Technical Topics:

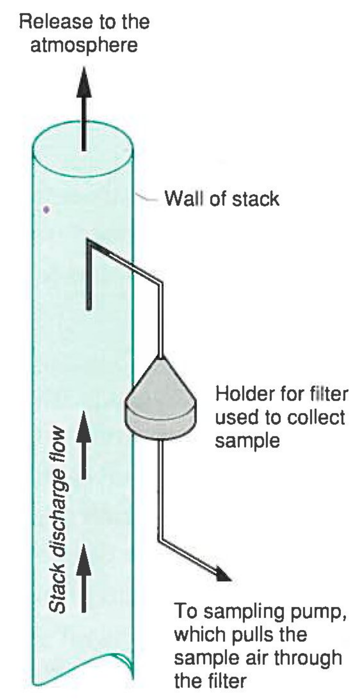
Estimating Plutonium Releases From Unmonitored Sources at Rocky Flats

Introduction

Plutonium discharges from a plant production building's ventilation stack are normally measured by an air sampling or monitoring system, as illustrated 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 pump is again operational.

Releases directly to the atmosphere from outdoor activities (spills or open burning, for example) are inherently more difficult to measure. Such release processes are usually not well controlled. The way in which the released material moves through the environment depends on changing wind and weather conditions. For these reasons such releases are rarely monitored at the source.

Ventilation Stack Air Monitoring System



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

1) During the 1957 fire, the exhaust air sampling system stopped functioning when the electrical power went off;

2) For several years in the early 1960s, drums containing waste oil contaminated with plutonium were stored outdoors in an area known as the 903 Pad; undetected leakage from the drums contaminated the surrounding soil.

Technical Topics: This series of papers explains the research design, methods and terminology used in the State of Colorado's health studies related to the Rocky Flats Plant. For information about this ongoing research to identify past contaminant releases from the plant and assess potential health risks, call the Colorado Department of Health at (303) 692-2640 or 692-2652.

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Later disturbance of the soil in the 903 Pad area by human activity and by winds caused the contamination to move offsite. That movement was not monitored at the 903 Pad, but was detected in air and soil samples collected at downwind locations.

It is essential to the State of Colorado's dose reconstruction project to make estimates of the quantities of plutonium released in these situations. Although incomplete, the data available must be used with knowledge of the physical processes involved to assess the magnitude of the releases. While this discussion focuses on plutonium, it applies to other contaminant particles as well.

How Estimates Are Made

When the release of a contaminant was not monitored, the goal is to make an estimate that is reasonably consistent with all the relevant information. The term *reasonably consistent* is 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:

1) Information about the source of the release and the process that caused it;

2) Data about environmental conditions at the time of the release; and

3) Results of field measurements of concentrations of contaminants in air, vegetation and soil.

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

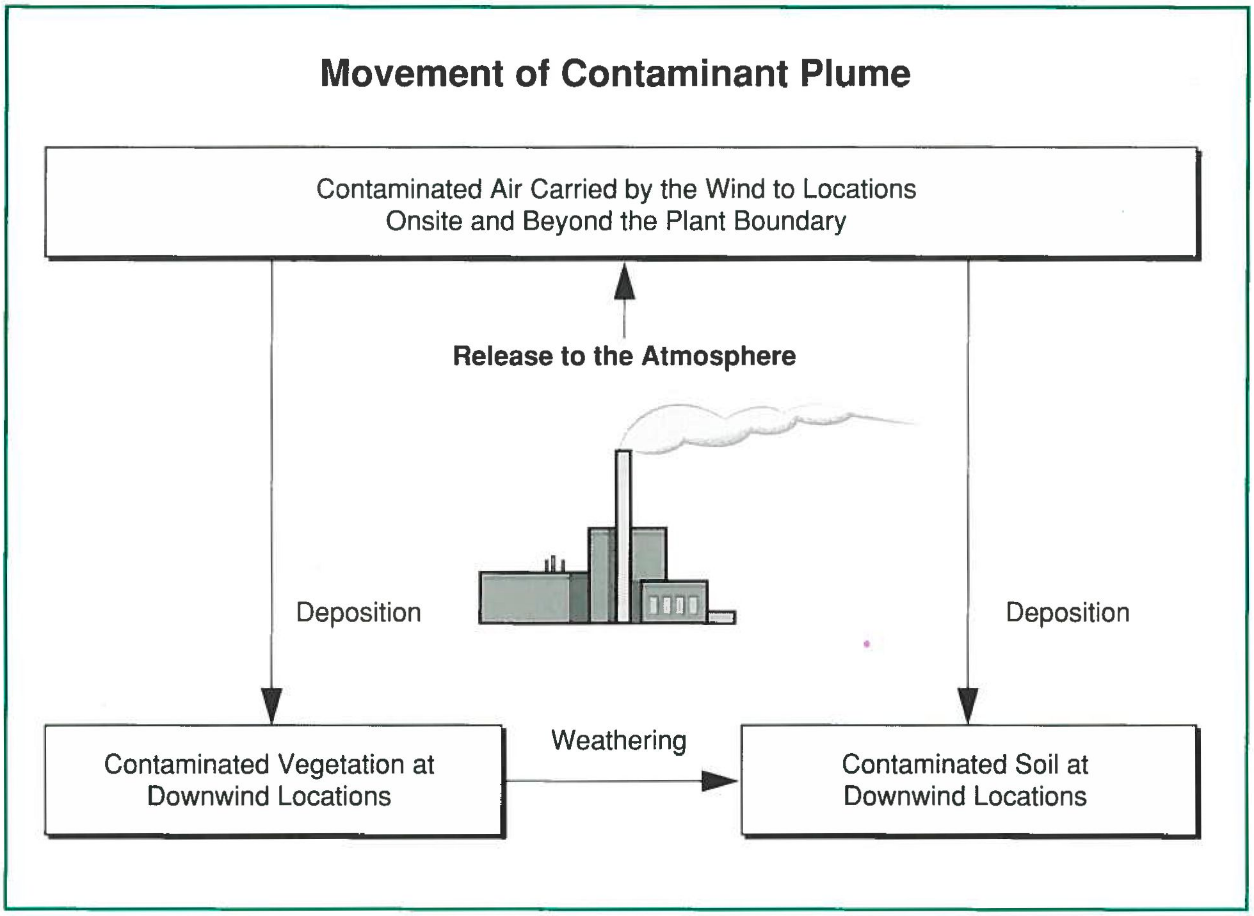
Scientists make estimates using a combination of relevant data and mathematical models. When data are relatively plentiful, scientists rely less on models. For partially or completely unmonitored releases, the set of data is always incomplete, and it is never possible to know exactly how much material was released. The goals are 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 another technical topics paper "Uncertainty in Analyzing Health Risks.")

When possible, it is desirable to make several estimates of a particular release. This may be accomplished using different models of the same process or several independent alternative approaches. While the degree of confidence in each estimate will vary, the different approaches may lead scientists to a consensus about the size of the release.

The following sections describe various ways to estimate unmonitored releases.

Environmental Data That Show Evidence of Plume Passage

Plutonium releases to the atmosphere are 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 will reflect the passage of that plume. This information can be used to estimate the release. The flow chart below gives a simplified picture of the important processes.

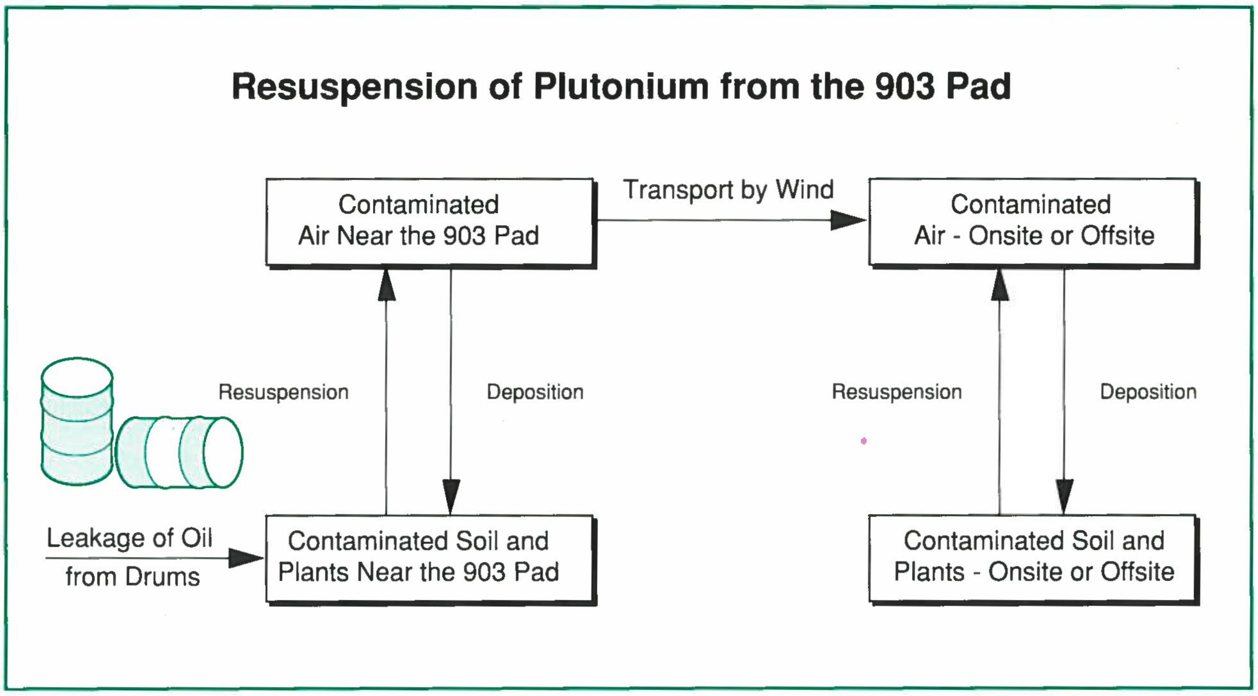


The plutonium contamination measured in air at onsite and offsite locations that were in the path of the released material can be used to estimate the amount released. It is important to understand meteorological conditions at the site because an essential part of the calculation is to make best estimates of the meteorological dispersion factors for the sampling locations. These are used with the data on air concentrations to obtain estimates of the release.

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

Resuspension of Plutonium

The term *resuspension* refers to the process by which contaminated soil particles are lifted into the air by turbulence due to wind or by other activities such as excavation or vehicle traffic. Resuspension was an important mechanism for release and redistribution of plutonium from the vicinity of the 903 Pad. The flow chart below illustrates the processes that affected movement of the contamination.

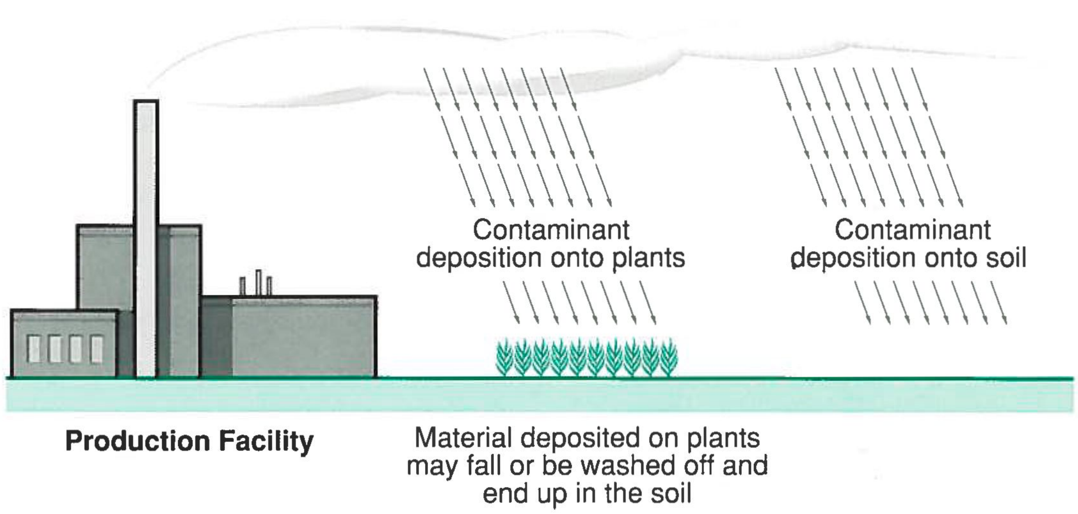


Some of the resuspended material is deposited locally, but some is carried by the wind to more distant locations. Deposition of plutonium will also occur in those locations, and the deposited material is subject to later resuspension and further redistribution. Although the figure shows only two cycles, the resuspension and deposition processes continue to occur and gradually move material from the initial source of contamination. The movement is generally along the path followed by the prevailing winds. Transport in other wind directions also occurs but is less prevalent.

Resuspension is complicated because many factors can affect the process. Scientists have developed several mathematical models to estimate the amount of resuspension that will occur under various conditions. Measurements of resuspended plutonium under conditions similar to those at the Rocky Flats site may show that one or more of the models is superior.

Mathematical models applicable to the Colorado Front Range environment will be used in calculations of resuspension of plutonium from the oil leakage at the 903 Pad. Predictions of resuspension using these models are essential to define movement of plutonium in the environment following the original release of contaminated material. Estimates of human exposure will be based in part on the resuspension models. As in the case of estimating direct releases to the atmosphere (discussed earlier), measurements of plutonium on vegetation and in soil at downwind locations can be used to check the predictions made by the models.

Deposition of Contaminants in the Environment



Use of In-Plant Measurements and Process Information

In-plant measurements and process data may provide valuable information for estimating releases from a facility stack, even though the actual discharge was unmonitored. The following paragraphs offer several examples of how estimates might be made. The approach in any particular case will depend upon the data that are available.

Measurements of plutonium in room air or in secondary ventilation ducts leading to the exhaust stack may be useful to estimate releases during a period 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 will also contribute to the reliability of the estimate.

Knowledge of the process leading to the release can also be used to estimate the quantity that was released. This approach could be 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. This information on the amounts of fire-generated particles can be used to estimate releases from other fires, taking into account the similarities or differences between the laboratory conditions and those in the facility in 1957.

Airborne plutonium particles will adhere to building surfaces just as they deposit on vegetation and soil surfaces in the environment. 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 what happened.

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 estimate a release. In this approach, scientists try to account for all of the plutonium that was initially present. Several pieces of data are needed for a material balance evaluation:

(a) a final inventory of the plutonium in production pieces and scraps in the area,

(b) the quantity of plutonium present in residual contamination of building surfaces and filters (if appropriate) and

(c) the amount of plutonium (Pu) contamination in waste materials removed from the area.

The release can be estimated because the amounts accounted for before and after the event must balance. The equation is shown in the box.

Material Balance Calculation

Initial Pu inventory = (a) final Pu inventory + (b) residual Pu contamination + (c) Pu in wastes removed + Pu released

If the initial plutonium inventory is known and the quantities (a), (b) and (c) 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 surface contamination may be particularly difficult to obtain. Uncertainties in waste disposal amounts make the material balance calculation inappropriate for evaluation of releases over long time periods.

Summary

Incidents that caused the largest plutonium releases from the Rocky Flats Plant were unmonitored. Therefore, relevant data and mathematical models must be used to estimate public exposure to these releases. The goal is to calculate best estimates of the releases using the available data and knowledge of the physical processes that affected the movement of the contaminants that were released. Although uncertainties may be relatively large, these estimates are essential to the State's dose reconstruction project to develop a comprehensive assessment of exposures to the public from past Rocky Flats releases.

Other Technical Topics Papers Related to the Health Studies on Rocky Flats

- Risk to Human Health and the Environment
- Source Term Estimates
- Exposure Pathways
- Uncertainty in Analyzing Health Risks
- Verifying Historical Data
- Quality Assurance for the Health Studies on Rocky Flats
- Movement of Contaminated Groundwater from the Rocky Flats Plant
- Research on Adverse Health Effects Related to the Rocky Flats Plant
- Assessing Health Risks from Nuclear Facilities: Epidemiology and Risk Assessment

Call (303) 692-2640 or 692-2652 for copies of these papers.

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