Chapter 3

Radiological Effluent Monitoring

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THIS chapter describes the Savannah River Site (SRS) radiological effluent monitoring program and summarizes the 2001 effluent monitoring data results.

Radiological effluent monitoring results are a major component in determining compliance with applicable dose standards, which can be found in chapter 5, "Potential Radiation Doses," and in appendix A, "Applicable Guidelines, Standards, and Regulations." Also, SRS management philosophy is that potential exposures to members of the public and to onsite workers be kept as far below regulatory standards as is reasonably achievable. This philosophy is known as the "as low as reasonably achievable" (ALARA) concept.

SRS airborne and liquid effluents that potentially contain radionuclides are monitored at their points of discharge by a combination of direct measurement and/or sample extraction and analysis. Each operating facility maintains ownership of and is responsible for its radiological effluents. Safety and Health Operations (S&HO) and the Environmental Protection Department's Environmental Monitoring Section (EMS) perform most of the radiological effluent monitoring functions. S&HO personnel collect and screen air and liquid samples from regulated (radiologically controlled) areas and maintain monitoring equipment on stacks and at some liquid effluent discharge points. EMS personnel collect and analyze most liquid effluent samples and analyze most of the airborne effluent samples. Results of these analyses are compiled and reported in monthly radioactive releases reports.

Approximately 4,000 radiological effluent samples were collected at 61 points of discharge and analyzed during 2001.

A complete description of the EMS sampling and analytical procedures used for radiological effluent monitoring can be found in sections 1102 and 1103 of the *Savannah River Site Environmental Monitoring Section Plans and Procedures*, WSRC–3Q1–2, Volume 1 (SRS EM Program, 2001). A summary of data results is presented in this chapter; more detailed data can be found in *SRS Environmental Data for 2001* (WSRC–TR–2001–00475).

Airborne Emissions

Process area stacks that release or have the potential to release radioactive materials are monitored continuously by applicable online monitoring and/or sampling systems [SRS EM Program, 2001]. Filter paper samples, used to collect radioactive particles, generally are gathered daily and screened initially for radioactivity by S&HO personnel. Charcoal canisters, used to collect radioiodines, are gathered weekly at some locations and monthly at locations with lower potential for release. S&HO personnel routinely transfer the filter paper samples and charcoal canisters weekly to EMS sampling personnel for transport to, and analysis in, the EMS laboratories.

Depending on the processes involved, discharge stacks also may be monitored with "real-time" instrumentation by area operations and/or S&HO personnel to determine instantaneous and cumulative atmospheric releases to the environment. Tritium is one of the radionuclides monitored with continuous real-time instrumentation.

Description of Monitoring Program

Sample Collection Systems

Sample collection systems vary from facility to facility, depending on the nature of the radionuclides being discharged. Generally, S&HO personnel are

responsible for ensuring that the sampling systems are maintained and for collecting the filter papers and charcoal filter samples.

The following effluent sampling and monitoring changes were made during 2001:

- Air effluent sampling at the 321–M stacks was discontinued at the end of October, following the completion of deactivation work.
- Air effluent sampling at the portable $C0_2$ blaster decon exhaust was discontinued in June because of a lack of work.

Continuous Monitoring Systems

SRS reactor and tritium facilities use real-time instrumentation to determine instantaneous and cumulative atmospheric releases of tritium and noble gas radioisotopes. All other monitored radionuclides are sampled using filter papers, charcoal filters, or molecular sieve.

Laboratory Analysis

EMS provides most of the radioanalytical laboratory services required to conduct the site airborne effluent monitoring program. However, tritium in airborne effluents is measured at each applicable operating facility. Also, specific low-level analyses for iodine-129 were performed by an onsite laboratory during 2001.

Effluent Flow Rates

Stack effluent flows generally are determined with hot-wire anemometers, Pitot tubes, or fan capacity calculations. Sample line flow rates usually are determined with in-line rotameters or hot-wire anemometers. Flow rates are used to determine the total quantity of radioactive materials released.

Diffuse and Fugitive Sources

Estimates of radionuclide releases from unmonitored diffuse and fugitive sources also are included in the SRS radioactive release totals. These unmonitored sources include ponds, contaminated land areas, and structures without ventilation—or with ventilation but without well-defined release points.

Diffuse and fugitive releases are calculated using the U.S. Environmental Protection Agency's (EPA's) recommended methods. The methods produce conservative estimates of release levels having a large uncertainty associated with them. However, for consistency with other reported data, the estimates are reported to three significant figures.

Monitoring Results

The total amount of radioactive material released to the environment is quantified by using data obtained from continuously monitored airborne effluent releases points and estimates of diffuse and fugitive sources in conjunction with calculated release estimates of unmonitored radionuclides from the separations areas.

The unmonitored radionuclides are fission product tritium, carbon-14, and krypton-85. These radionuclides cannot be measured readily in the effluent streams; therefore, the values are calculated on an annual basis and are based on production levels in the separations areas.

Because of increased operations in H-Canyon, the amount of krypton-85 estimated to have been released by the site increased 19 percent—from 52,800 Ci in 2000 to 64,700 Ci in 2001. This accounts for 58 percent of the total radioactivity released to the atmosphere from SRS operations. However, because krypton is a noble (chemically inert) gas, it is not readily absorbed by the human body and thus results in only a small amount of dose, even though the released amount is relatively high.

The data in table 3–1 on page 37 are a major component in the determination of offsite dose estimations from SRS operations. The calculated individual and collective doses from atmospheric releases are presented in chapter 5, as is a comparison of these offsite doses to EPA and the U.S. Department of Energy (DOE) dose standards.

Beta- and Alpha-Emitting Radionuclides

Unspecified alpha and beta emissions have become large contributors (on a percentage basis) to offsite doses, especially for the airborne pathway from diffuse and fugitive releases. Because some (if not most) of these emissions are from naturally occurring

Diffuse and Fugitive Sources

Emissions from DOE facilities include those from point sources (stacks or vents) and those from diffuse and fugitive sources. A diffuse source is defined as an area source. Examples of diffuse sources include resuspension of contaminants deposited on open fields and evaporation from holding ponds and basins. A fugitive source is defined as an undesigned localized source. Process leaks that discharge to the atmosphere by a path other than a stack or vent are fugitive releases. Unmonitored evaporation releases from open tanks and drums also are considered fugitive releases.

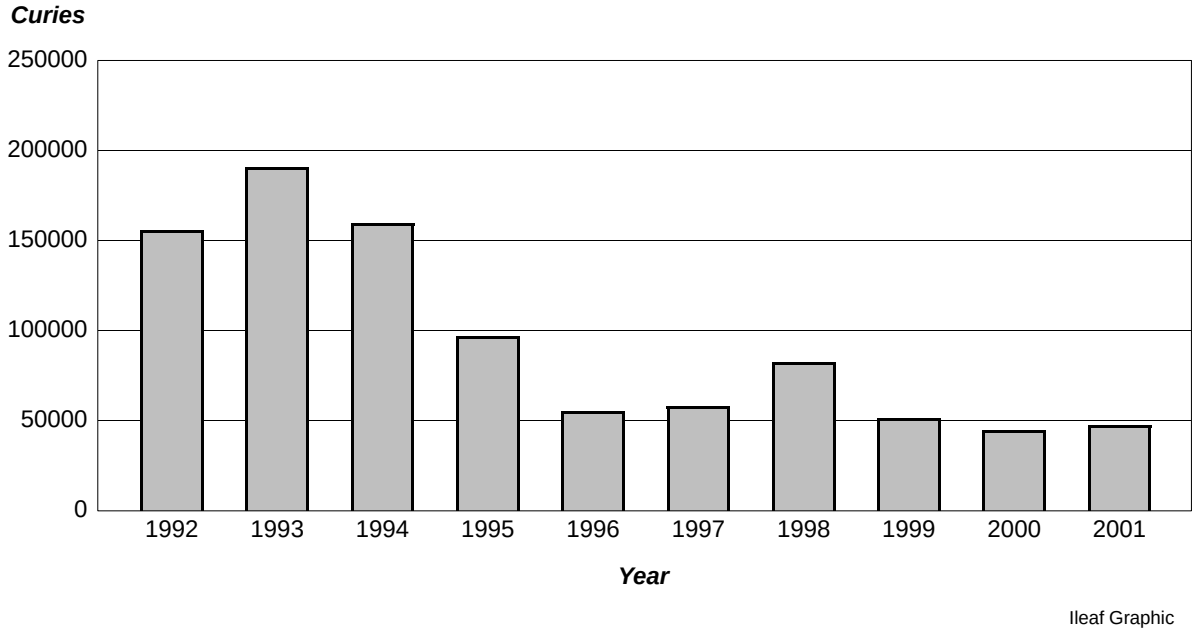

Figure 3–1 Ten-Year History of SRS Annual Atmospheric Tritium Releases

radionuclides, these emissions are accounted for separately from actual strontium-90 and plutonium-239 emissions.

Therefore, releases of unspecified alpha emissions and nonvolatile beta emissions are listed separately in the source term. Prior to 2000, these emissions were included in plutonium-239 and strontium-89,90 releases.

For dose calculations, the unspecified alpha releases were assigned the plutonium-239 dose factor, and the unspecified nonvolatile beta releases were assigned the strontium-90 dose factor (chapter 5).

Tritium

Tritium in elemental and oxide forms accounts for 42 percent of the total radioactivity released to the atmosphere from SRS operations. As an isotope of hydrogen, tritium acts the same as hydrogen chemically and physically and thus is extremely difficult to remove selectively from air effluent streams. During 2001, about 47,400 Ci of tritium were released from SRS, compared to about 44,800 Ci in 2000.

Because of improvements in facilities, processes, and operations and because of changes in the site's mission, the amount of tritium (and other atmospheric radionuclides) released has been reduced throughout the history of SRS. During the early years at SRS, large quantities of tritium were discharged to the atmosphere. The maximum yearly release of 2.4 million Ci of tritium occurred during 1958. In recent years, because of the changes in the site's missions and the existence of the Replacement Tritium Facility, the total amount of tritium released has fluctuated but has remained less than 100,000 Ci per year (figure 3–1).

Comparison of Average Concentrations in Airborne Emissions to DOE Derived Concentration Guides

Average concentrations of radionuclides in airborne emissions are calculated by dividing the yearly release total of each radionuclide from each stack by the yearly stack flow quantities. These average concentrations then can be compared to the DOE derived concentration guides (DCGs) in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

DCGs are used as reference concentrations for conducting environmental protection programs at all DOE sites. Based on a 100-mrem exposure, DCGs are applicable at the point of discharge (prior to dilution or dispersion) under conditions of continuous exposure (assumed to be an average inhalation rate of 8,400 cubic meters per year). This means that the DOE DCGs are based on the highly conservative assumption that a member of the public has direct access to—and continuously breathes, or is immersed in—the undiluted air effluent 24 hours a day, 365 days a year. However, because of the distance between most SRS operating facilities and the site boundary, and because the wind rose at SRS shows

no strong prevalence (chapter 5), this scenario is highly improbable.

Average annual radionuclide concentrations in SRS air effluents can be referenced to DOE DCGs as a screening method to determine if existing effluent treatment systems are proper and effective. The 2001 atmospheric effluent 12-month average concentrations, their comparisons against the DOE DCGs, and the quantities of radionuclides released are provided, by discharge point, in *SRS Environmental Data for 2001*.

Most of the SRS radiological stacks/facilities release small quantities of radionuclides at concentrations below the DOE DCGs. However, certain radionuclides—tritium (in the oxide form) from the reactor facilities and the tritium facilities and americium-241 and plutonium-239 in F-Area from the 6.1 and 6.4 dissolvers—were emitted at concentration levels above the DCGs. Because of the extreme difficulty involved in removing tritium and because of current facility designs, site missions, and operational considerations, this situation is unavoidable. The offsite dose consequences from all atmospheric releases during 2001, however, remained well below the DOE and EPA annual atmospheric pathway dose standard of 10 mrem (0.1 mSv) (chapter 5).

Liquid Discharges

Each process area liquid effluent discharge point that releases or has potential to release radioactive materials is sampled routinely and analyzed for radioactivity [SRS EM Program, 2001]. The radiological liquid effluent sampling locations at SRS are shown, along with the surface water surveillance sampling locations, in chapter 4, “Radiological Environmental Surveillance” (page 48, figure 4–4).

Site streams also are sampled upstream and downstream of seepage basins to obtain data to calculate the amount of radioactivity migrating from the basins. These results are important in calculating the total amount of radioactivity released to the Savannah River as a result of SRS operations.

Description of Monitoring Program

Sample Collection Systems

Liquid effluents are sampled continuously by automatic samplers at, or very near, their points of discharge to the receiving streams. EMS personnel normally collect the liquid effluent samples weekly and transport them to the EMS laboratory for analysis.

Continuous Monitoring Systems

Depending on the processes involved, liquid effluents also may be monitored by area operations and/or S&HO personnel with real-time instrumentation to ensure that instantaneous releases stay within established limits. Because the instruments have limited detection sensitivity, online monitoring systems are not used to quantify liquid radioactive releases from SRS.

Laboratory Analysis

EMS provides most of the radioanalytical laboratory services required to conduct the site liquid effluent monitoring program.

Flow Rate Measurements

Liquid effluent flows generally are determined by one of two methods: U.S. Geological Survey flow stations or commercial flow meters. Effluent flow rates are used to determine the total radioactivity released.

Monitoring Results

Data from continuously monitored liquid effluent discharge points are used in conjunction with site seepage basin and Solid Waste Disposal Facility migration release estimates to quantify the total radioactive material released to the Savannah River from SRS operations. SRS liquid radioactive releases for 2001 are shown by source in table 3–2, page 40.

The data in this table are a major component in the determination of offsite dose consequences from SRS operations. The calculated individual and collective doses from site liquid releases are presented in chapter 5, as is a comparison of these offsite doses to EPA and DOE dose standards.

Beta- and Alpha-Emitting Radionuclides

Unspecified alpha and beta emissions have become large contributors (on a percentage basis) to offsite doses, especially for the liquid pathway from diffuse and fugitive releases. Because some (if not most) of these emissions are from naturally occurring radionuclides, these emissions are accounted for separately from actual strontium-90 and plutonium-239 emissions.

Releases of unspecified alpha emissions and nonvolatile beta emissions are listed separately in the source term. Prior to 2000, these emissions were included in plutonium-239 and strontium-89,90 releases.

For dose calculations, the unspecified alpha releases were assigned the plutonium-239 dose factor, and the unspecified nonvolatile beta releases were assigned the strontium-90 dose factor (chapter 5).

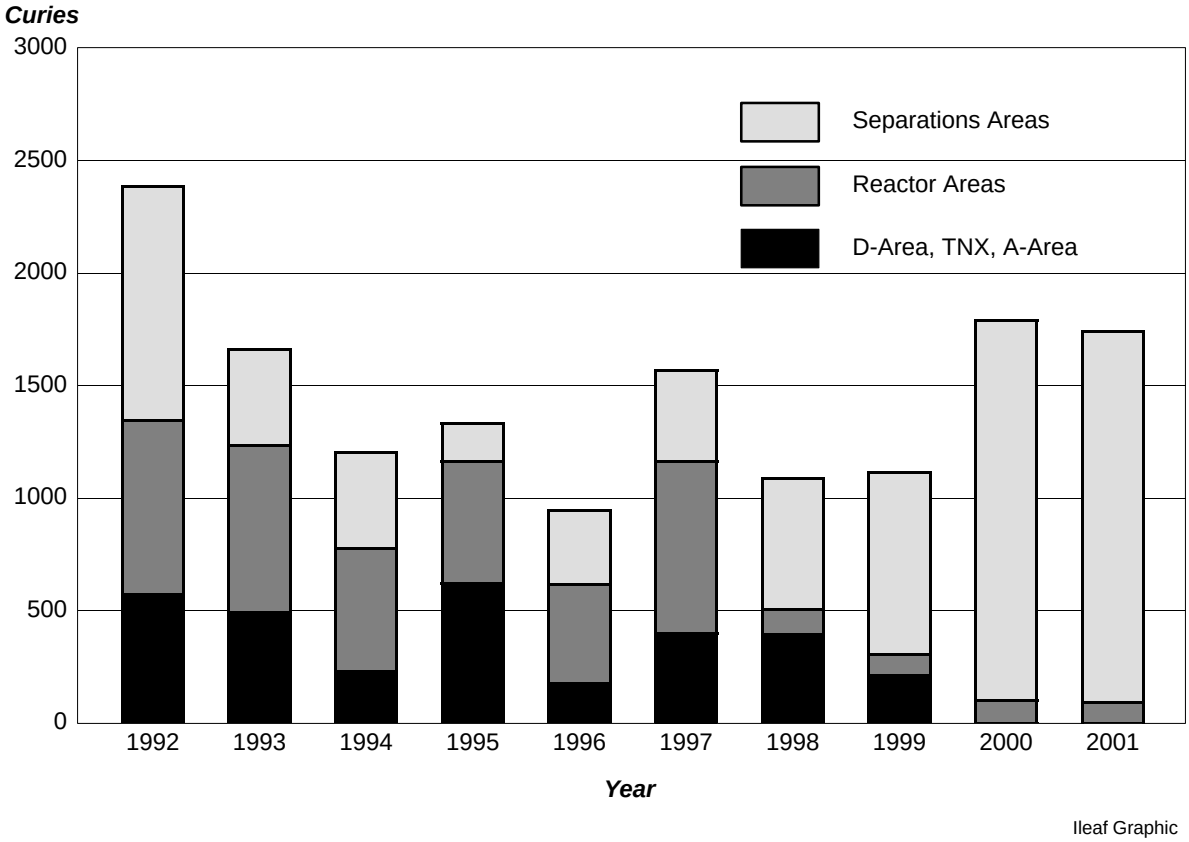

Figure 3–2 Direct Releases of Tritium to SRS Streams, 1992–2001

Operations at D-Area and TNX were discontinued in 2000 and 2001, respectively. Releases from A-Area and the reactor areas currently represent only a small percentage of the total direct releases of tritium to site streams.

Direct Discharges of Liquid Effluents

Direct discharges of liquid effluents are quantified at the point-of-release to the receiving stream, prior to dilution by the stream. The release totals are based on measured concentrations and flow rates.

Tritium accounts for nearly all of the radioactivity discharged in SRS liquid effluents. The total amount of tritium released directly from process areas (i.e., reactor, separations, Effluent Treatment Facility) to site streams during 2001 was 1,748 Ci**,** which was slightly less than the 2000 total of 1,795 Ci.

Direct releases of tritium to site streams for the years 1992–2001 are shown in figure 3–2, where it can be seen that the total amount of tritium released has fluctuated but has remained less than 2,000 Ci per year in recent years.

Comparison of Average Concentrations in Liquid Releases to DOE Derived Concentration Guides

In addition to dose standards, DOE Order 5400.5 imposes other control considerations on liquid releases. These considerations are applicable to direct discharges but not to seepage basin and Solid Waste Disposal Facility migration discharges. The DOE order lists DCG values for most radionuclides. DCGs are used as reference concentrations for conducting environmental protection programs at all DOE sites. These DCG values are not release limits but screening values for “best available technology” investigations and for determining whether existing effluent treatment systems are proper and effective.

According to DOE Order 5400.5, exceedance of the DCGs at any discharge point may require an investigation of “best available technology” waste treatment for the liquid effluents. Tritium in liquid effluents is specifically excluded from “best available

technology" requirements; however, it is not excluded from other ALARA considerations. DOE DCG compliance is demonstrated when the sum of the fractional DCG values for all radionuclides detectable in the effluent is less than 1.00, based on consecutive 12-month average concentrations.

DCGs, based on a 100-mrem exposure, are applicable at the point of discharge from the effluent conduit to the environment (prior to dilution or dispersion). They are based on the highly conservative assumption that a member of the public has continuous direct access to the actual liquid effluent and consumes 2 liters of the effluent every day, 365 days a year. However, because of security controls and the distance between most SRS operating facilities and the site boundary, this scenario is highly improbable.

For each site facility that releases radioactivity, EMS compares the monthly liquid effluent concentrations and 12-month average concentrations against the DOE DCGs. The 2001 liquid effluent 12-month average concentrations, their comparisons against the DOE DCGs, and the quantities of radionuclides released are provided, by discharge point, in *SRS Environmental Data for 2001*.

The data show that the U3R–2A ETF outfall at the Road C discharge point exceeded the DCG guide for 12-month average tritium concentrations during 2001. However, as noted previously, DOE Order 5400.5 specifically exempts tritium from "best available technology" waste treatment investigation requirements. This is because there is no practical technology available for removing tritium from dilute liquid waste streams. In 1992, in consideration of ALARA principles for tritium discharges and while reviewing, analyzing, and modifying the process for controlling liquid releases of radioactive effluents, SRS identified several options and alternatives to continuing with these discharges at the U3R–2A ETF outfall. None of these alternatives was considered viable on a cost/benefit basis. No other discharge points exceeded the DOE DCGs during 2001.

Table 3–1 Radioactive Atmospheric Releases by Source

	Curies[a]					
Radionuclide	**Reactors**	**Separations[b]**	**Reactor Materials**	**SRTC[c]**	**Diffuse and Fugitive[d]**	**Total**
Note: Blank spaces indicate no quantifiable activity.						
GASES AND VAPORS						
H-3(oxide)	2.41E+03	3.00E+04			6.07E+02	3.30E+04
H-3(elem.)		1.44E+04				1.44E+04
H-3 Total	2.41E+03	4.44E+04			6.07E+02	4.74E+04
C-14		1.70E–01			8.76E–05	1.70E–01
Kr-85		6.47E+04				6.47E+04
Xe-133		4.82E–06				4.82E–06
Xe-135		7.57E–02				7.57E–02
I-129		1.29E–02			1.29E–06	1.29E–02
I-131		2.05E–06		6.13E–06		8.18E–06
I-133				4.26E–04		4.26E–04
PARTICULATES						
Ac-228					4.07E–06	4.07E–06
Am-241		1.52E–04	5.72E–09		1.15E–04	2.67E–04
Am-243					9.90E–07	9.90E–07
Bi-214					1.29E–06	1.29E–06
Ce-141					4.16E–05	4.16E–05
Ce-144					1.43E–04	1.43E–04
Cm-242					1.43E–08	1.43E–08
Cm-244		3.90E–06	2.23E–09		4.76E–05	5.15E–05
Cm-245					4.18E–07	4.18E–07
Cm-246					1.01E–06	1.01E–06
Co-58					1.27E–04	1.27E–04
Co-60		4.40E–08		3.25E–07	8.59E–04	8.59E–04
Cr-51					1.21E–04	1.21E–04
Cs-134		1.94E–08			1.31E–04	1.31E–04
Cs-137		1.18E–03			2.22E–03	3.40E–03
Eu-152					4.15E–05	4.15E–05
Eu-154					1.53E–05	1.53E–05
Eu-155					7.85E–07	7.85E–07
Hg-203					2.29E–10	2.29E–10

a One curie equals 3.7 E+10 Becquerels.
b Includes separations, waste management, and tritium facilities
c Savannah River Technology Center
d Estimated releases from minor unmonitored diffuse and fugitive sources

Table 3–1 Radioactive Atmospheric Releases by Source

	Curies[a]					
Radionuclide	Reactors	Separations[b]	Reactor Materials	SRTC[c]	Diffuse and Fugitive[d]	Total
Mn-54					2.52E–08	2.52E–08
Na-22					2.09E–08	2.09E–08
Nb-94					4.56E–08	4.56E–08
Nb-95					1.13E–04	1.13E–04
Ni-63					4.38E–06	4.38E–06
Np-237					1.09E–08	1.09E–08
Np-239					1.24E–07	1.24E–07
Pa-233					2.29E–10	2.29E–10
Pa-234					1.76E–08	1.76E–08
Pb-212					2.74E–06	2.74E–06
Pb-214					6.58E–07	6.58E–07
Pm-147					1.34E–05	1.34E–05
Pu-236					1.22E–10	1.22E–10
Pu-238		9.15E–05	3.67E–09		3.99E–05	1.31E–04
Pu-239		2.62E–04	1.37E–08		1.94E–03	2.20E–03
Pu-240					8.51E–07	8.51E–07
Pu-241					6.70E–06	6.70E–06
Pu-242					2.09E–08	2.09E–08
Ra-226					5.25E–06	5.25E–06
Ra-228					4.16E–06	4.16E–06
Ru-103					4.23E–05	4.23E–05
Ru-106					9.92E–07	9.92E–07
Sb-124					8.09E–09	8.09E–09
Sb-125					5.37E–05	5.37E–05
Se-79					4.58E–09	4.58E–09
Sn-126					1.69E–07	1.69E–07
Sr-89					3.34E–07	3.34E–07
Sr-90		1.42E–04			3.57E–03	3.71E–03
Tc-99					1.89E–06	1.89E–06
Th-228					3.97E–06	3.97E–06
Th-230					2.71E–06	2.71E–06
Th-232					1.75E–06	1.75E–06

a One curie equals 3.7 E+10 Becquerels.
b Includes separations, waste management, and tritium facilities
c Savannah River Technology Center
d Estimated releases from minor unmonitored diffuse and fugitive sources

Table 3–1 Radioactive Atmospheric Releases by Source

	Curies[a]					
Radionuclide	**Reactors**	**Separations[b]**	**Reactor Materials**	**SRTC[c]**	**Diffuse and Fugitive[d]**	**Total**
Th-234					1.03E–04	1.03E–04
Tl-208					2.58E–06	2.58E–06
U-232					4.46E–11	4.46E–11
U-233					3.90E–08	3.90E–08
U-234		3.85E–05	3.43E–06		2.84E–04	3.26E–04
U-235		3.91E–06	5.16E–07		6.59E–06	1.10E–05
U-236					7.17E–10	7.17E–10
U-238		9.33E–05	4.93E–07		3.18E–04	4.12E–04
Zn-65					2.23E–05	2.23E–05
Zr-95					1.68E–05	1.68E–05
Alpha	5.49E–05	3.69E–05		1.49E–08	1.33E–03	1.42E–03
Beta-Gamma	3.81E–04	1.70E–04	1.10E–05		3.22E–02	3.28E–02

a One curie equals 3.7 E+10 Becquerels.
b Includes separations, waste management, and tritium facilities
c Savannah River Technology Center
d Estimated releases from minor unmonitored diffuse and fugitive sources

Table 3–2 Radioactive Liquid Releases by Source (Including Direct and Seepage Basin Migration Releases)

	Curies[a]				
Radionuclide	**Reactors (C,K,L,P,R)**	**Separations[b] (F-Area, H-Area.**	**Reactor Materials (M-Area)**	**SRTC[c] (A-Area)**	**Total**
Note: Blank spaces indicate no quantifiable activity.					
H-3	1.28E+03	3.03E+03		7.94E–01	4.32E+03
Sr-90	5.92E–05	2.04E–02			2.05E–02
Tc-99		4.56E–02			4.56E–02
I-129		7.82E–02			7.82E–02
Cs-137	2.25E–02	5.80E–02			8.05E–02
U-234		2.09E–05	3.10E–05	4.28E–05	9.47E–05
U-235		9.05E–07		7.92E–07	1.70E–06
U-238		3.97E–05	3.55E–05	4.90E–05	1.24E–04
Pu-238		1.36E–05	2.85E–05	2.92E–06	4.50E–05
Pu-239		5.12E–06	2.31E–06		7.43E–06
Am-241		1.35E–06	5.72E–06		7.07E–06
Cm-244		1.22E–06	5.87E–06		7.09E–06
Alpha	3.26E–03	1.98E–02	2.59E–03	3.09E–03	2.87E–02
Beta-Gamma	2.56E–02	5.63E–02	1.73E–04	3.05E–03	8.51E–02

a One curie equals 3.7 E+10 Becquerels.
b Includes separations, waste management, and tritium facilities
c Savannah River Technology Center