# Methods for Estimating Radiation Doses from Short-lived Gaseous Radionuclides and Radioactive Particles Released to the Atmosphere during Early Hanford Operations

## Summary

The Centers for Disease Control and Prevention contracted with *Risk Assessment Corporation* to develop methods to estimate worst case radiation doses from short-lived gaseous radionuclides and radioactive particles released to the atmosphere from the Hanford facilities near Richland, Washington, during early years of operation. The work addressed some concerns that remained following the Hanford Environmental Dose Reconstruction (HEDR) Project. The HEDR Project focused on doses to members of the public, located offsite, from releases of radioactive materials from the Hanford Site. Our study considers possible doses to persons who worked or lived *on* as well as near the Hanford Site, including military personnel stationed on the Site to protect the facilities, construction workers, and maintenance personnel whose radiation exposures were not monitored. The methods developed address outdoor exposure of people to radioactive materials released to the atmosphere; they do not address exposure to workers inside Site buildings.

There were two types of releases of radioactive materials that were more important for persons onsite than for the offsite public. The first was releases of short-lived radionuclides that decayed appreciably in transit to offsite locations. The second type was radioactive particles, the largest of which settled onsite close to the release points. The scope of work specified that the calculations should use approaches that would generally yield dose estimates higher than those actually received.

A screening procedure was used to identify the radionuclides that contributed most to doses to persons exposed onsite. Military and construction personnel worked onsite during the 1940s and 1950s. Because the nature of the releases had changed during this period, scientists estimated the dose contributions from twelve radionuclides at eight different times between 1944 and 1961. In the overall ranking, the four most important radionuclides were iodine-131, cerium-144, argon-41, and plutonium-239. Of less overall importance were ruthenium-103, ruthenium-106, cesium-137, and strontium-90. Scientists estimated releases of and doses from these eight radionuclides.

In addition to ongoing routine releases of radioactive materials to air, there were brief periods of unusually high releases in the late 1940s and early 1950s. Scientists collected historical data to estimate the amounts released, which reflect substantial uncertainties in the available information. Larger radioactive particles, called “active particles,” were released at some of these times. In the 1940s, corrosion of the ductwork in two chemical separations plants produced environmental contamination with large active particles containing a mixture of radioactive materials. In the 1950s, large particles of ammonium nitrate that contained radioactive ruthenium were released from the stack of a third separations plant (REDOX).

Many measurements of radioactivity in the environment were made during the early years of operation. Historical measurements of particles collected from contaminated areas helped scientists define the characteristics of active particles that were released. The environment near the separations plants, where the large iodine-131 and radioactive particle releases occurred, was most highly contaminated. Radioactivity was spread by the wind, mainly to the east and southeast of the release points. Concentrations of radionuclides in air and on the ground generally decreased rapidly with increasing distance from the contamination sources, but some particles are known to have traveled long distances.

The primary way that people working and living onsite were exposed to radioactive releases was by breathing the contaminated air. When estimating doses due to this exposure pathway, scientists assumed that all of the released radionuclides were contained in small, easily inhaled particles or gases. People were also exposed to direct radiation from the airborne radioactivity and from radioactivity that had deposited on the ground. Persons who lived and worked in particularly dusty environments, such as those in some military units, were more likely to swallow radionuclides that were present in the dust and dirt. Scientists estimated radiation doses to many individual organs and tissues as well as the dose that effectively represents the dose to the entire body (the effective dose). The calculations include exposures while at work and during the remainder of the day at a residence location, which may also have been onsite.

The methods estimate total doses from airborne releases of radioactive particles and gases from 5 separations plants and 7 reactors. A map in the report illustrates the estimated radiation doses received at various locations on and near the Site if someone had been continuously outdoors from January 1, 1945, through December 31, 1961. The highest effective dose was estimated to be 6.5 rem at an onsite location southeast of the separations plants. Iodine-131 made the largest contribution to the effective dose, and the thyroid received the highest estimated absorbed dose to an individual organ (~120 rad). It is not likely that any real person was exposed in this manner. If a worker had been at the maximum exposure location for 2000 hours per year and spent the rest of the time offsite just east of the Site, his cumulative effective dose would have been approximately 2.6 rem (with a 50-rad thyroid dose). To illustrate the methodology as it might be used to address public health concerns, the report also provides examples using hypothetical exposure scenarios during periods of larger releases of radioactive materials.

Contact with large active particles is difficult to reconstruct. Historic ground contamination surveys provide information about the concentrations of active particles to which persons were exposed. A method was developed to estimate the probability of contact with active particles when working in a contaminated area. Environmental survey data show that individuals in and near the separations areas were exposed to much greater concentrations of highly active particles than people in offsite areas. Worst-case calculations for large active particles indicate that inhalation of such a particle could lead to a lung dose of ~40 rad. Even larger particles can be swallowed by accident, and it was estimated that a dose of ~80 rad to the lower large intestine could have been received. It is not known whether anyone actually received doses of this magnitude as the result of inhalation or ingestion of such particles. The largest and most highly radioactive particles comprise only a small part of the distribution of particles that were present. Skin contact with a highly active particle for an appreciable time would produce an observable burn or lesion, which could have been noted in personal medical records. Some cases of skin irritation attributed to active particles were reported historically.

The methods developed in this study provide a tool for CDC to help answer questions raised by individuals about their past radiation exposures at Hanford. The results of this work indicate that past radiation doses to people onsite from airborne releases from Hanford facilities occurred mainly from breathing iodine-131 in the air. Exposures to particles may also have produced large doses in some cases. Additional work to assess more fully the likelihood and consequences of individual contact with active particles is underway.