

Technical Topic Papers Rocky Flats Historical Public Exposures Studies/h3>

Estimating Plutonium Releases from Unmonitored Sources at Rocky Flats

How were the plutonium releases to the environment measured?

Plutonium discharges from a plant production building's ventilation stack are normally measured by an air sampling or monitoring system, as shown schematically in the figure below. However, air sampling or monitoring systems can fail. When a sampler fails (for example, when the sampling pump stops), there may be no measurements, or only partial samples, of the discharge until the system is again operational.

Releases directly to the atmosphere from outdoor activities such as spills or open burning, are more difficult to measure. Such releases usually are not well controlled and are usually not well-monitored at the source.

Two of the largest releases of plutonium from Rocky Flats were not measured at the point of release.

- During the 1957 fire, the exhaust air sampling system stopped functioning when the electrical power went off;**
- From about 1958 through 1968, drums containing plutonium-contaminated waste oil and solvents were stored outdoors in the 903 Area near the east edge of the site. Leakage from the drums contaminated the surrounding soil. Later disturbance of the soil in the 903 Area by human activity and by winds caused the contamination to move off-site. That movement was not monitored at the 903 Area, but was detected in air and soil samples collected at downwind locations.**

It was essential to the State of Colorado's Historical Public Exposures Studies on Rocky Flats to make estimates of the quantities of plutonium released in these situations. Although incomplete, the available data were used with knowledge of the physical processes involved to assess the magnitude of the releases. While the discussion here focuses on plutonium, it applies to other contaminant particles as well.

How were release estimates made?

When the release of a contaminant was not monitored, the goal was to make an estimate that was reasonably consistent with all relevant information. The term reasonably consistent was used to make it clear that the pieces in this type of puzzle never fit together perfectly. The estimate of a release to the atmosphere will generally depend on three types of information:

- Information about the source of the release and the process that caused it;**
- Data about environmental conditions at the time of the release; and**
- Results of field measurements of concentrations of contaminants in air, vegetation and soil.**

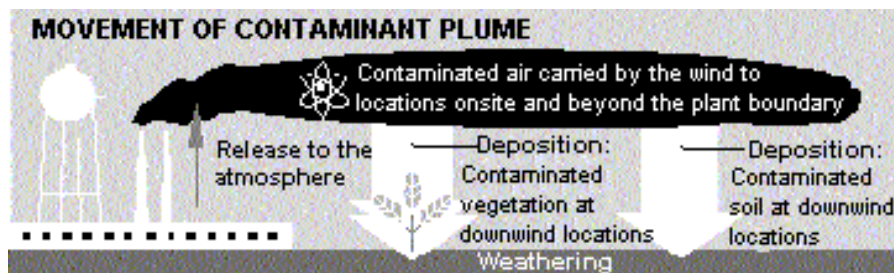
Data on environmental conditions were used to predict dispersion, deposition and resuspension of the released material. Based on these predictions, the amounts found in the environment were related to the amount released from the source. The size of the estimated release and the observed environmental contamination were found to be reasonably consistent.

Scientists make estimates using a combination of relevant data and mathematical models. When data are relatively plentiful, scientists rely less on models. For unmonitored releases, it is never possible to know exactly how much material was released. The goal was to make a best estimate of the amount released and to define the uncertainty associated with that estimate. The concept of uncertainty is discussed in Technical Topic Paper Uncertainty in Analyzing Health Risks. Scientists usually define uncertainty as a range of values within which the real number most likely falls.

When possible, scientists made several estimates of a particular release. This was accomplished using different models of the same process or several independent approaches. While the degree of confidence in each estimate varied, the different approaches helped develop consensus about the size of the release.

The following sections describe various ways to estimate unmonitored releases.

Can environmental data show evidence of plume passage?



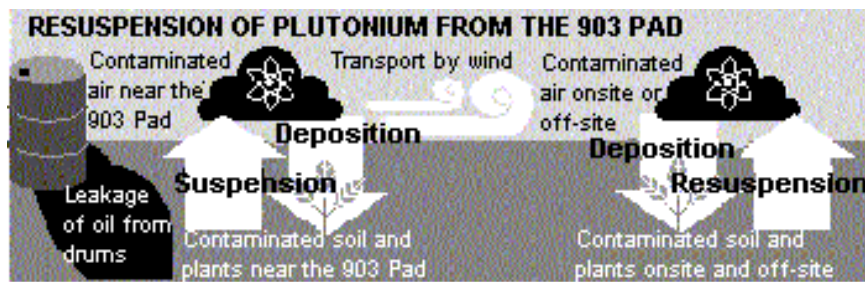
Plutonium releases to the atmosphere were dispersed and carried by the wind, forming a plume of contaminated air. Samples of air, vegetation and soil taken during and soon after the release reflect the passage of that plume. This information was used to estimate the release. The flow chart below gives a simplified picture of the important processes.

The plutonium contamination measured in air at various locations was used to estimate the amount of plutonium released. Meteorological conditions at the time of release were an essential part of the calculation, allowing researchers to estimate atmospheric dispersion and the air concentrations at the sampling locations. These were compared with actual air concentration measurements to check the estimates of the release at those specific locations.

Plutonium particles in the atmosphere settled onto vegetation and soil along the path of the plume. Scientists at Rocky Flats and elsewhere have measured particle deposition under a variety of meteorological conditions. The knowledge gained from such measurements was applied to Rocky Flats releases. Data on plutonium in vegetation and soil samples were used in a manner similar to that described for air sampling data to check estimates of the size of the release. If the soil samples were collected at later times, scientists had to consider deposition from other sources, and resuspension after the event, when making the assessment.

What is suspension of Plutonium?

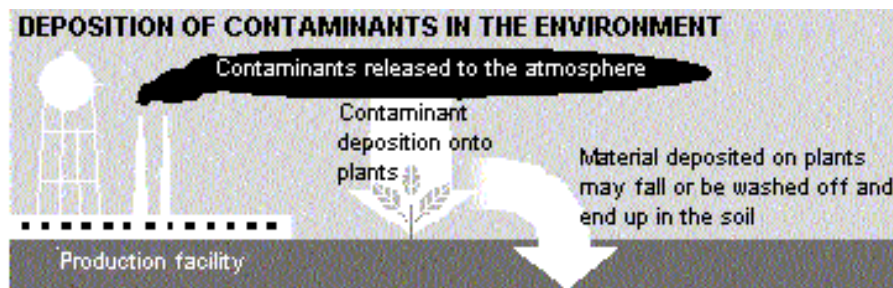
Airborne suspension refers to the process by which contaminated soil particles are lifted by the wind from a contaminated source into the air. Suspension was an important mechanism for release of plutonium from the vicinity of the 903 Area. The chart below illustrates processes that influence airborne suspension.



Most of the heavier suspended material was deposited near the 903 Area, but some was carried by the wind to more distant locations. Deposition of finer particles of plutonium occurred in those locations, and the deposited material was subject to later resuspension and further redistribution. Although the figure shows only two cycles, the processes continue to occur and gradually move material farther from the initial source of contamination. The movement was generally along the path followed by the prevailing winds. Transport in other wind directions also occurred but is less common.

Suspension is complicated because many factors can affect the process. Scientists have developed mathematical models to estimate the amount of suspension that occurs under various conditions.

Mathematical models applicable to the Colorado Front Range environment were used in calculations of suspension of plutonium from the barrel leakage in the 903 Area. These models were essential to estimate movement of plutonium in the environment after it was suspended into the air. Estimates of human exposure were supported by the resuspension models. Once again, measurements of plutonium on vegetation and in soil at downwind locations were used to check the predictions made by the models.



How were in-plant measurements and process information used?

In-plant measurements and process data provided valuable information for estimating releases from a facility stack, even when an actual discharge was unmonitored. The following paragraphs provide examples of such estimates. The

approach in any particular case depended on the data available.

Measurements of plutonium in room air or in secondary ventilation ducts leading to the exhaust stack were useful to estimate releases during other periods when an effluent monitor was out of service. Knowledge of the plant processes and the amount of material produced during such a monitoring system outage contributed to the accuracy of the estimate.

Knowledge of the processes leading to the release was used to estimate the quantity that was released. This approach was used for the plutonium fire that occurred in September 1957. Researchers at other facilities have measured the amounts of airborne particles produced when plutonium metal is burning. The conditions leading to such measurements were compared to the 1957 conditions, and 1957 fire releases were thus estimated.

Airborne plutonium particles adhere to building surfaces as well as deposit on vegetation and soil surfaces. Knowledge of the amount of contamination on floors, walls and equipment in the building and in ductwork can be used to estimate the amount of plutonium that was in the air during the accident. This information can provide a check on other evaluations of vent and stack releases, and environmental concentrations.

For a particular event that occurred in a relatively short time period, such as the 1957 fire, a material balance evaluation is sometimes used to develop an upper bound for the release. In this approach, scientists try to account for all of the plutonium that was initially present, assuming that any missing material left the facility as airborne dust and smoke. Several pieces of data are needed for a material balance evaluation:

- (a) inventories of the plutonium in production pieces and scraps before and after the accident,**
- (b) the quantity of plutonium present as contamination on building surfaces and filters, and**
- (c) the amount of plutonium contamination in waste materials removed from the area.**

The equation shown in the box assumes that the amounts accounted for before and after the event must balance.

If the initial plutonium inventory is known and, if the unknown quantities can be estimated, then the amount of plutonium released can be calculated. The uncertainty of the release estimate will reflect the uncertainties in all the quantities in the calculation. Data on the amount disposed as waste and the amounts of residual surface contamination are particularly difficult to obtain. There are few estimates of the amount of solid wastes disposed during the early years at Rocky Flats. For that reason and others, a reliable mass balance estimate of the release from the 1957 fire could not be made.

Summary

Incidents that caused the largest plutonium releases from Rocky Flats were unmonitored. Therefore, relevant data and mathematical models were used to estimate public exposure to these releases. The goal was to calculate best estimates of the releases using available data and knowledge of the physical processes that affected movement of the contaminants. Although uncertainties were large, these estimates were essential to the State's Historical Public Exposures Studies on Rocky Flats to develop a comprehensive assessment of exposures to the public from past Rocky Flats releases.