note that inhaled or ingested plutonium is not a guaranteed death sentence. It is not a strong poison as is popularly reported, but inhalation and/or ingestion will add to an individual's radiation dose.

Small Nuclear Explosion Compared to the Chernobyl Accident

An atomic bomb explosion results in a great amount of damage due to blast and fire, followed by the highly radioactive fallout. At Chernobyl there was no nuclear detonation so the initial local damage was limited to the Unit 3 Reactor Building and adjacent structures. However, the amount of radioactive material released during the accident was far more than would have resulted from a nuclear explosion. An atomic bomb contains perhaps a few kilograms of weapons-grade Uranium or Plutonium. Chernobyl's reactor core contained tons of this material. Also, since the reactor had operated continuously for several months before the accident, there was a large inventory of fission products in the core. The fire in the reactor core burned for approximately three weeks and a huge quantity of fallout was produced. Large areas around the power plant had to be abandoned and contamination was spread as far as Western Europe, Africa and the Far East.

The Author

K. Paul Steinmeyer is the founder and president of Radiation Safety Associates, Inc., and president of RSA Laboratories. He began his career more than 30 years ago as a reactor operator on a nuclear-powered submarine. His experience in the nuclear industry includes consulting work for the U.S. Nuclear Regulatory Commission, the United Nations Development Programme, the International Atomic Energy Agency, and numerous materials licensees. He is a Registered Radiation Protection Technologist (NRRPT), a member of the Health Physics Society, and serves as senior editor for *Radiation Protection Management* and *RSO Magazine*. Paul is the co-author of *Mathematics Review for Health Physics Technicians*.