CHAPTER 8

RADIONUCLIDES IN AIR AND RAINWATER

ABSTRACT

This chapter discusses radionuclide concentrations measured in air and rainwater collected on or in the vicinity of the Savannah River Site (SRS). We evaluated these data with regard to their potential usefulness for dose reconstruction. We also attempted to validate the reported concentrations by making comparisons among as many data sources as possible. These data included original handwritten compilations for many years. We have found these original data to consistently correspond to the information reported in monthly, semiannual, and annual summary reports.

We compiled and examined air and rainwater data to determine their usefulness for source term verification, model validation, and direct exposure assessment. In general, the air data are most valuable for source term verification and model validation. However, the potential usefulness of the data may be limited in many cases by spatial resolution. The rainwater data may be useful for identifying long-term trends; however, they are limited in their use for source term verification and model validation. Appendix K further discusses potential uses for environmental monitoring data.

INTRODUCTION

Air and rainwater have been sampled at various locations on or in the vicinity of the SRS since measurements of natural background levels of radioactivity began in 1951. Air represents a major pathway for transport of SRS releases and exposure of offsite individuals, and so can be extremely important to a historic dose reconstruction. Radionuclide-specific data from air filters located in the effluent stream from stacks may be used to validate airborne source terms and dispersion models. In the absence of specific effluent data, air monitoring results could be used to develop airborne source terms, particularly in cases of unplanned releases. If the data are of high quality and above detection limits, they may also be used directly to quantify human exposure via the airborne pathways.

This chapter summarizes reported information regarding radionuclide concentrations in air and rainwater on or in the vicinity of the SRS. We examined several sets of routine semiannual and annual environmental monitoring reports prepared by the SRS contractor, which span the years 1953 through 1991. See Chapter 7, Table 7-1 for a complete description of the various monitoring report series. We reviewed additional documents for information pertaining to air and rainwater monitoring at the SRS. These include monthly monitoring reports from 1951 through 1956, from 1960 through 1971, and from 1976 through 1990; weekly monitoring reports from 1954 through 1964; and handwritten compilations of original environmental monitoring results from 1959 through 1973 that were photographed in a format similar to microfiche.

The handwritten compilations of original effluent and environmental monitoring results, recorded on ledger sheets, are the primary sources of original data. The data represent results reported for each time period of measurement (e.g., weekly or biweekly). The sheets were photographed in a format similar to microfiche and mounted on computer cards with a hole cut in

the center. These cards, called aperture cards, were found for August 1959 through December 1973. The aperture card data were compiled in Excel spreadsheets and were cross-checked with the data presented in the semiannual and annual Health Physics monitoring reports. Generally, average concentrations reported for a specific time period (usually 6 months or a year) in a report were compared with averages computed using the aperture card data on the Excel spreadsheets. In general, good agreement is observed between the aperture cards and reports. For the time period before August 1959, data are available from the weekly and semiannual monitoring reports. These data are incomplete and are typically reported as semiannual averages. From 1974 onward, data are available on computer printouts, called monthly reports, in frequencies that correspond to the sampling periods.

A synopsis of the types of data available, their sources, and the name of the Excel workbooks containing the aperture card data are shown in Table 8-1. Data from semiannual, annual, and monthly reports were not electronically compiled for two main reasons. First, they are easily obtained from the reports. On the other hand, aperture card data are not easily handled (one must either read the cards with a special reader or handle oversized photocopies) and tend to be illegible. Second, data from semiannual and annual reports represent averages for each 6-month period or year and do not provide the degree of resolution needed for a dose reconstruction that individual sample results will provide.

The results were evaluated in light of their potential usefulness to the dose reconstruction. Usefulness was considered in terms of the following:

- The contaminant is a key contaminant (i.e., screened in Task 3 of Phase I of the dose reconstruction to potentially contribute significantly to dose [Meyer et al. 1995])
- The contaminant was monitored during the period of interest (i.e., 1951 through 1990)
- Contaminant concentrations were above detection limits
- The results demonstrate expected trends (spatially and temporally)
  - Concentrations were generally higher onsite than offsite
  - Concentrations were generally higher during periods of elevated releases
- The medium is directly impacted by releases.

The potential usefulness of the data was considered to ensure that efforts were focused on those contaminants that would most likely be addressed in the next phase of the dose reconstruction.

The following sections present a description and evaluation of the air monitoring program and a description and evaluation of the rainwater monitoring program. Following the discussions of the air and rainwater data, data usefulness and limitations are addressed. Appendix A contains details related to the analytical procedures associated with collecting and measuring air samples.

Table 8-1. Description of Airborne Radionuclide Data

Radionuclide	Time period	Description of data	Source of data	Name of Excel workbook
Gross alpha	1955—1958	Semiannual average and maximum for all locations	Semiannual reports	Data not compiled
	1959—1973	Individual results[a]	Aperture cards	Alpha-Beta-all.xls[b]
	1974—1975	Annual average and maximum for each location	Annual reports	Data not compiled
	1976—1990	Individual results	Monthly reports	Data not compiled
Gross particulate beta	1954—1958	Semiannual average and maximum for all locations	Semiannual reports	Data not compiled
	1959—1973	Individual results	Aperture cards	Alpha-Beta-all.xls[b]
	1974—1975	Annual average and maximum for each location	Annual reports	Data not compiled
	1976—1990	Individual results	Monthly reports	Data not compiled
^{131}I	1954—1958	Semiannual average and maximum for all locations	Semiannual reports	Data not compiled
	1959—1973	Individual results	Aperture cards	Iodine-all.xls[b]
	1974—1975	Annual average and maximum for each location	Annual reports	Data not compiled
	1979—1990	Monthly composite results for onsite (three sites), perimeter, 25-mi, and 100-mi areas	Monthly reports	Data not compiled
$^{89, 90}Sr$	1967—1975	Semiannual averages of monthly composite results for F-Area and H-Area, plant perimeter, 25-mi radius, and 100-mi radius areas	Annual reports	Data not compiled
	1976—1990	Monthly composite results for F-Area, H-Area, and 3/700 Area, perimeter, 25-mi, and 100-mi areas	Monthly reports	Data not compiled
	1974—1990	Annual, minimum, maximum, and average values for each location	Annual reports	Data not compiled
^{3}H	1956—1958	Maximum result	Semiannual reports	Data not compiled
	1959—1973	Individual results	Aperture cards	Tritium-all.xls[b]
	1974—1975	Annual minimum, maximum, and average for each location	Annual reports	Data not compiled
	1976—1990	Individual results	Monthly reports	Data not compiled

Table 8-1. (Continued)

Radionuclide	Time period	Description of data	Source of data	Name of Excel workbook
Gamma nuclides (^{137}Cs, ^{7}Be, ^{54}Mn, ^{95}Zr/Nb, ^{106}Ru, ^{144}Ce	1964–1973	Monthly composite results for F-Area, H-Area, and 3/700 Area, perimeter, 25-mi, and 100-mi areas	Aperture cards	Gamma-all.xls[b]
	1974–1990	Annual minimum, maximum, and average for each location	Annual reports	Data not compiled
	1979–1990	Monthly composite results for F-Area, H-Area, and 3/700 Area, perimeter, 25-mi, and 100-mi areas	Monthly reports	Data not compiled
^{238}Pu, ^{239}Pu	1977–1990	Monthly composite results for F-Area, H-Area, and 3/700 Area, perimeter, 25-mi, and 100-mi areas	Monthly reports	Data not compiled
^{3}H in rainwater	1954-1963, 1974-1990	Semiannual or annual maximum, and average for each location	Semiannual and annual reports	Data not compiled
^{131}I in rainwater	1954-1963	Semiannual or annual maximum, and average for each location	Semiannual and annual reports	Data not compiled
Gamma radio-nuclides, Sr , and Pu in rainwater	1974-1990	Semiannual or annual maximum, and average for each location	Semiannual and annual reports	Data not compiled
Gross alpha in rainwater	1956-1963	Semiannual or annual maximum, and average for each location	Semiannual and annual reports	Data not compiled
Nonvolatile beta in rainwater	1954-1963	Semiannual or annual maximum, and average for each location	Semiannual and annual reports	Data not compiled
Specific radionuclides in rainwater	1977-1990	Individual results	Monthly reports	Data not compiled
Specific radionuclides in rainwater	1959—1973	Individual results	Aperture cards	Tritium-all.xls, Iodine-all.xls, Gamma-all.xls[b]
Particle deposition	1960	Individual results	Aperture cards	Particles-all.xls

[a] Individual results are for each location and for each period of collection (typically weekly).

[b] A worksheet is available for each year. For example, the gross beta activity data for 1959 may be found in the workbook entitled Alpha-Beta-all.XLS, in the worksheet entitled “1959 – beta”.

RADIONUCLIDE CONCENTRATIONS IN AIR

Tables 8-2, 8-3, and 8-4 (located in Addendum 8A at the end of this chapter) present summaries of the types of air monitoring data obtained by the SRS contractor at onsite, 25-mi, and 100-mi sampling locations. Each horizontal line in the tables represents a change in the routine monitoring program, such as, the addition of new sampling sites. A brief history of the air monitoring program is presented below.

During the preoperational monitoring program (Reinig et al. 1953), in June 1951–January 1953, air was sampled continuously at two onsite locations using CWS #6 filter paper and a dual pump unit. One pump was running while the other pump was off, at 6-h intervals, and the filter of the inactive pump was analyzed for gross beta. A Geiger-Mueller (GM) counter constantly recorded the activity on air filters. Radon and thoron concentrations were estimated using buildup and decay curves. Radioautographs were made of filters weekly to estimate the quantity of particles suspended in the air sampled at 12 inner perimeter and three 25-mi radius locations. Also, during the preoperational period, fallout particles were trapped through settling on adhesive flypaper emplaced at the 12 inner perimeter locations and counted weekly using radioautographs. Deficiencies in the preoperational survey are reviewed in *The 1951 Preoperational Environmental Survey for the Savannah River Plant - In Retrospect* (Du Pont 1962a).

Routine air monitoring began on January 1, 1953. The routine monitoring program was essentially a continuation of the preoperational monitoring program, conducted at selected onsite and 25-mi locations. However, additional sampling sites were gradually added to the onsite monitoring network to collect more gross beta and suspended particle data (Albenesius 1954).

Beginning in 1955, air filters were counted weekly for gross alpha, using alpha scintillation counters. Continuous air samplers with a flow rate of 2.0 cfm and 2-in. CWS #6 filters were used for this purpose. Also, in the same year, silver nitrate impregnated HV70 filters were used to collect radioiodine (Alexander and Horton 1956).

Starting in 1956, tritium in air was collected at onsite and 25-mi radius stations using silica gel. The design basis of the regional air monitoring program at that time can be found in Horton (1957).

Major changes in the air monitoring program were implemented in 1960 and 1961. Air filters were no longer analyzed for suspended particles in 1960 and the particulate fallout study was discontinued in 1961. The regional monitoring program was expanded to include background sites. Sampling at 100-mi radius locations (Columbia, South Carolina; Greenville, South Carolina; Macon, Georgia; and Savannah, Georgia, was initiated in 1961. This background monitoring program began with sampling and analysis for gross alpha and gross beta and was expanded in 1962 to include ^{131}I and gamma-emitting radionuclides. Gamma spectroscopy was also used to analyze air filters collected at onsite and 25-mi radius locations beginning in 1962. These and other changes, especially in procedures, may be found in Marter and Boulogne (1962).

By 1973, air filters were routinely analyzed for $^{89,90}Sr$. Routine analysis of filters for $^{239,240}Pu$ followed in 1974. Iodine-131 was eliminated from the routine monitoring program from 1974 through 1979, but no documented rationale could be found for this deletion. However, it is possible that the analyses were discontinued because this radionuclide was rarely detected in air samples. The data from aperture cards show that ^{131}I was usually below the detection limits.

The 1980 air monitoring program consisted of 19 onsite, 8 offsite (25-mi radius), and 4 background (100-mi radius) monitoring locations (Du Pont 1981). The locations of the onsite and 25-mi perimeter sampling sites, referenced above, are shown in Figure 8-1.

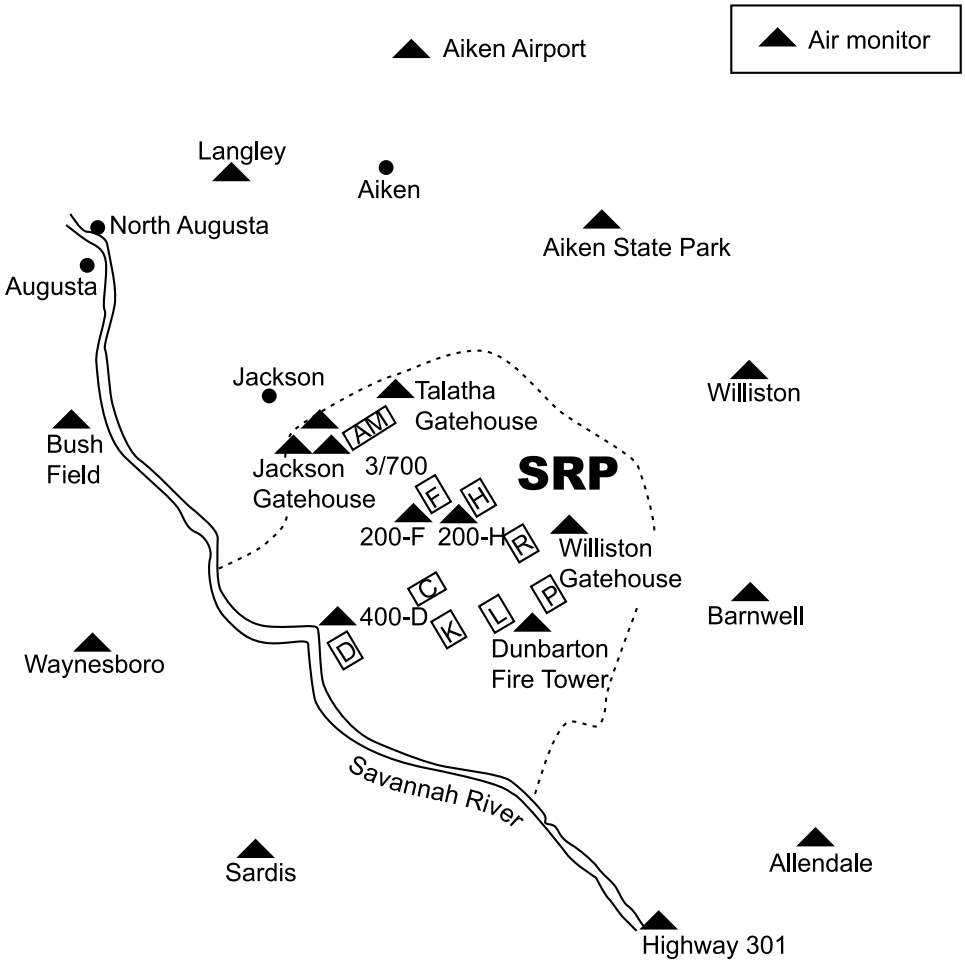

Figure 8-1. Onsite and 25-mi radius air monitoring locations.

The following sections present the results of the air monitoring program by type of radionuclide measured. The SRS environmental monitoring program results of air sampling for radionuclides discussed in this chapter have been compiled in Excel spreadsheets.

Measurements of Beta-Gamma Emitters in Air

The beta-gamma emitters that were routinely monitored in air by SRS were radioiodine, strontium, tritium, and ^{137}Cs. Collection periods varied as monitoring program personnel determined the need. In addition, gross particulate alpha and gross particulate beta activity was measured during preoperational monitoring and weekly thereafter. Two of these radionuclides (i.e., radioiodine and tritium) were identified in the initial screening process as the largest contributors to the screening dose from airborne releases (Meyer et al. 1995).

On the other hand, little knowledge can be obtained from measurements of gross alpha activity. Neither of the key radionuclides released to air is an alpha-emitter. While great effort could be made to use the gross alpha data, it is inefficient given the relative insignificance of potential doses because of releases of the key alpha emitters (plutonium and uranium). Gross alpha data were used as a screening technique to detect anomalies (i.e., sudden increases over background), not to identify specific radionuclides. For these reasons, gross particulate alpha measurements were not examined.

Air filters that were used to measure emissions from SRS facilities were not analyzed for specific isotopic alpha activity until the early 1970s because of the low release rates and the small potential for plutonium release. Instead, filters were submitted for laboratory analysis for specific alpha emitters only if gross beta-gamma activity was detected above background.

Gross Beta Measurements in Air

Gross particulate beta activity concentrations in air can be useful to demonstrate patterns, especially when the source of activity is known. This pattern was evident during the years when global fallout from nuclear weapons testing was elevated. Figure 8-2 demonstrates temporal trends for the years 1959 through 1964, peak fallout years. The peaks in activity compare well at all locations and with measurements made by the U.S. Public Health Service (PHS) at Columbia. This figure confirms that peak measurements were primarily due to global fallout and not to SRS operations.

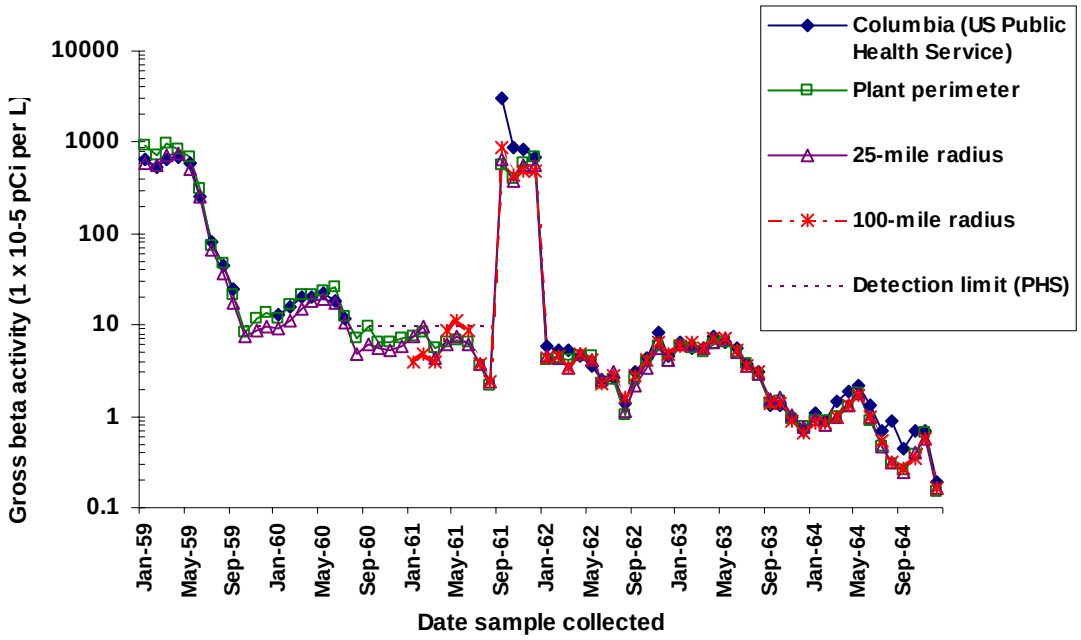

Figure 8-2. Average monthly concentrations of particulate beta radioactivity measured on and off the SRS by the SRS and by the U.S. Public Health Service from 1959 through 1964. The highest gross beta activity (2970 × 10-5 pCi L^{-1}) was measured in Columbia in September 1961. Link to tabulated figure data.

The close correspondence between PHS and SRS data particularly during the period from June 1962 through 1964 serves to verify SRS measurements.

Radioiodine Measurements in Air

Sampling for volatile and particulate forms of ^{131}I at onsite, plant perimeter, and 25-mi radius locations began in 1955. Sampling at locations 100 mi from the SRS was initiated in 1962 to provide data on background concentrations of radionuclides (Du Pont 1962b).

According to Kantelo et al. (1990), ^{131}I has been detected at locations close to the F and H separations areas in most years. At the plant perimeter and 25-mi locations, ^{131}I was detected from 1955 through 1963. Near the 100-mi radius, ^{131}I was detected only during 1962 and 1963.

Original data (i.e., from aperture cards) could not be found for years before 1959. This is unfortunate because the highest average concentrations of ^{131}I in air were reported during 1956 (see Table 8-5.) Figure 8-3 presents average monthly ^{131}I concentrations measured in air at onsite, perimeter, 25-mi, and 100-mi areas from 1959 through 1966. We calculated these averages by using original data. The highest monthly averages estimated for this period are generally far less than the semiannual averages reported for 1956 (Mealing 1957a, 1957b).

Table 8-5. Average Semiannual ^{131}I Concentrations in Air from 1955 through 1958

	Average radioiodine concentration in air (10^{-14} μCi mL^{-1})						
Location	Jul.–Dec. 1955	Jan.–Jun. 1956	Jul.–Dec. 1956	Jan.–Jun. 1957	Jul.–Dec. 1957	Jan.–Jun. 1958	Jul.–Dec. 1958
400-F[a]	7	700	580	150	94	6	22
200-H[a]	28	570	470	390	110	8	28
Dunbarton Fire Tower[b]	7	Data incomplete	47	54	49	8	26
Talatha Gatehouse[b]	3	67	38	40	54	8	24
400-D[b]	6	60	36	41	42	8	12
Williston Gatehouse[b]	10	64	34	45	53	8	25
700-A[b]	3	70	20	27	42	7	31
Waynesboro[c]	4	14	19	30	43	7	24
Aiken Airport[c]	2	19	16	27	20	8	22
Allendale[c]	3	13	12	21	28	8	19

[a] Onsite location.
[b] Plant perimeter location.
[c] 25-mi radius location.

Figure 8-3 also indicates that SRS releases impacted concentrations of ^{131}I measured in air at perimeter and 25-mi locations during the first halves of 1959 and 1961. Interestingly, ^{131}I concentrations appear to be equivalent during the last part of 1961, 1962, and the first part of 1963. This pattern confirms that shown in Figure 8-3 and may reflect increased global fallout. After 1963, only onsite concentrations were consistently measured above the detection limit.

The impact of SRS releases on perimeter locations can also be examined by looking at the ratios of the monthly ^{131}I concentrations at different areas (see Figure 8-4). For example, the ratio

of onsite to 25-mi radius ^{131}I concentrations are, with few exceptions, greater than 1. This indicates that F-Area and H-Area concentrations are elevated relative to 25-mi radius locations from 1959 through 1963, reflecting emissions from F-Area and H-Area stacks. The times when the ratio approaches or equals 1 indicates equivalent concentrations at both areas, possibly reflecting global fallout (e.g., late 1959, early 1961, late 1962, and early 1963). Figure 8-4 also shows ^{131}I concentrations at plant perimeter locations relative to concentrations measured at 25-mi radius locations. Radioiodine concentrations have been elevated at plant perimeter locations relative to 25-mile radius locations only a few times (most notably, during June and July 1959, the summer of 1961, and October 1961).

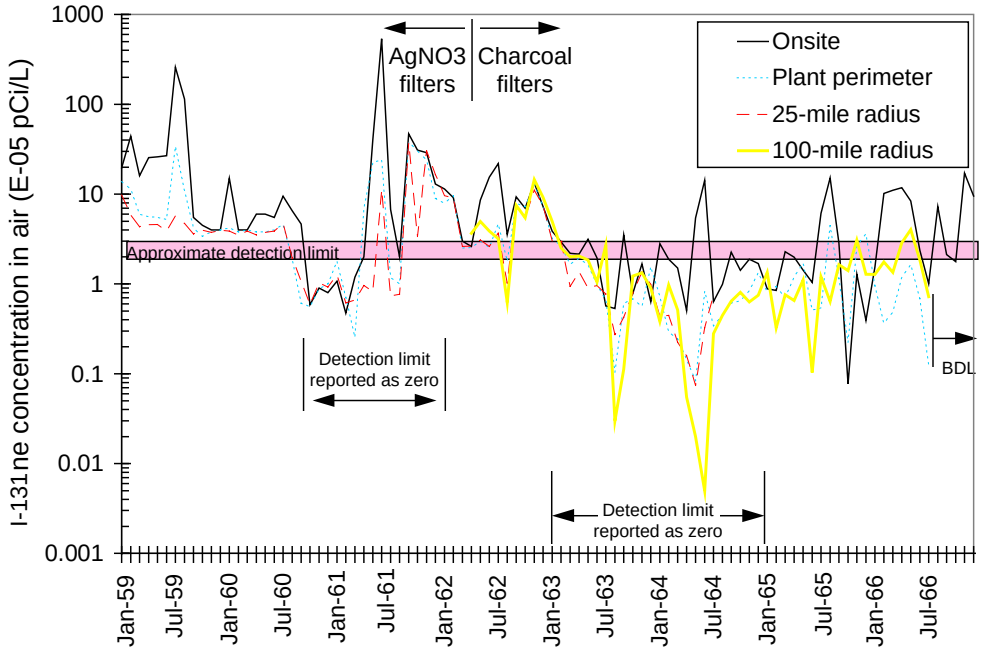

Figure 8-3. Average monthly concentrations of ^{131}I measured on and off the SRS by the SRS from 1959 through 1966 (BDL=all individual measurements below detection limits). The approximate detection limit during this time was about 2×10^{-5} pCi L^{-1}. Link to tabulated figure data.

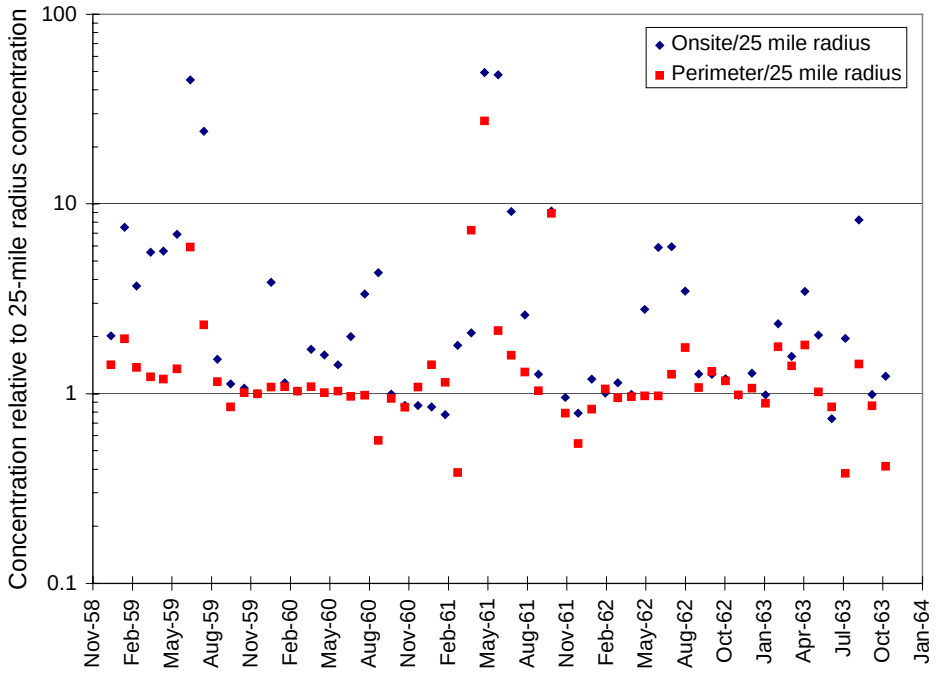

Figure 8-4. Iodine-131 concentrations measured at F-Area, H-Area, and 25-mi radius locations relative to concentrations measured at 25-mi radius and perimeter locations. Link to tabulated figure data.

Although original data were not available for all years (e.g., before 1956), other reports were found that assessed original data to ascertain temporal and spatial patterns. Kantelo et al. (1990) used a slope analysis technique to determine that the SRS was the principle source of radioiodine in the local atmospheric environment during 1956. Annual average ^{131}I concentrations were estimated for each onsite, perimeter, and 25-mi sampling location and plotted against distance (Figure 8-5). The distances used were measured from the center of the two Chemical Separations Areas because greater than 99% of the atmospheric radioiodine released from the SRS originated from this area (Kantelo et al. 1990). Logarithmic scales were used so that a straight line would result. The slope of this line was then used to indicate whether the Site emissions impacted the perimeter and offsite locations. A slope of one indicates no difference between concentrations measured at onsite, perimeter, and 25-mi stations. A large negative slope implies that SRS releases influenced ^{131}I concentrations measured at offsite areas. In Figure 8-5, it is obvious that releases from the separations area had a much greater impact on the local offsite environment in 1956 than in 1962. Slopes calculated in this manner by Kantelo et al. (1990) show the greatest impact from the SRS occurred during 1956 (see Table 8-6). Slopes approached zero during 1962 and 1963, reflecting global fallout concentrations.

Figure 8-6 illustrates the slopes derived, from aperture card data, for the years 1959 through 1963. Figure 8-7 is another way of illustrating the impact of SRS releases on the immediate environment. In this case, the chart axes are expressed using an arithmetic, rather than a geometric, scale.

Table 8-6. Slopes of Annual Average ^{131}I Concentrations in Air as a Function of Distance[a]

Year	Slope
1955	-0.46
1956	-1.05
1957	-0.52
1958	-0.27
1959	-0.62
1960	-0.11
1961	-0.32
1962	-0.06
1963	0.00

[a] Source: Kantelo et al. (1990).

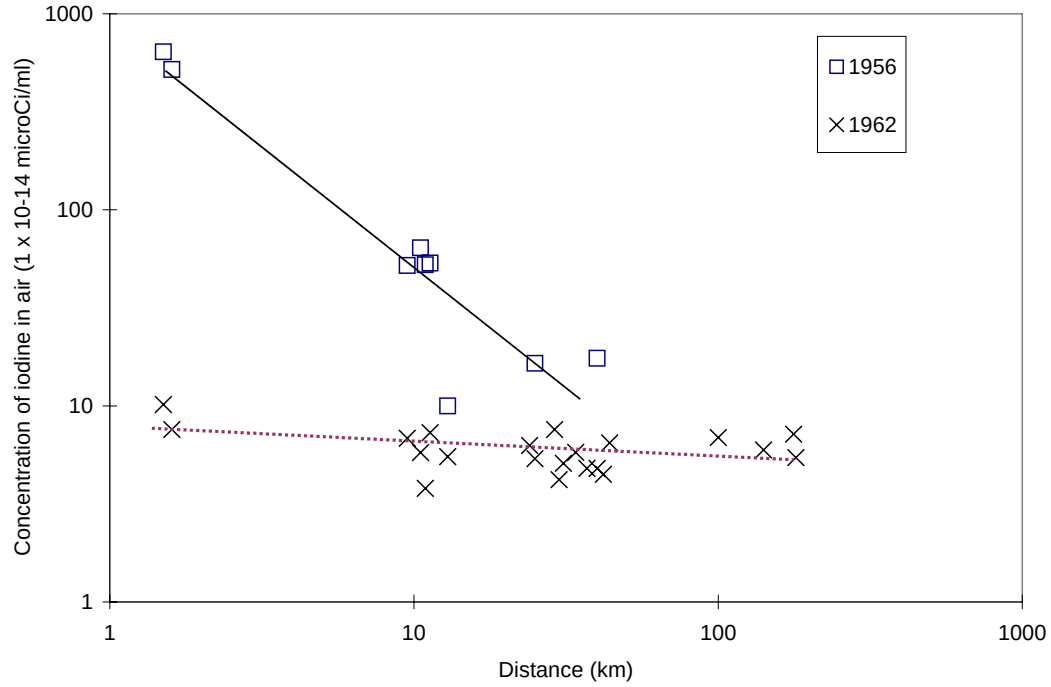

Figure 8-5. Annual average concentrations of ^{131}I in air with distance from the center of the Chemical Separations Area at SRS for two representative years (source: Kantelo et al. 1990). Link to tabulated figure data.

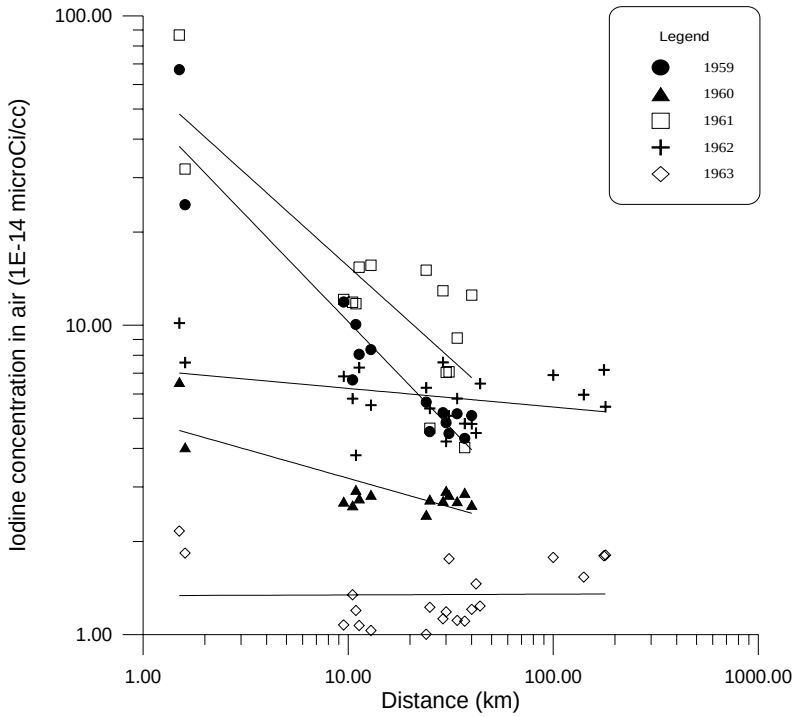

Figure 8-6. Annual average concentrations of ^{131}I in air with distance from the center of the Chemical Separations Area at SRS for the years 1959–1963 (data derived from aperture cards). The figure shows that he highest concentration was measured closest to the site in 1961 at about 90×10^{-14} µCi ml^{-1} (9×10^{-5} pCi L^{-1}). Link to tabulated figure data.

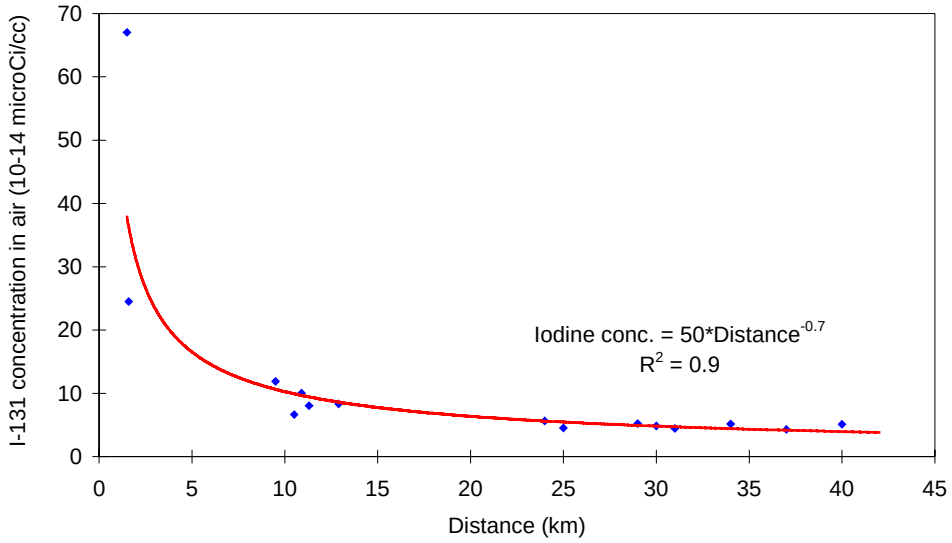

Figure 8-7. Annual average concentrations of ^{131}I in air with distance from the center of the Chemical Separations Area at SRS during 1959 (data derived from aperture cards). Link to tabulated figure data.

There are no apparent spatial dispersion patterns associated with ^{131}I releases to the atmospheric environment as illustrated in Figures 8-8 through 8-10. Figure 8-8, which represents 1959, shows elevated concentrations near the source of release (1.5 km), somewhat elevated concentrations at the plant perimeter (9.5–13 km), and background concentrations at the 25-mi (25–44 km) radius locations. However, no one direction appears to predominate in terms of concentration. This reflects the variable wind patterns at the SRS. Figures 8-9 and 8-10, which represent the fallout years of 1962 and 1963, show fairly equivalent concentrations as a function of distance and direction; however, the onsite concentrations appear to be slightly higher.

Ideally, the original data (collected weekly and biweekly) can be used to verify or identify routine and unplanned releases. For example, according to Kantelo et al. (1990), the only acute release incident because of the inadvertent reprocessing of very short-cooled materials occurred during May and June 1961. A plot of weekly concentrations of ^{131}I in air measured at onsite and perimeter locations clearly shows elevated concentrations during this period (see Figure 8-11). Figure 8-11 also indicates elevated releases from October through December, reflecting increases in production rates.

Figure 8-12 compares release data with data monitored at the two onsite locations for the year 1964. Elevated concentrations at 200-F and 200-H during May and June tracked increased releases during this period. However, higher releases of ^{131}I during August and September are not closely correlated with concentrations measured at the two onsite locations during the same period. The small number (two) of onsite stations decreases the probability that an elevated release event will be detected in the environment.

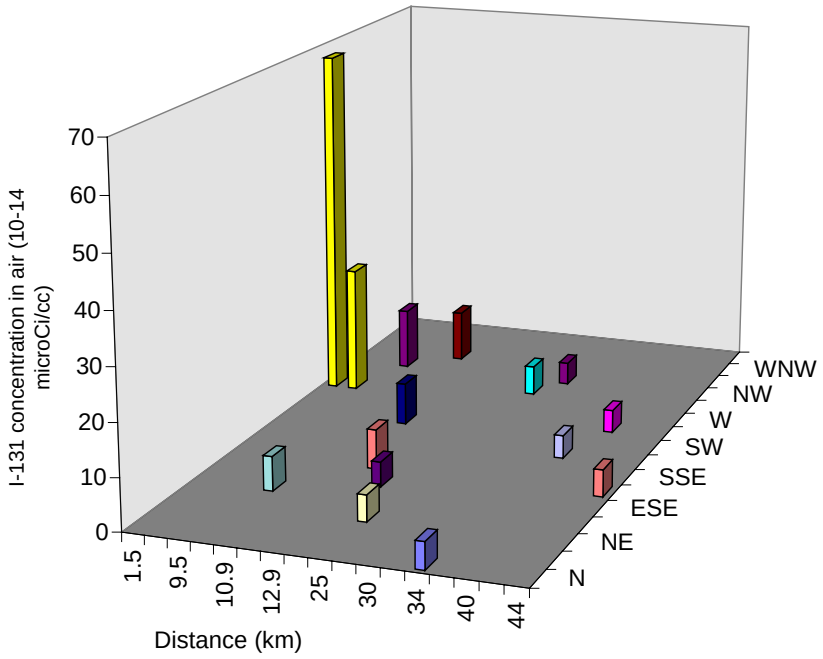

Figure 8-8. Annual average concentrations of ^{131}I in air with distance and direction from the center of the Chemical Separations Area at SRS during 1959 (note that X value axis is not to scale) (data derived from aperture cards). Link to tabulated figure data.

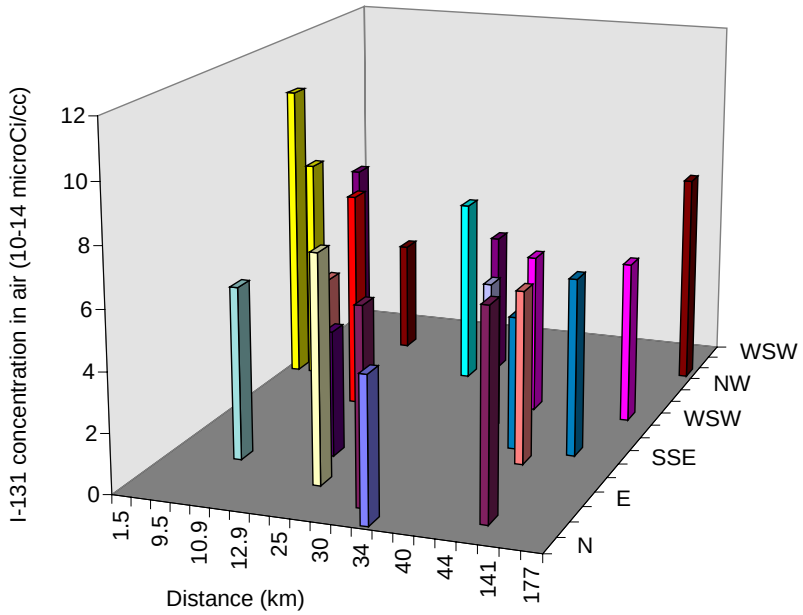

Figure 8-9. Annual average concentrations of ^{131}I in air with distance and direction from the center of the Chemical Separations Area at SRS during 1962 (note that X value axis is not to scale) (data derived from aperture cards). Link to tabulated figure data.

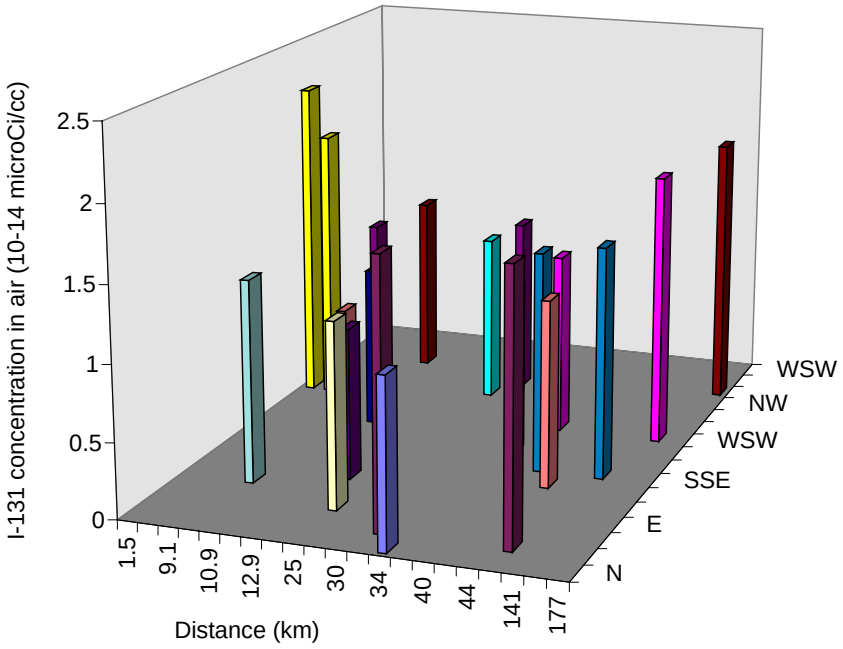

Figure 8-10. Annual average concentrations of ^{131}I in air with distance and direction from the center of the Chemical Separations Area at SRS during 1963 (note that X value axis is not to scale). Data derived from aperture cards. Link to tabulated figure data.

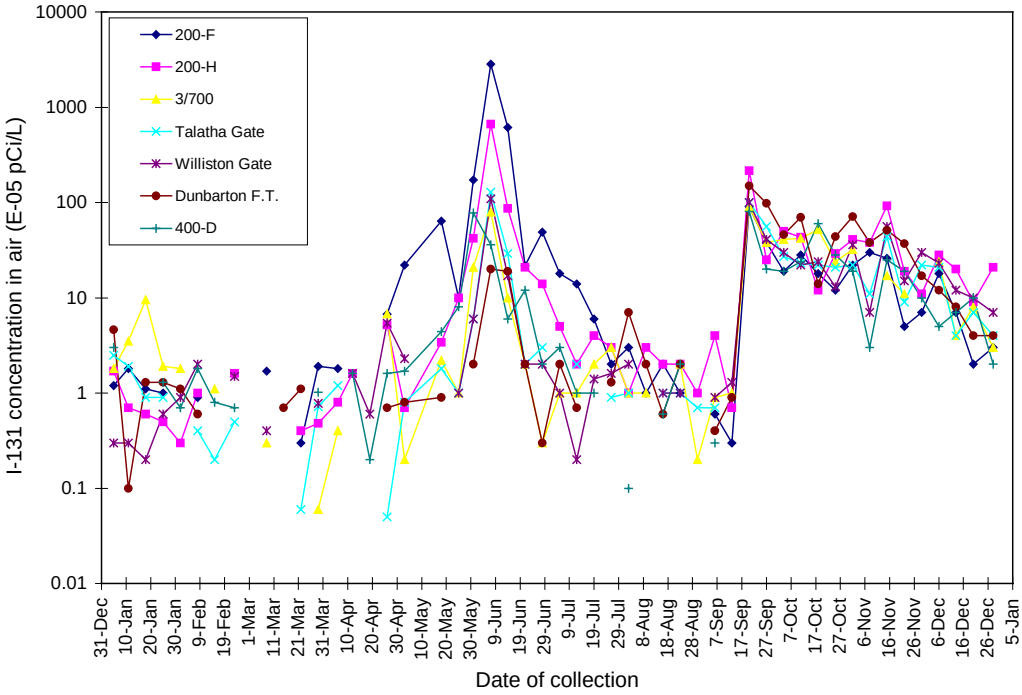

Figure 8-11. Concentrations of ^{131}I measured in air at onsite and perimeter locations during 1961 showing the impacts of incidents during May and June and increased atmospheric releases from the SRS during October through December (data derived from aperture cards). Link to tabulated figure data.

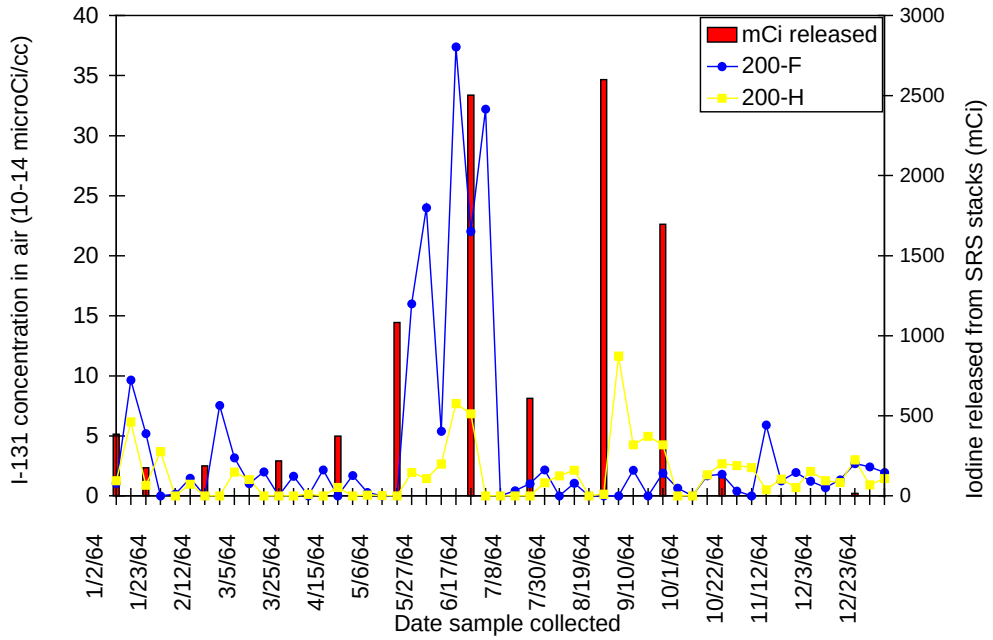

Figure 8-12. Comparison of monthly ^{131}I releases with ^{131}I concentrations measured in air effluents and two onsite locations during 1964 (data derived from aperture cards). Link to tabulated figure data.

Radiostrontium Measurements in Air

Analysis of air filters for ^{90}Sr at onsite, plant perimeter locations, 25-mi radius, and 100-mi radius began in 1967. Carlton et al. (1992) evaluated the spatial pattern with distance for two time periods: during (1967–1975) and after (1976–1986) atmospheric nuclear testing. They found no consistent spatial pattern with distance from the SRS. However, they observed that the average ratio of $^{90}Sr/^{137}Cs$ inside the SRS boundary was similar to that found in bomb fallout during the earlier period and more like those from SRS releases after 1976. They also noted that measurements made after 1976 were very low and had correspondingly high measurement errors.

Unfortunately, individual sample measurements were not available and, thus, an independent, in-depth data evaluation could not be made.

Tritium Measurements in Air

Measurements of the tritium content of atmospheric water vapor have been made since 1960 at and around the SRS. Tritium is the only radionuclide that has been consistently measured above detection levels by the air monitoring network. The major source of tritium in the environment during the period of SRS operations is from nuclear testing, which began in 1945 and peaked in the early 1960s (Murphy et al. 1991). Most of the tritium released from the SRS has been from the tritium facilities (F-Area and H-Area). Tritium released from these areas is in two forms: elemental tritium (HT) and the oxide form (HTO). The oxide form (tritiated water) is approximately 25,000 times more radiotoxic than elemental form because it is easily absorbed and incorporated into living tissue (Elwood 1971). Tritium released from the reactor areas is almost entirely HTO. The SRS air monitors contain silica gel that absorbs water and, therefore, sample the HTO form of tritium. Studies of the HT-to-HTO ratios in atmospheric releases from the separations areas were conducted from 1976 through 1979. These studies indicated that the overall percentages for the 1976–1979 period were 44% HT and 56% HTO (Murphy et al. 1991). However, significant variations in release rates and HT-to-HTO ratios were observed because of differences in the nature of the work and in the operating periods of the various facilities.

There appears to be little correlation between reported atmospheric releases with environmental measurements of tritium in air (see Figures 8-13 and 8-14.) The primary factors that can result in environmental measurements that do not track release measurements include the form of tritium released and variable meteorological conditions over the period of release. The environmental samplers only collected tritiated water, not tritiated hydrogen gas. Meteorological factors, such as temperature, wind speed, and wind direction, determine the direction, dispersion, and height of a contaminant plume. The environmental samplers, thus, may not have always been in the plume path or they sampled concentrations that were not necessarily representative of mean concentrations in the plum. However, air data consistently show a decrease in tritium concentration relative to distance from the Site (Figures 8-15 and 8-16).

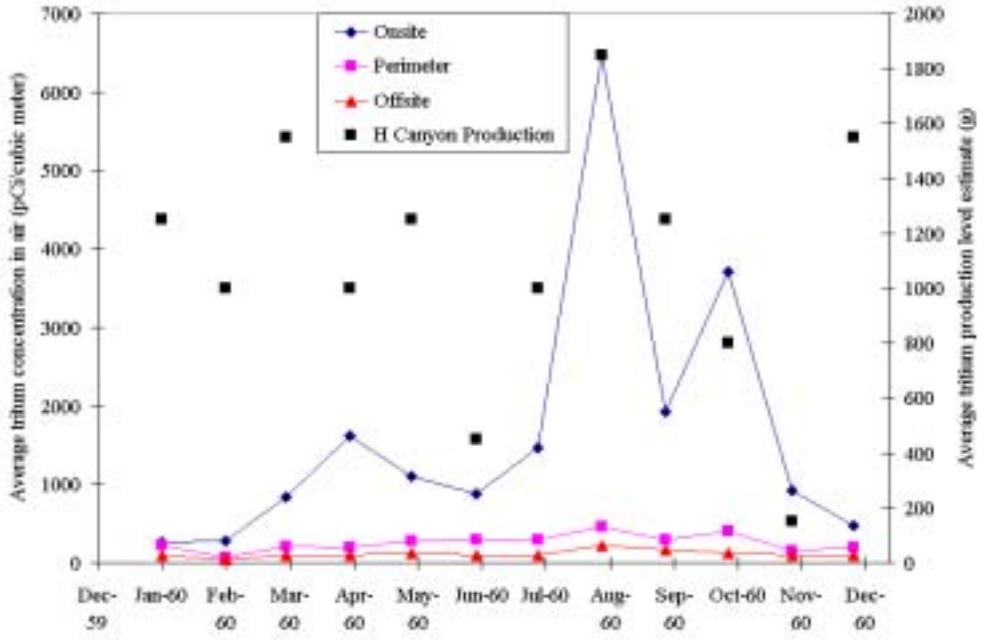

Figure 8-13. Average monthly tritium concentrations in moisture in air measured at onsite (F-Area and H-Area), SRS perimeter, and offsite (25-mi radius) locations during 1960. Production rates projected for the H-Area facility are also shown (see Chapter 2 of this report) (data derived from aperture cards). Link to tabulated figure data.

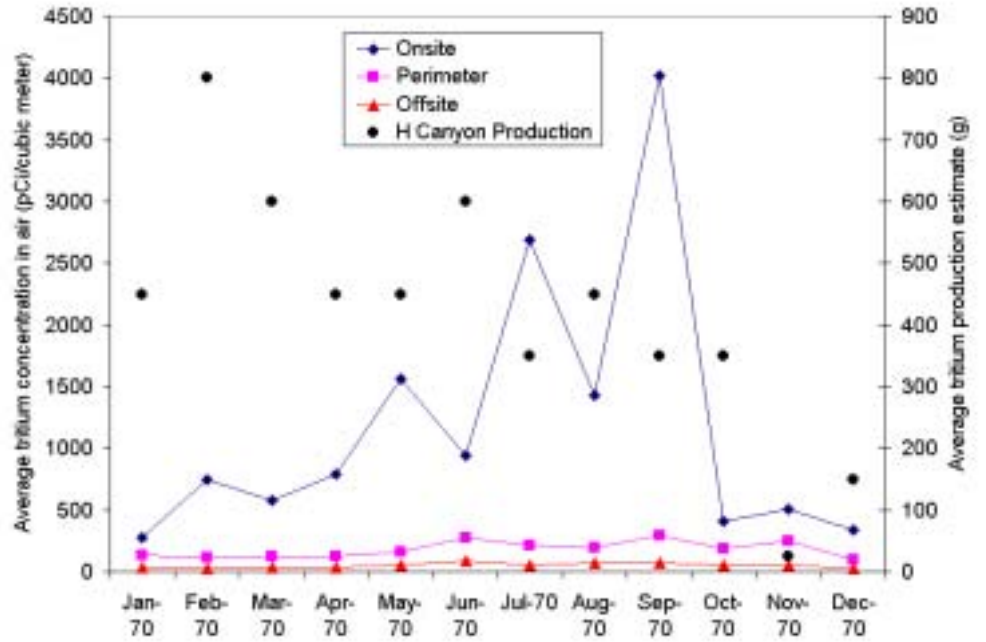

Figure 8-14. Average monthly tritium concentrations measured in moisture in air at onsite (F-Area and H-Area), SRS perimeter, and (25-mi radius) offsite locations during 1970. Production rates projected for the H-Area facility are also shown (see Chapter 2 of this report) (data derived from aperture cards). Link to tabulated figure data.

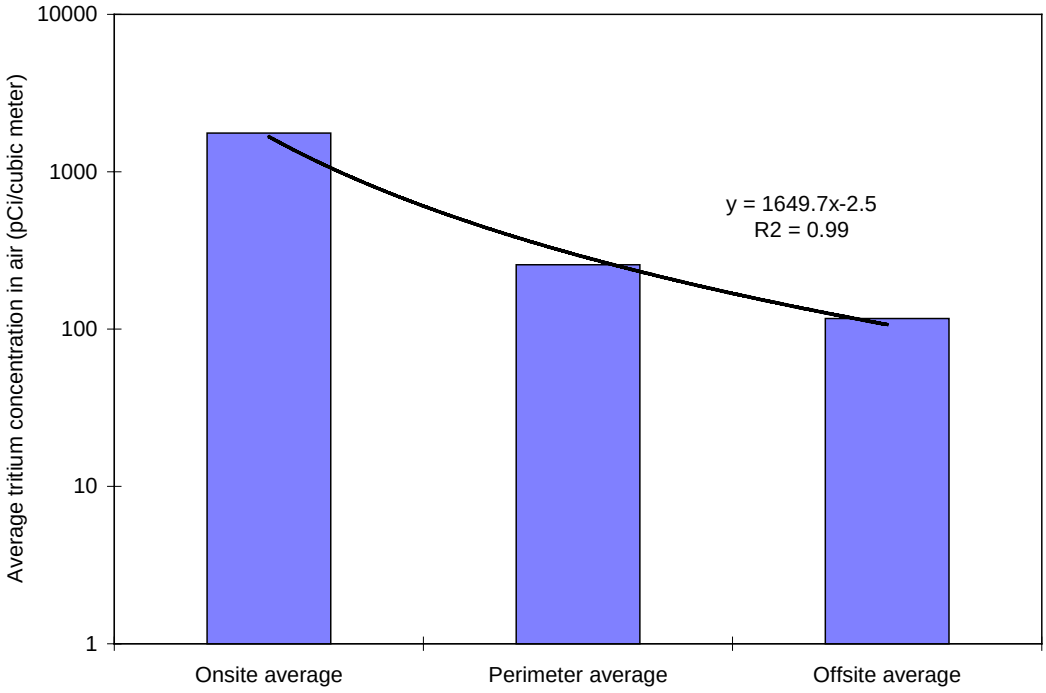

Figure 8-15. Relationship of average annual tritium concentrations measured in moisture in air during 1960 with distance from F-Area and H-Area (onsite locations) (data derived from aperture cards). Link to tabulated figure data.

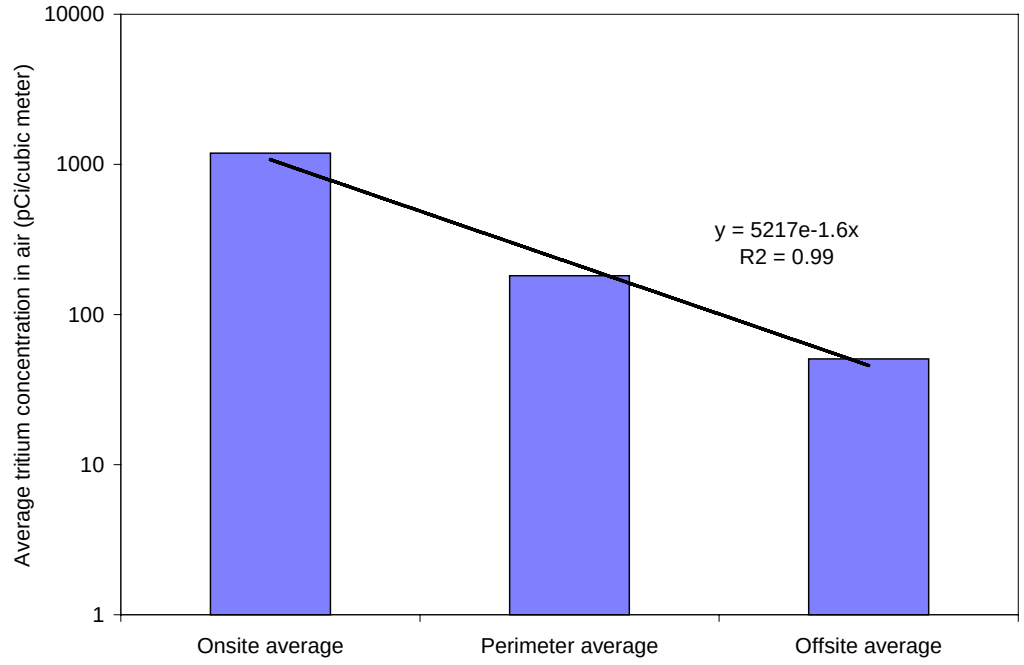

Figure 8-16. Relationship of average annual tritium concentrations measured in moisture in air during 1970 with distance from F-Area and H-Area (onsite locations) (data derived from aperture cards). Link to tabulated figure data.

Figures 8-17 and 8-18 show individual results for F-Area and H-Area monitors during 1960 and 1970. It is clear that the H-Area monitor consistently measures higher concentrations of tritium in the air than the F-Area monitor. This may reflect higher releases from the production facility in that area. Unfortunately, no weekly or biweekly release data are available for comparison. However, Murphy et al. (1991) shows a positive correlation between the amount of tritium released and concentrations of tritiated water in air at 20 km.

Cesium Measurements in Air

Measurements of gamma-emitting radionuclides began in July 1964 with monthly composites made of samples collected at F-Area, H-Area, perimeter, and 25-mi locations. Only one series of measurements was made in 1964. Beginning in 1965, monthly composites were analyzed routinely. Cesium-137 is the only gamma-emitting radionuclide that has been consistently measured above detection limits. The exception is during the early years, when other radionuclides (e.g., ^{54}Mn, ^{103}Ru, ^{106}Ru, and ^{144}Ce) from nuclear testing fallout were measured. It is expected that the concentrations of ^{137}Cs measured in the earliest years are associated with fallout from atmospheric weapons testing. Figure 8-19 shows measurements obtained from July 1964 through 1965. The impact of global fallout is obvious in the pattern of similar concentrations measured at each distance from the SRS.

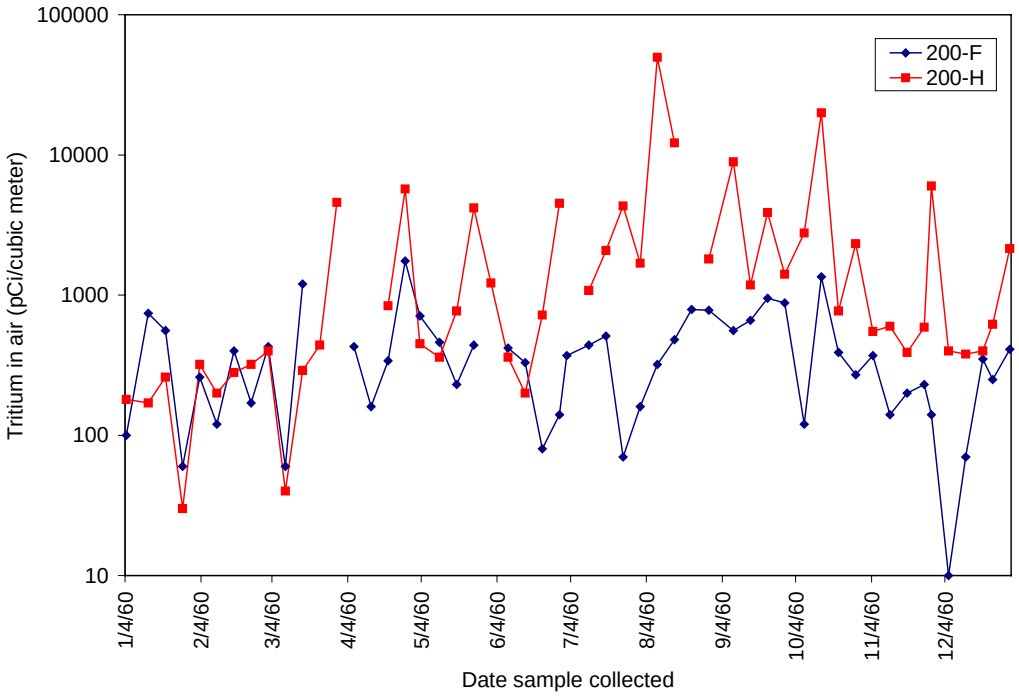

Figure 8-17. Weekly tritiated water measurements made in air at F-Area and H-Area during 1960 (data derived from aperture cards). Link to tabulated figure data.

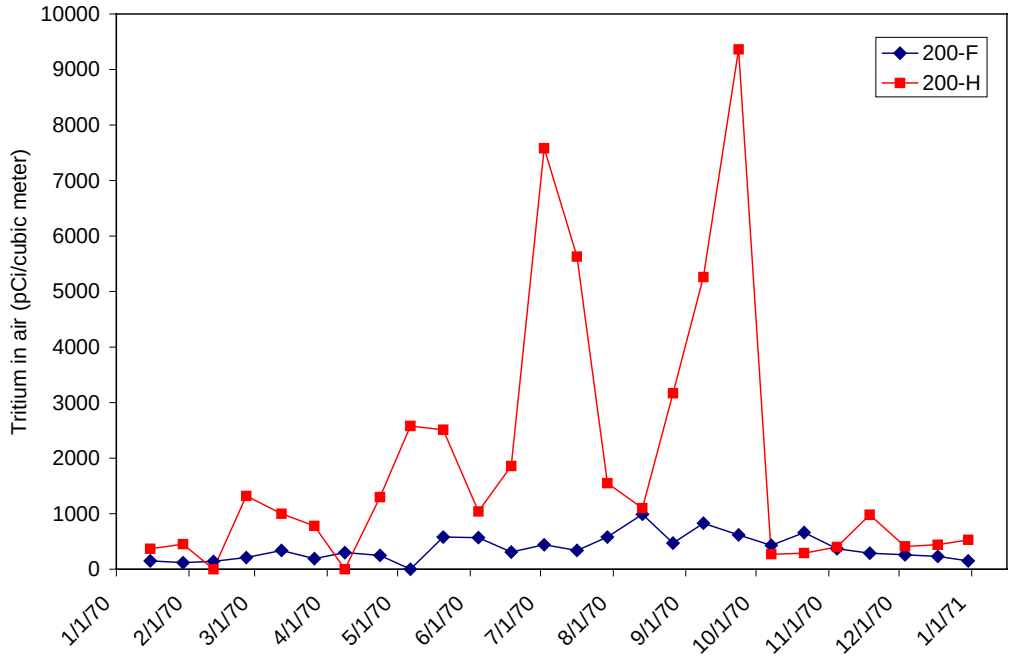

Figure 8-18. Biweekly tritiated water measurements made in air at F-Area and H-Area during 1970 (data derived from aperture cards). Link to tabulated figure data.

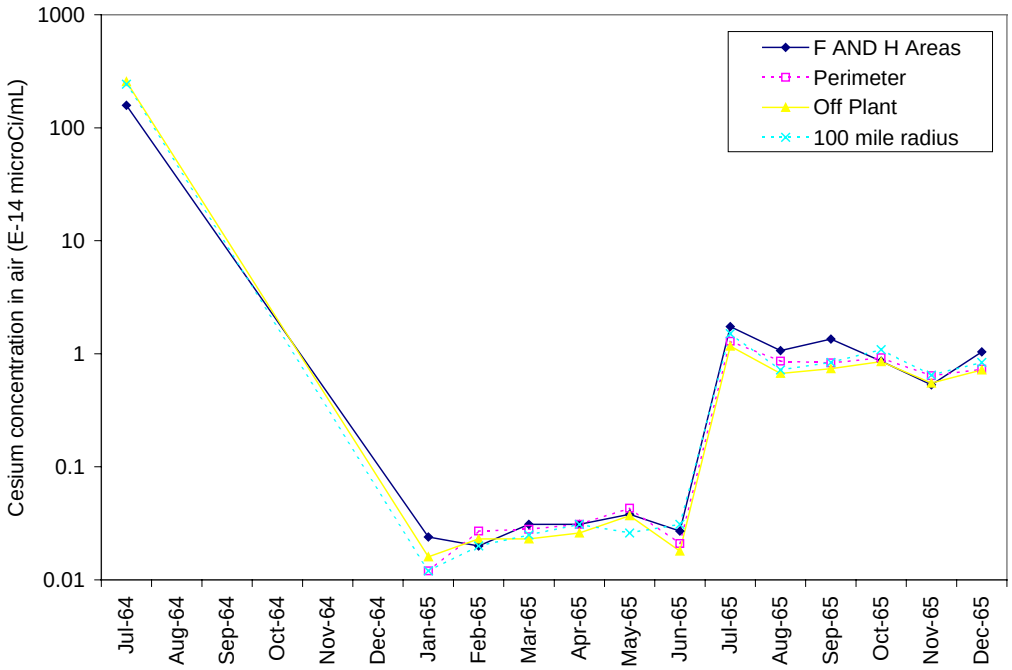

Figure 8-19. Monthly averages of ^{137}Cs measured at onsite, perimeter, 25-mi radius, and 100-mi radius locations from July 1964 through 1965 (data derived from aperture cards). Link to tabulated figure data.

During later years, Site releases appear to impact measurements made close to the SRS. Figure 8-20 shows higher concentrations of ^{137}Cs at F-Area and H-Area locations than at perimeter, 25-mi radius, and 100-mi radius locations during 1973.

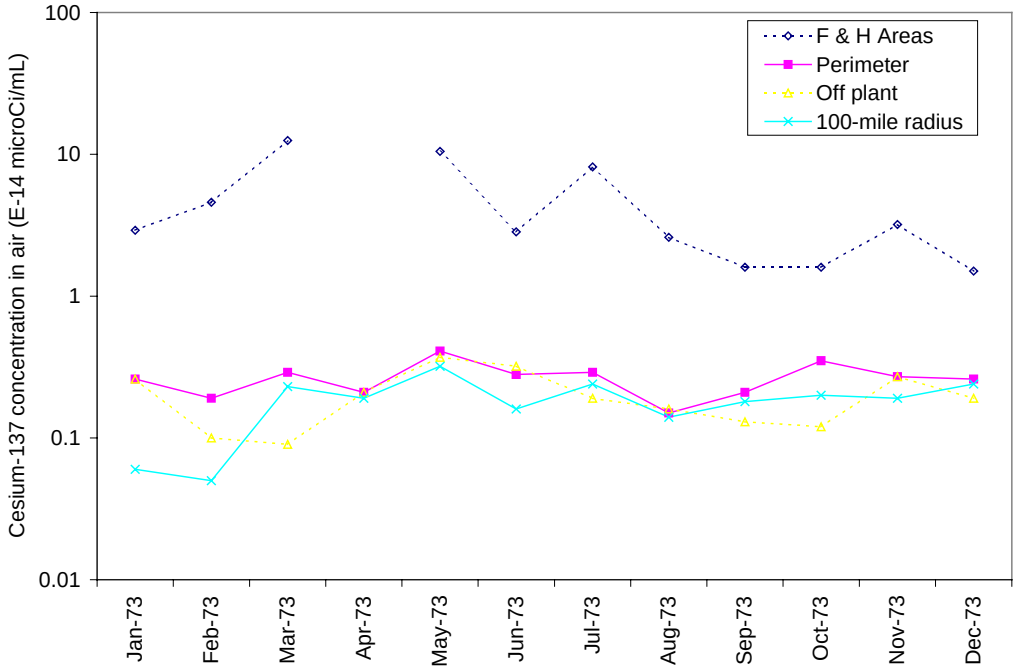

Figure 8-20. Monthly averages of ^{137}Cs measured at onsite, perimeter, 25-mi radius, and 100-mi radius locations during 1973 (data derived from aperture cards). Link to tabulated figure data.

Background Measurements of Radionuclides in Air

The SRS was not the only potential source of radionuclides in the environment (see Chapter 6 of this report). Fallout from atmospheric weapons testing was a source of both radionuclides in the environment and, therefore, in milk samples. Fallout concentrations of these radionuclides were greatest in the early 1960s. The concentrations in fallout decreased significantly from 1963 onward following the bomb-testing moratorium. The PHS (currently the U.S. Environmental Protection Agency [EPA]) initiated an air monitoring program for the southeast United States in 1955, and it provides the only independent source of air monitoring data. The monitoring location that is closest to the SRS is Columbia, South Carolina. Unfortunately, only particulate beta activity was measured (Figure 8-2). However, it is possible to compare these data with SRS particulate beta activity results for validation of these data during fallout years. At present, no other sources of independent monitoring data are available for comparison with SRS data.

RADIONUCLIDE CONCENTRATIONS IN RAINWATER

This section summarizes reported information regarding tritium concentrations in rainwater collected from locations on and in the vicinity of the SRS. Deposition of tritium in rainfall can be the result of two processes: rainout and washout. Rainout incorporates tritium in precipitation as it forms in clouds. Washout occurs when precipitation falling from the cloud passes through air containing tritium. Washout of tritium from air that has received tritium from facility stacks or evaporation from seepage basins is the process that is most important in the vicinity of SRS.

Rainwater data were found in aperture cards that were dated 1962 through 1965, 1968, and 1972 through 1973. The aperture cards represent the primary sources of original data. The data available from aperture cards were transcribed and recorded in Microsoft Excel workbooks entitled "Tritium-all.xls." Five sets of environmental monitoring reports spanning the years 1954 through 1991 were also examined. Only three sets of monitoring reports had information regarding tritium concentrations in rainwater: (1) *Health Physics Regional Monitoring, 1954–1963*, (2) *Environmental Monitoring at the Savannah River Plant, 1964–1991, Environmental Monitoring in the Vicinity of the Savannah River Plant, 1971–1983*, and (3) the *Savannah River Plant Environmental Report, 1984–1989*. The other two sets of monitoring reports (*Effect of the Savannah River Plant on Environmental Radioactivity, January 1962–June 1971* and *Environmental Monitoring at the Savannah River Plant, 1964–1976*) did not contain any information regarding tritium concentrations in rainwater.

Sample Collection, Preparation, and Analysis

Since 1962, rainwater has been collected at air monitoring stations located at onsite, plant perimeter, and 25-mi radius locations. During the period from 1961 through 1972, there were three onsite, five plant perimeter, and ten 25-mi radius locations. The number of onsite locations was increased to 6 in 1974 and to 10 in 1983. The number of plant perimeter locations was increased to 10 in 1973, to 12 in 1974, and to 13 in 1976. The number of 25-mi radius locations increased to 12 in 1974. This sampling regimen was consistent through 1985. In 1986, the number of routine plant perimeter and 25-mi radius locations was reduced to one station at Darkhorse. In 1978, rainwater collection began at four 100-mi radius locations, including Columbia and Greenville, South Carolina, and Macon and Savannah, Georgia.

Rainwater was collected in 2 × 2-ft fallout collection pans. The water was passed through an ion exchange column and collected in plastic jugs for weekly analyses through 1980. Analysis frequencies were not reported from 1981 through 1991, but sample numbers are indicative of bimonthly analysis for plant perimeter and 25-mi radius locations and quarterly analysis for 100-mi radius locations. Following collection, tritium concentrations were determined by liquid scintillation counting. Beginning in 1962, rainwater samples were also analyzed for iodine; beginning in 1965, they were analyzed for other radionuclides. The data for these radionuclides do not appear to be useful for dose reconstruction purposes and, therefore, are not discussed in this chapter.

Tritium Concentrations in Rainwater

Figures 8-21 and 8-22 show a decrease in tritium concentration in rainwater deposition as function of distance from the Site. This pattern is similar to that for tritium in air (see Figure 8-14) and indicates that the tritium measured in rainwater resulted from the washout of tritiated water vapor. Figure 8-23 shows a generally close correlation between the concentration of tritiated water vapor in air and tritium in rainwater. This helps to confirm that the source of tritium in rainwater is from the washout of tritium in water vapor.

There were no apparent directional trends for the plant perimeter, 25-mi radius, and 100-mi radius locations. This is consistent with the tritium concentrations measured in vegetation.

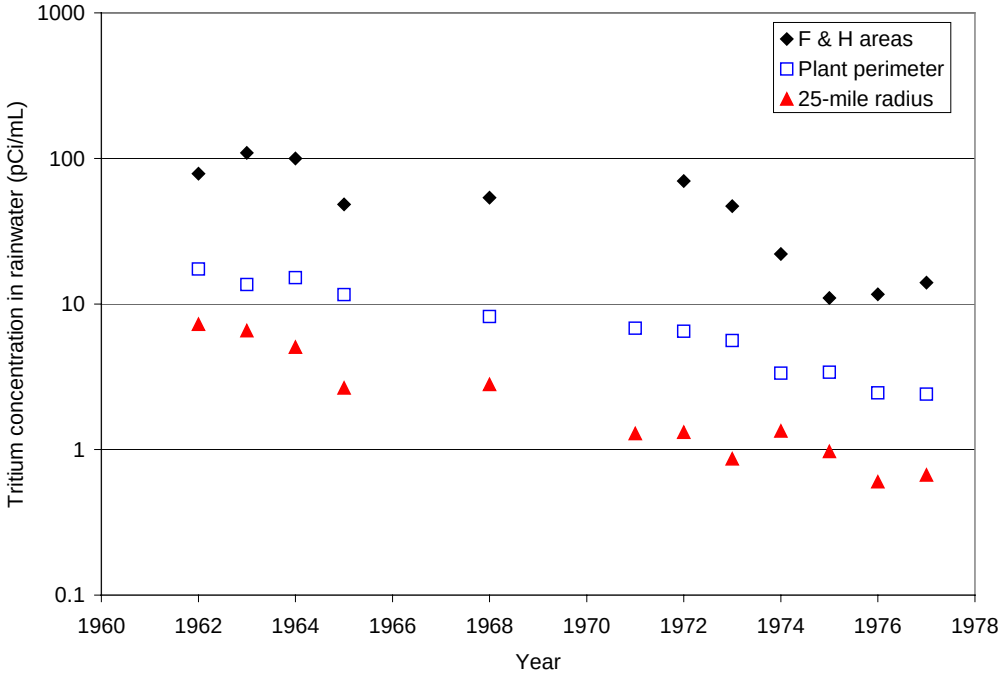

Figure 8-21. Annual averages of tritium measured in rainwater collected at onsite (F-Area and H-Area), site perimeter, and 25-mi radius locations from 1962 through 1977. Data were not available for 1966, 1967, 1969, and 1970 (data derived from aperture cards). Link to tabulated figure data.

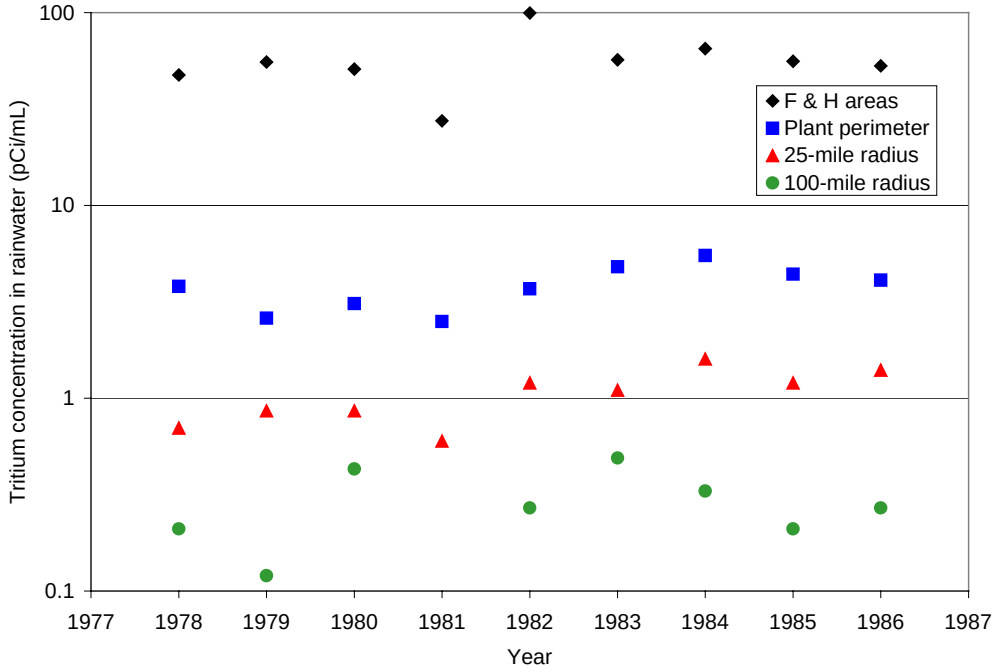

Figure 8-22. Annual averages of tritium measured in rainwater collected at onsite (F-Area and H-Area), Site perimeter, 25-mi radius and 100-mi radius locations from 1978 through 1986 (data derived from aperture cards). Link to tabulated figure data.

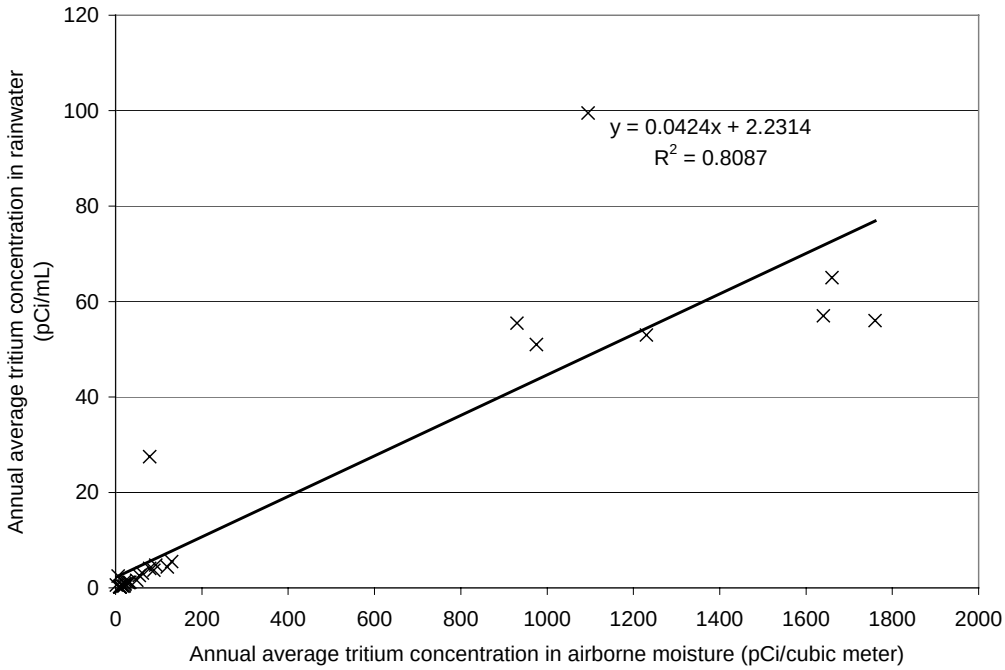

Figure 8-23. The annual average concentration of tritium in rainwater compared to the concentration in water in air at each monitoring location (1979–1986) (data derived from aperture cards). Link to tabulated figure data.

In general, reported tritium concentrations in rainwater are well correlated with reported tritium concentrations in vegetation. Table 8-7 shows average reported concentrations for rainwater and vegetation from 1984 through 1986. Vegetation and rainwater concentrations are within a factor of 2 for all locations.

Table 8-7. Average Tritium Concentrations in Vegetation and Rainwater from 1984 through 1986[a]

Location	Rainwater (pCi mL^{-1})	Vegetation (pCi mL^{-1})
F-Area and H-Area	58	44
Plant perimeter	4.7	9.1
25-mi radius	1.4	2.3
100-mi radius	0.34	0.52

[a] Source: Annual monitoring reports.

Background Measurements of Radionuclides in Rainwater

The EPA has measured tritium in rainwater collected at various locations throughout the United States since 1974. Before 1974, only gross beta concentrations were measured. Since 1975, this information has been reported in a series of reports published by EPA entitled *Environmental Radiation Data*. Concentrations were reported for Columbia and Barnwell, South Carolina, for a number of years. These data were useful for comparing and verifying the concentrations reported by the SRS for the same locations. Table 8-8 shows reported concentrations by the EPA and SRS for Columbia, South Carolina, from 1982 through 1990 and for Barnwell, South Carolina, and the Barnwell gate location from 1979 through 1986.

Table 8-8. Comparison of SRS and EPA-reported Tritium Concentrations[a]

	Columbia		Barnwell[b]	
Year	SRS	EPA	SRS	EPA
1979			2.6	0.65
1980			3.9	2.23
1981			3.1	1.16
1982	0.48	0.61	4	1.13
1983	1.4	0.40	5.5	1.31
1984	0.68	0.60	6.6	1.74
1985	0.51	0.56	4.1	1.14
1986	0.70	0.29	3.4	1.63
1987	0.19	0.29		
1988	0.12	0.27		
1989	0.06	0.29		
1990	0.11	0.23		

[a] Data from annual reports and from EPA Environmental Radiation Data.
[b] SRS reported concentrations for the Barnwell gate and EPA reported concentrations for Barnwell, South Carolina.

The concentrations reported by the EPA and SRS correlate well for the samples collected at Columbia and are near the limits of detection (0.2 pCi/g for the EPA). The SRS reported concentrations at the Barnwell gate are higher than those reported by the EPA for Barnwell, South Carolina. This would be expected since Barnwell, South Carolina, is approximately 10 km east of the Barnwell gate at the plant perimeter, and concentrations decrease rapidly with distance from the Site.

ELECTRONICALLY COMPILED AIR AND RAINWATER DATA

The various data summarized in this chapter are electronically compiled in several Microsoft Excel® workbooks. One workbook (Ch8-Figure_data.xls) contains the figures depicted in this chapter as well as the tabulated data that were used to produce the figures. In this workbook, there is a separate chart for each figure and each worksheet contains the tabulated data for one or a group of figures. Iodine.xls, Beta.xls, and Tritium.xls contain worksheets that summarize data tabulated from aperture cards that were used to generate the figures found in Ch8-Figure_data.xls, and they are referenced within this workbook.

The remaining data consist of workbooks containing all the aperture card data we compiled that are related to monitoring of air and rainwater, described in Table 8-1. These data can be accessed by clicking on the following hyperlinks: Iodine-all.xls, Tritium-all.xls, Gamma-all.xls, Alpha-Beta-all.xls, and Particle_data-all.xls. The file name reflects the contaminant(s) measured, and a separate spreadsheet exists for each year. For example, the spreadsheet entitled "1965 – air" in the workbook entitled "Tritium-all.xls" contains tritium measurements made in during 1965. Most of the aperture card data were not used to generate figures in this chapter but are included here to provide the reader with a complete electronic set of original data. It should also be noted that much of the data on the aperture cards is unreadable or barely legible. *RAC* recopied many of these sheets very carefully on a separate trip to the SRS, but many of the cards are not capable of adequate enhancement. The data entered on the worksheets represent a best attempt at recreating the handwritten ledgers. If specific data could not be read, that was noted on the spreadsheet.

USEFULNESS OF AIR AND RAINWATER MONITORING DATA

Factors that determine how useful the air and rainwater monitoring data may be for reconstructing historical releases from the SRS include

- The availability of original monitoring datasets for detailed analyses
- Sufficient datasets to allow spatial and/or temporal trends in the data to be identified
- The ability to differentiate between Site releases of contaminants and other sources of the same contaminants in the environment.

The following sections discuss these factors in more detail.

Availability of Original Monitoring Measurements

Air Monitoring Data

One of the problems with the air monitoring data that are reported in the quarterly, semiannual, and annual reports is that the results are often averaged over large spatial areas or

over more than one sample period for a given location. For example, for the period from 1955 through 1956, the ^{131}I results are reported as a semiannual average and a maximum for each 6-month period. Any releases that occur during a shorter time period will be masked in the 6-month average. This averaging limits the data evaluation that can be performed to confirm elevated releases. In addition to limiting the ability to perform source term verification, it restricts the use of the data in detecting any unplanned releases. Because these averages provide poor resolution, it is unlikely that the semiannual data can be used for more than confirming long-term trends and averages estimated using original data that are available from 1959 on.

The aperture cards provide individual monitoring data from 1959 through 1973. Only summary data are available from annual reports for 1974 and 1975. For the time period after 1975, computer printouts of individual monitoring data exist. However, except for onsite locations, concentrations of ^{131}I were below detection limits after 1963. It appears that only the onsite ^{131}I data will be useful for the dose reconstruction after this year. Gross beta and tritium measurements are consistently above detection limits for all years. Although the number of air sampling stations fluctuated over the history of the SRS operations, a comprehensive dataset of gross beta, ^{131}I, tritium, and gamma-emitting radionuclide measurements in air has been compiled in the aperture cards and the computer-generated monthly reports.

Rainwater Monitoring Data

Results in the semiannual and annual monitoring reports are reported as averages and maxima for the reporting period (i.e., semiannual or annual) at each monitoring location. Releases that occur during a shorter time period cannot be discerned. This limits the data evaluation that can be performed to confirm elevated releases. In addition to limiting the ability to perform source term verification, it restricts the use of the data in detecting any unplanned releases. Because these averages provide poor resolution, it is unlikely that the data provided in the environmental monitoring reports can be used for more than identifying long-term trends and averages.

The aperture cards located during Phase I of the dose reconstruction provide individual monitoring data from 1962 through 1965, 1968, and 1972 through 1973. These data will perhaps be useful in determining more detailed spatial and temporal trends. Only summary data are available from annual reports for 1967, 1969 through 1971, and 1974 through 1986.

Availability of Spatial and Temporal Datasets

Air Monitoring Data

Figures 8-2 through 8-20 demonstrate that the datasets can provide spatial and temporal information for use in the dose reconstruction. It remains to be determined in a subsequent phase of the dose reconstruction if there are enough data to be useful for source term verification or development or for validation of dispersion models. In some cases, the frequency of measurements may not provide the resolution necessary for these uses. For example, ^{137}Cs data are measurements of monthly composite samples. Most of the data sets for gross beta activity, ^{131}I, and tritium represent weekly or biweekly measurements at individual locations, and as such, they may be particularly useful to a dose reconstruction.

Factors that determine the value of these data include the availability of original data for detailed analyses, sufficient datasets to allow trends in the data to be identified, and the ability to differentiate between Site releases and other sources of the same contaminants in the environment. Weekly and biweekly datasets are available for the key radionuclides (i.e., tritium and radioiodine) for most years of concern (1959–1990), providing good temporal resolution. Spatial resolution is more limited, however, as there were few samplers located onsite during the early years, when releases were higher. Results generally indicate a trend of decreasing radionuclide concentrations from the Site to offsite locations, except during periods of high global fallout. This implies that the air sampling data can be used to verify SRS releases.

Rainwater Monitoring Data

Figures 8-21 through 8-23 demonstrate that the data sets can provide some spatial and temporal information for use in the dose reconstruction. Tritium in rainwater data indicate a trend of decreasing radionuclide concentrations from the Site to offsite locations, indicating SRS is the source of tritium. Unfortunately, data are not available for all years, and there are few onsite samplers during the early years of monitoring. It remains to be determined in a subsequent phase of the dose reconstruction if there are enough data to be useful for source term verification or development or for validation of dispersion models.

Summary: Data Usefulness

The historic air and rainwater monitoring data that are available demonstrate spatial and temporal patterns that reflect what is known about SRS releases. The key contaminants detected in air and rainwater during the period of interest (1951–1990) are radioiodine and tritium. As expected, concentrations decrease with distance from the Site and in many cases track known periods of elevated releases. The datasets may, thus, be useful for verifying source term estimates. Further analysis in a subsequent phase of the dose reconstruction can help to determine if there are enough data to be useful for source term or validation of dispersion models. The data may be limited by insufficient temporal and spatial resolution because weekly or biweekly datasets are not available for all years, particularly during the earliest years of Site operations. The highest reported releases occurred during the operational period before 1959. The measurements also represent a limited number of sampling locations, particularly onsite during the early years of monitoring.

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ADDENDUM 8A

Table 8-2. Onsite air monitoring program summary (1951–1990)

Table 8-3. 25-mile air monitoring program summary (1951–1990)

Table 8-4. 100-mile air monitoring program summary (1961–1990)

Note: The information contained in the following tables was obtained primarily from SRS monitoring reports. See chapter 7, table 7-1 for a complete description of the various monitoring report series.

Table 8-2. Onsite Air Monitoring Program Summary (1951–1990) (per Chapter 7, Table 7-1)

			Analytical parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
9/1/51	9/30/52	Weekly	x					Radon and thoron	CMX and Dunbarton fire tower
1/1/54	6/30/55	Weekly	x					Radon and thoron	Talatha gatehouse, Williston gatehouse, Dunbarton fire tower, 200-F, 200-H, 400-D, and 300-700
7/1/55	6/30/57	Weekly	x	x					Talatha gatehouse, Williston gatehouse, Dunbarton fire tower, 200-F, 200-H, 400-D, and 300-700
1/1/56	12/31/56	Weekly			x				Four locations along the 200-F 1-mile perimeter
1/1/57	6/30/57	Weekly			x				Four locations on the F-Area 1-mile radius perimeter, and at F-Area and H-Area air monitor buildings
7/1/57	12/31/57	Weekly	x	x	x				Talatha gatehouse, Williston gatehouse, Dunbarton fire tower, 200-F,200-H, 400-D, and 3/700
1/1/60	6/30/60	Weekly	x	x	x		x	Gamma analysis of 200-F and 400-D samples	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 300/700, Green Pond Church, Military Recreation Site, and Jackson
7/1/60	6/30/62	Weekly	x	x	x		x	Gamma spectroscopy performed when counting time available.	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 300/700, Green Pond Church, Military Recreation Site, and Jackson
7/1/62	12/31/62	Weekly	x	x	x		x	Gamma spectroscopy performed when counting time available.	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 300/700, and Jackson
1/1/65	12/31/66	Weekly	x	x	x		x	Cs-137, Ce-144, Ru-106, Zr/Nb-95, Mn-54	Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson
1/1/67	12/31/67	Biweekly	x	x	x	x	x	Cs-137, Ce-144, Ru-106, Zr/Nb-95, Mn-54	Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson
1/1/68	12/31/69	Biweekly	x	x	x	x	x	Cs137; Ce141,144; Ru-103,106; Zr-95,Nb-95; Be-7	Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson
1/1/70	12/31/70	Biweekly	x	x	x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson
1/1/71	12/31/71	Biweekly	x	x	x				Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson
1/1/71	12/31/71	Monthly				x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 3/700, and Jackson

Table 8-2. (continued)

			Analytical Parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
1/1/72	12/31/72	Biweekly	x	x	x				Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 700-A, 735-A, Jackson, and Green Pond
1/1/72	12/31/72	Monthly				x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7	Talatha gatehouse, Williston gatehouse, Dunbarton Fire Tower, 400-D, 200-F, 200-H, 700-A, 735-A, Jackson, and Green Pond
1/1/73	12/31/73	Weekly	x		x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Eight stations near the plant perimeter (one of which appears to actually be offsite)
1/1/74	12/31/74	Monthly					x	Pu-238; Pu-239.	Twelve stations near the plant perimeter
1/1/74	12/31/74	Weekly	x		x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Twelve stations near the plant perimeter
1/1/75	12/31/75	Biweekly			x				A-Area, F-Area, H-Area, Dunbarton (DFT), Williston Gate, Par Pond, Allendale Gate, A-14, Barnwell Gate, D- Area, Dark Horse, Talatha Gate, Green Pond, Highway 21/167, Jackson, Pattersons Mill, East Talatha, and Windsor Road
1/1/75	12/31/75	Monthly				x	x	Be-7; Zr-95,Nb-95; Ru-103,106; Cs-137; Ce-141,144; Pu-238; Pu-239.	A-Area, F- Area, H-Area, Dunbarton (DFT), Williston Gate, Par Pond, Allendale Gate, A-14, Barnwell Gate, D- Area, Dark Horse, Talatha Gate, Green Pond, Highway 21/167, Jackson, Pattersons Mill, East Talatha, and Windsor Road
1/1/75	12/31/75	Weekly	x						Eighteen stations, at A-Area, F-Area, H- Area, Dunbarton (DFT), Williston Gate, Par Pond, Allendale Gate, A-14, Barnwell Gate, D-Area, Dark Horse, Talatha Gate, Green Pond, Highway 21/167, Jackson, Pattersons Mill, East Talatha, and Windsor Road
1/1/76	12/31/76	Biweekly			x				A-Area, F-Area, H-Area, Dunbarton, Par Pond, Williston Gate, Allendale Gate, A-14, Barnwell Gate, D- Area, Dark Horse, East Talatha, Green Pond, Highway 21/167, Jackson, Pattersons Mill, Talatha Gate, West Jackson, and Windsor Road
1/1/76	12/31/76	Monthly				x	x	Be-7; Zr-95,Nb-95; Ru-103,106; Cs-137; Ce-141,144; Pu-238; Pu-239.	A-Area, F-Area, H-Area, Dunbarton, Par Pond, Williston Gate, Allendale Gate, A-14, Barnwell Gate, D- Area, Dark Horse, East Talatha, Green Pond, Highway 21/167, Jackson, Pattersons Mill, Talatha Gate, West Jackson, and Windsor Road

Table 8-3. 25-mile Air Monitoring Program Summary (1951–1990) (per Chapter 7, Table 7-1)

			Analytical parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
9/1/51	6/30/54	Weekly	x				x	Radon and thoron	Aiken Airport, Allendale, and Waynesboro
7/1/54	6/30/55	Weekly	x						Aiken Airport,Allendale, and Waynesboro
7/1/55	12/31/56	Weekly	x	x					Aiken Airport,Allendale, and Waynesboro
1/1/57	12/31/57	Weekly	x	x	x				Aiken Airport, Allendale, and Waynesboro (all). Langley, Bush Field, Williston, Barnwell, and Sardis (radiodine only)
1/1/58	12/31/60	Weekly	x	x	x				Aiken Airport, Allendale, Waynesboro, Langley, Bush Field, Williston, Barnwell, and Sardis
1/1/61	12/31/61	Weekly	x	x	x				Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/62	12/31/62	Weekly	x	x	x		x	Gamma spectroscopy performed when counting time available	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/63	12/31/64	Weekly	x	x	x		x	Cs-137, Ce-144, Ru-103, Ru-106, Zr/Nb-95, Mn-54, Ba/La-140	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/65	12/31/65	Weekly	x	x	x		x	Cs-137, Ce-144, Ru-106, Zr/Nb-95, Mn-54	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/66	12/31/66	Biweekly	x	x	x		x	Cs-137, Ce-144, Ru-106, Zr/Nb-95, Mn-54	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/67	12/31/71	Biweekly	x	x	x	x	x	Cs-137, Ce-144, Ru-106,-103, Zr/Nb-95	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/72	12/31/72	Biweekly	x		x	x	x	Cs-137, Ce-144, Ru-106,-103, Zr/Nb-95	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301

Table 8-3. (continued)

			Analytical parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
1/1/73	12/31/74	Weekly	x		x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Aiken Airport, Allendale, Waynesboro, Langley, Williston, Barnwell, Sardis, Bush Field, Aiken State Park, and Highway 301
1/1/74	12/31/74	Monthly					x	Pu-238; Pu-239.	Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/75	12/31/80	Biweekly			x				Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/75	12/31/83	Monthly				x	x	Be-7;Zr-95,Nb-95; Ru-103,106; Cs-137; Ce-141,144; Pu-238; Pu-239.	Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/75	12/31/81	Weekly	x						Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/79	12/31/81	Monthly		x					25-mi perimeter: Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/80	12/31/83	Quarterly			x				Four distant locations, about 100 mi from the plant, in Columbia and Greenville, South Carolina, and Macon and Savannah, Georgia
1/1/81	12/31/83	Biweekly	x						25-mi perimeter: Augusta, Langley, Aiken Airport, Aiken State Park, Springfield, Lees, Olar, Allendale, Perkins, Waynesboro, South Richmond, and Highway 301
1/1/84	12/31/90								

[a] Gross beta activity.

[b] Gamma-emitting and other radionuclides.

Table 8-4. 100-mile Air Monitoring Program Summary (1961–1990) (per Chapter 7, Table 7-1)

			Analytical parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
1/1/61	12/30/61	Weekly	x						Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/62	12/31/62	Weekly	x	x			x	Gamma spectroscopy performed when counting time available.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/63	12/31/65	Weekly	x	x			x	Cs-137, Ce-144, Ru-103, Ru-106, Zr/Nb-95, Mn-54, Ba/La-140	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/66	12/31/66	Biweekly	x	x			x	Cs-137, Ce-144, Ru-106, Zr/Nb-95, Mn-54	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/67	12/31/67	Biweekly	x	x		x	x	Cs-137, Ce-144, Ru-106,-103, Zr/Nb-95	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/70	12/31/70	Biweekly	x		x	x	x	Cs137; Ce141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/71	12/31/71	Biweekly	x	x	x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/72	12/31/72	Biweekly	x		x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/73	12/31/74	Weekly	x		x	x	x	Cs-137; Ce-141,144; Ru-103,106; Zr-95,Nb-95; Be-7.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/74	12/31/74	Monthly					x	Pu-238; Pu-239.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/75	12/31/79	Biweekly			x				Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/75	12/31/78	Monthly				x	x	Be-7;Zr-95,Nb-95; Ru-103,106; Cs-137; Ce-141,144; Pu-238; Pu-239.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/75	12/31/83	Weekly	x						Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/79	12/31/79	Biweekly			x				Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/79	12/31/79	Monthly		x		x	x	Be-7;Zr-95,Nb-95; Ru-106; Cs-137; Ce-144; Pu-238; Pu-239.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA

Table 8-4. (continued)

			Analytical Parameters						
From date	To date	Collection frequency	α,β[a]	^{131}I	^{3}H	^{90}Sr	γ[b]	Gamma-emitting, other nuclides	Specific sampling locations
1/1/80	12/31/82	Monthly		x		x	x	Be-7;Zr-95,Nb-95; Ru-106; Cs-137; Ce-144.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/81	12/31/83	Quarterly			x				Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA
1/1/83	12/31/90	Monthly					x	Be-7; Sr-89,90; Zr-95,Nb-95; Ru-106; Cs-137; Ce-144.	Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA

[a] Gross alpha activity and gross beta activity.

[b] Gamma-emitting and other radionuclides.