Risk from Plutonium in the Environment at Rocky Flats

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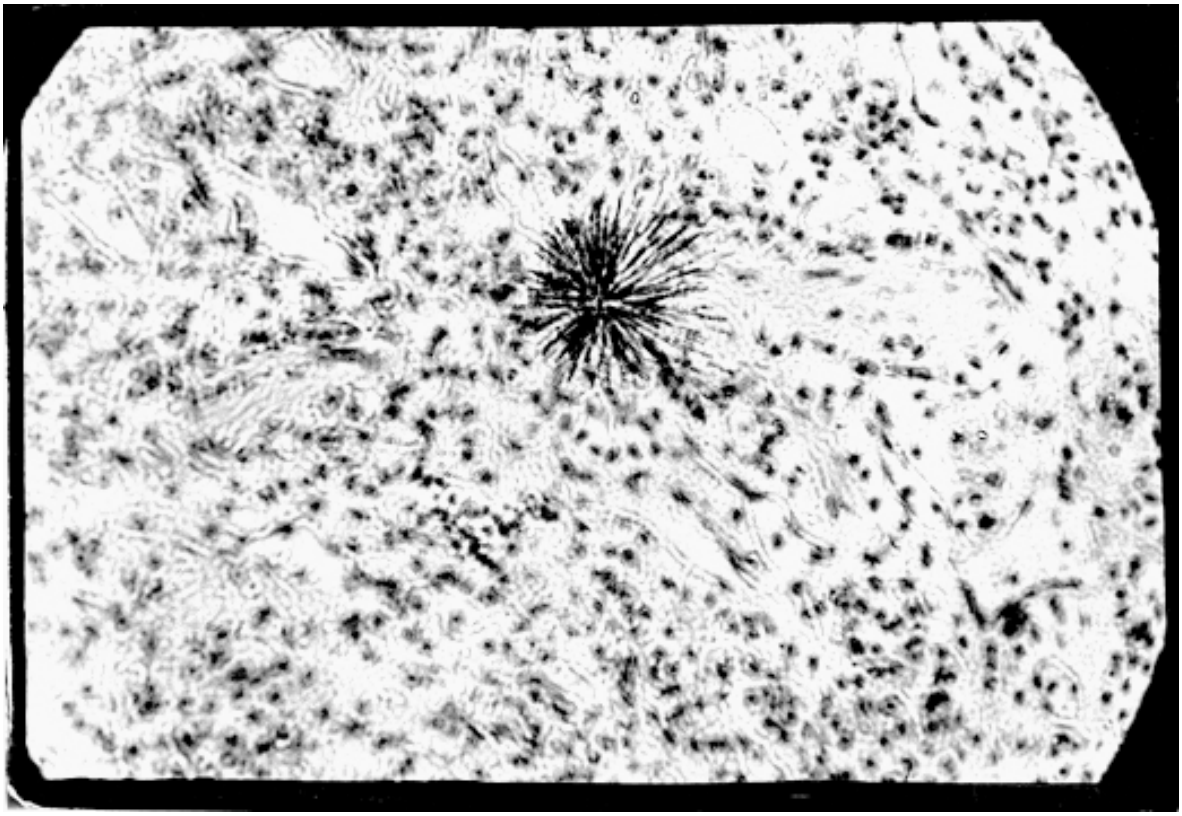
• **Toxic:** All radioactive materials emit energy in the form of electron volts that can damage human tissue. But the highly concentrated energy emitted by plutonium makes it "fiendishly toxic, even in small amounts" (Glenn Seaborg, who in 1941 isolated and named plutonium, quoted in Jeremy Bernstein, *Plutonium* [2007], p. 105).

• **Long-term danger:** Plutonium 239, the material of principal concern at Rocky Flats, has a half-life of 24,110 years. It remains dangerously radioactive for more than a quarter-of-a-million years. Tiny particles left in the environment pose an essentially permanent danger.

• **Potentially lethal if internalized:** The alpha radiation emitted by plutonium cannot penetrate skin like x-rays or gamma radiation. But tiny particles inhaled, ingested, or otherwise taken into the body through an open wound may lodge in the lungs, liver, surface or marrow of bone, the gonads or elsewhere. For as long as plutonium resides in the body it continually bombards the immediately surrounding tissue with radiation. The result may be cancer, genetic defects, harm to the immune system. The latent period for cancer is likely to be 20 to 30 years.



• **Plutonium particle in lung tissue:** "The black star in the middle of this picture shows the tracks made by alpha rays emitted from a particle of plutonium-239 in the lung tissue of an ape. The alpha rays do not travel very far, but once inside the body, they can penetrate more than 10,000 cells within their range. This set of alpha tracks (magnified 500 times) occurred over a 48-hour period" (Robert Del Tredici, *At Work in the Fields of the Bomb* [1987], plate 39).

• **Hazardous in very small amounts**: Plutonium particles of 10 or less microns can be inhaled. The average diameter of human hair is about 50 microns. Meteorologist W. Gale Biggs concluded that most airborne particles at Rocky Flats were probably smaller than 0.01 microns ("Emissions and Monitoring of Plutonium from Rocky Flats," April 26, 2007). Particles too small to see are not too small to do harm.

• **More harmful than other forms of radiation:** Internal alpha emitters like plutonium are much more harmful than the equivalent dose from penetrating gamma or x-ray radiation. To account for the difference, the International Commission on Radiological Protection (ICRP) refers to the "relative biological effectiveness" (RBE) of alpha emitters. Looking at the potential harm to different organs and for different disease end-points, ICRP concludes that the average RBE for alpha emitters is 20. This means that, on average, internalized plutonium is 20 times more

harmful than penetrating radiation of the same dose. But because 20 is an average, for some body organs and certain cancers as well as for particular individuals the actual RBE can be higher, sometimes much higher. For example, the RBE for bone cancer ranges as high as 320. (Helen A. Grogan et al, *Assessing Risk of Exposure to Plutonium*, Feb. 2000 [Risk Assessment Corporation], pp. 6.27-6.39)

• **Plutonium RBE and the Rocky Flats cleanup standards:** Those who set the cleanup standards for Rocky Flats followed the ICRP in using 20 as the RBE for plutonium. This averaging approach disregards the harm that may result from plutonium exposure to certain organs of the body or to given individuals; it does not protect the most vulnerable members of the population. The Rocky Flats Cleanup Agreement allows 50 picocuries of plutonium per gram of soil to remain in the top 3 feet of soil after "cleanup," much larger quantities below 3 feet. Doubling the plutonium RBE to 40 would reduce the 50 picocuries allowed in upper soil to 25; each RBE doubling would reduce by half the amount of plutonium allowed in the top 3 feet of soil. To provide maximum protection for those susceptible to bone cancer (RBE of 320), the cleanup level would be 0.015 picocuries per gram.

• **All the Rocky Flats site contaminated:** Historically, while some areas at Rocky Flats were more heavily contaminated than others, plutonium particles released in fires, accidents, and routine operations were laid down across the whole of the site. This conclusion is suppoted by soil sampling done at predominantly upwind locations by F. Ward Whicker of Colorado State University and Harvey Nichols of the University of Colorado.

• **Inadequacy of the Rocky Flats cleanup:** Plutonium left in the Rocky Flats environment is in the form of very fine particles that can be inhaled or ingested. The government agencies responsible for the cleanup made no effort to clean the site to the maximum extent possible. They knowingly left an unknown quantity of plutonium in the environment. Their assumption that this plutonium would remain "relatively immobile" is countered by M. Iggy Litaor's discovery in the wet conditions of 1995 that plutonium in soil at Rocky Flats migrates. Also, in 1996 Shawn Smallwood identified18 species of burrowing animals at the site that dig down to as much as 16 to 20 feet below the surface and constantly move soil and its contents. Plutonium particles brought to the surface can be picked up by wind and moved to other locations near and far. There is no guarantee that plutonium left in the Rocky Flats environment will remain safely in place or even on the site.

• **Excess cancers among Rocky Flats workers exposed to purportedly safe levels:** In 1987 Gregg S. Wilkinson of DOE's Los Alamos Lab published results of his study showing that some exposed Rocky Flats workers with internal plutonium deposits as low as 5% of DOE's purportedly safe permissible lifetime body burden developed a variety of cancers in excess of what was normal for workers who had not been exposed (*American Journal of Epidemiology*, vol. 125, no. 2 [1987], pp. 231-250).

• **Harm from a single particle:** Tom K. Hei and colleagues at Columbia University demonstrated that a single plutonium alpha particle induces mutations in mammal cells. Cells receiving very low doses were more likely to be damaged than destroyed. Replication of these damaged cells constitutes genetic harm, and more such harm per unit dose occurs at very low doses than would occur with higher dose exposures. "These data provide direct evidence that a single alpha particle traversing a nucleus will have a high probability of resulting in a mutation and highlight the need for radiation protection at low doses." In a follow-up study, they found that "a single alpha particle can induce mutations and chromosome aberrations in [adjacent] cells that received no direct radiation exposure to their DNA" (*Proceedings of the National Academy of Sciences*, vol. 94 [Apr. 1997], pp. 3765-3770; and vol. 98 [4 Dec. 2001], pp. 14410-14415).

• **Plutonium and genetic harm:** A British research team concluded that the RBE for chromosomal damage from plutonium exposure is essentially "infinite," because the extent of harm to the human gene pool is incalculable (M. A. Khadim et al, *Nature*, vol. 355, no. 20 [Feb. 1992], pp. 738-740). Herman Muller, awarded a Nobel Prize for his discovery that radiation exposure had genetic effects harmful to future generations, predicted gradual reduction of the survival ability of the human species due to the effect on DNA of exposure to very low levels of radiation over several generations ("Radiation and Heredity," *American Journal of Public Health*, 1964, vol 54, no. 1, pp. 42-50).

• **"Genetic uncertainty problem" for wildlife:** Genetic specialist Diethard Tautz says that effects of radiation exposure on a given species of wildlife may not be readily apparent in individuals of that species until the passage of several generations. ("A genetic uncertainty problem," *Trends in Genetics*, vol. 16 [Nov. 2000], pp. 475-477). This finding suggests that wildlife at Rocky Flats could in the long-term be hurt by conditions at the site.

For more detail on environmental conditions at Rocky Flats and on plutonium health effects see "Plutonium and People Don't Mix" at http://media.wix.com/ugd/cff93e_c22798032f2e468f9af7d9ccb317169f.pdf