

3. OFFSITE DOSE COMMITMENT FROM SRP OPERATIONS

Radioactive materials are released to the environment from SRP operations primarily by the following pathways:

- Releases to the atmosphere by process building ventilation exhaust stacks and by evaporation from seepage basins.
- Releases to surface streams by direct discharge or indirectly by discharge to seepage basins with a fraction ultimately discharging to the streams by ground water transport.

In these releases, the chemical composition of the wastes, their mode of release, and their behavior in the environment all affect the ultimate radiation dose received by the population groups in the general area of SRP. The largest part of the radiation dose received by the local population from exposure to SRP radioactive releases is by the following pathways:

- Inhalation and immersion in an atmosphere containing radioactive materials.
- Indirect ingestion of tritium (^3H) and ^{131}I to the whole body and thyroid, respectively, via the air-grass-cow-milk pathway.
- Ingestion of river water downstream from SRP.

To determine the population dose commitment from SRP operations, mathematical models were developed to relate release data to dose vectors or pathways. These models are discussed in Appendix G. Radiochemical analyses of various environmental media, i.e., air, water, foods, etc., are used to supplement and verify the models. The models are used to calculate lifetime dose commitment (70 years) to several different affected population groups.

Another pathway that could result in exposure to offsite individuals derives from the previous transport and deposition of long-lived gamma emitters (primarily ^{137}Cs) in the swamp downstream of SRP, where they provide a small radiation field.¹ It is conceivable that an individual could receive a whole body dose of a few mrem to a few tens of mrem if he used the swamp for fishing, hunting, or launching boats into the river. Continuous occupancy during unflooded periods (77% of the time in an average year) in the small areas of the swamp where the activity has deposited could result in a dose to a hypothetical individual (none exists) of about 800 mrem/yr.⁷ These doses are not included in the estimates of effects of annual releases because there are no residents in the swamp area where the radioactivity is deposited and because the source of radiation was deposited in previous years and is relatively immobile.

DOSE COMMITMENT

"Dose commitment" means radiation dose equivalent that will be received in a lifetime (70 years) by population groups as a result of a given release of radioactive materials to the environment. It does not include global recycling of radioactive noble gases, tritium, and carbon-14. Dose commitments accounted for in the SRP environmental model are:

- External dose from radioactive materials in the atmosphere and on the earth's surface.
- Internal dose from radioactive materials entering the human body.

DOSE CALCULATIONAL TECHNIQUES

Techniques used for calculating dose were patterned after methods used by the International Commission on Radiological Protection (ICRP).^{8,9} "Standard Man" data were used except where infants were critical members of the population. Equations were derived (see Appendix G) for converting integral concentrations of radionuclides in various media to lifetime dose commitment via the various vectors. Special "equilibrium ratio" models were used for ^{14}C and ^{129}I . These models are also described in Appendix G. Dose commitments are presented in this report for individuals in dose units of "millirem" (mrem). Population dose commitment is the sum of individual doses in a population group and is presented in dose units of "man-rem."

TRITIUM DOSE CALCULATIONS

Tritium releases from SRP to the atmosphere and to surface streams account for a substantial portion of the population dose commitment discussed in the following sections of this report. Tritium doses were calculated with parameters listed in ICRP Publication 2.⁸ These parameters are compared to parameters taken from more-recent publications in Table III-5. The more-recent parameters, if used, would reduce tritium doses given in this report by about 30%. The reason for using the older, more-conservative parameters is to provide continuity and consistency with data previously published by SRP.

DOSE COMMITMENT FROM RELEASE OF RADIOACTIVE MATERIALS TO THE ATMOSPHERE

Dose commitment from release of radioactive materials to the atmosphere was calculated by the methods described in Appendices

F and G, using release data from Table III-1. Dose commitments shown in Table III-6 are upper-limit values because they apply to an individual who resided continuously at the plant perimeter for the periods shown; this hypothetical individual also regularly consumed milk from a cow pastured at the plant perimeter. No such person is known to exist. Thyroid dose from ^{131}I and ^{129}I to a perimeter infant (less than 1 year old) in 1975 would be approximately 0.22 mrem. This is a result of the iodine-air-grass-cow-milk vector and inhalation.

TABLE III-5

Parameters for Tritium Dose Calculations

	<i>Parameters Used in this Report</i>	<i>More-Recent Parameters</i>
Quality Factor	1.7 ^a	1.0 ^b
Effective Half-life in Body	12 days	10 days ^c
Organic Labeling Factor	None	

a. Reference 8.

b. Reference 10.

c. Reference 11.

TABLE III-6

Individual Dose Commitment at the Plant Perimeter
from SRP Atmospheric Releases

<i>Period</i>	<i>Dose Commitment, millirem</i>			
	<i>Whole Body</i>		<i>Thyroid Avg^{b,c}</i>	<i>Lung Avg^b</i>
<i>Avg</i>	<i>Max^a</i>			
1975	0.66	0.92	0.57 (1.23)	0.0003 (0.67)
1954-1975 (Total)	41	-	163.4 (204.4)	0.34 (41.3)

a. Maximum at point of highest dose on plant boundary averaged over the year.

b. Numbers in parentheses are the organ dose plus the whole body dose.

c. Thyroid doses shown are for an adult.

Of the 163.4 mrem adult thyroid dose for 1954-1975, 102 mrem occurred in 1956, a year of above normal ^{131}I releases. The total thyroid dose of 163.4 mrem includes an estimated 17.3 mrem from ^{129}I .

The population dose commitment from releases of radioactive materials to the atmosphere is compared to other sources of population exposure for 1975 and for the inclusive period 1954-1975 in Table III-7. The doses shown are to the population residing within 100 kilometers of the geographic center of the SRP site; this represents an annular ring, 50 miles in width, around the plant. Although population grew about 10% during this period, a constant population of 668,000 (1970 census) was used for the purpose of dose calculations. From the data in Table III-7, the population dose commitment from SRP sources as a percent of natural dose was 0.15% in 1975 and 0.39% for the period 1954-1975.

The contribution of individual radionuclides to the whole body population dose commitment is shown in Table III-8 for 1975. This table also shows the sources of releases on the SRP site. The data show that the greatest contributors of man-rem dose via atmospheric releases were tritium (^3H , half-life = 12.3 years), ^{41}Ar (a short-lived radioactive noble gas, half-life = 1.83 hours), and ^{14}C (half life = 5730 years). As shown in Table III-8, tritium contributed about 83% and ^{14}C and ^{41}Ar each contributed about 8% of the population dose commitment in 1975. For the period 1954-1975, tritium contributed 81% of the overall dose, and ^{41}Ar , 12%.

DOSE COMMITMENT FROM RELEASES OF RADIOACTIVE MATERIALS TO PLANT STREAMS

Construction of the Savannah River Plant began in 1951. During 1952 and 1953, small amounts of natural uranium were released to settling basins during preparations for startup of the plant. These settling basins overflow to natural basins which discharge to the Savannah River. Other radionuclides were not released until 1954, the first year of operation of SRP reactors.

During the 1950s, most release data were derived from gross alpha and gross nonvolatile beta analyses, supplemented by radiochemical separations and measurement of critical nuclides in composited samples. The state of technology of radioanalysis did not permit routine, running inventories of all radionuclides. By 1960, improvements in gamma spectrometry, low-level beta counting, liquid scintillation spectrometry, alpha spectrometry, and automatic data processing allowed a more-detailed inventory of individual radionuclides released.

TABLE III-7

Population Dose Commitment from Atmospheric Releases

Period	Population Size	Dose Commitment, man-rem			Total
		Natural Sources ^a	Artificial Sources ^a	SRP Sources	
1975	668,000	78,000	71,000	115	149,000
1954-1975	668,000	1,720,000	1,560,000	6,651	3,290,000

a. Based on an average annual dose to an individual of 0.117 rem from natural sources and 0.106 rem from artificial sources.
(See Section II.C, "Characterization of the Existing Environment.")

TABLE III-8

Contribution of Radionuclides to Whole Body Population Dose from SRP Atmospheric Releases in 1975

Nuclide	Total Dose, man-rem	Dose by Source Areas, man-rem		
		Reactors ^a	Separations ^a	Heavy Water Plant
³ H	96.0 ^a	49.9 ^a	44.9 ^a	1.0
⁴¹ Ar	9.2	9.2	-	-
¹⁴ C	9.0	5.3	3.7	-
Kr, Xe	0.88	0.47	0.41	-
^{129,131} I	0.12	-	0.12	-
Particulates	0.02	-	0.02	-
Total	115.2 ^a	64.9 ^a	49.2 ^a	1.0

a. Does not include dose from evaporation of tritium from seepage basins and waste tanks, estimated to be less than 3.0 man-rem.

Radionuclides in liquid effluents are analyzed at the point of release, in surface streams on the SRP site before entry into the Savannah River swamp, and in the Savannah River upstream and downstream from SRP. Many radionuclides that are measurable at the point of release (see Table III-1) are below the analytical limit of sensitivity after being diluted with river water. Therefore, many are not detectable in river water by routine analytical methods. Dose commitments to downstream consumers of river water are based on the release inventory and the following assumptions:

- No radionuclides are retained in the streams and swamp on the SRP site. This is known to be a pessimistic assumption for some radionuclides because of settling of particulates and sorption of dissolved material by minerals and organic matter in the stream-swamp. For example, only about 20% of the radiocesium released can be accounted for in river transport because of these phenomena.
- Approximately 5 days elapse between time of release of radionuclides and entry into the two water treatment plants approximately 100 miles downstream. Short-lived radionuclides are corrected for this decay time.
- The flow of the river at the water treatment plants is approximately 10% greater than at SRP. The increase in flow results from downstream tributaries of the Savannah River. For the period 1961-1975, the average flow at the downstream water treatment plants was approximately 12,000 cfs.
- No allowance is made for removal of radionuclides in the water treatment plants.
- Individuals served by the water treatment plants consume 1200 ml of river water each day.

Water is withdrawn from the Savannah River for consumption at two locations downstream from SRP. These are:

- Cherokee Hill Water Treatment Plant, Port Wentworth, Georgia. This plant has been treating Savannah River water during the entire period of operation of the Savannah River Plant. The water is used primarily for industrial and manufacturing purposes in an industrial complex near Savannah, Georgia. Some of the water is consumed by industrial workers and seamen. The water is also used in preparing bottled beverages at two bottling plants. The Cherokee Hill Water Treatment Plant has an effective consumer population of about 20,000.
- Beaufort-Jasper Water Treatment Plant near Hardeeville, S.C. This plant has been in operation since January 1965. Water is pumped from the Savannah River and flows by canal to the treatment plant. Some dilution of the river water occurs from influx of surface water into the canal. The water treatment plant serves a consumer population of approximately 50,000.

Dose calculations were made for consumers of downstream river water for the period 1957-1975 using the foregoing data and assumptions. Dose commitments for an individual consuming water only from these treatment plants are shown in Table III-9. These doses were calculated by methods described in Appendix G, using release data from Table III-1. The radionuclide contributing most of the whole body dose is tritium; its contributions to the total dose during the above periods were: 1975, 99%; 1965 through 1975, 87%; and 1957 through 1975, 81%. ^{137}Cs accounted for most of the remaining dose, based on the pessimistic assumptions used in these calculations.

Routine analysis of water from the two water treatment plants began in the mid-1960s. The only radionuclide of SRP origin detected by routine analytical procedures is tritium. (The tritium contribution to whole body dose for 1975 shown in Table III-9 is based on measured concentrations.) Dose commitment from tritium, as calculated by the assumptions used, is compared with dose as calculated from analysis of water from the two water treatment plants in Table III-10. There is reasonable agreement between the dilution calculations and calculations based on analysis of Port Wentworth water. The lower doses shown for Beaufort-Jasper result from the dilution of river water in the canal system by influx of surface water.

Population dose commitment from releases of radioactive materials to the Savannah River via SRP streams is compared in Table III-11 to other sources of population exposure for 1975 and for the inclusive period 1957-1975. The data for the latter period are appropriately adjusted to account for startup of the Beaufort-Jasper Water Treatment Plant in January 1965 with a resultant increase in river water consumer population. From the data in Table III-11, the population dose commitment as a percent of natural dose was 0.2% in 1975 and 0.5% for the period 1957-1975.

A hypothetical person who drinks untreated river water just downstream from SRP effluents and consumes river fish at the rate of 0.5 lb/wk would have received the dose commitment shown in Table III-12. Concentrations of radionuclides in water and fish were determined by analyses and include any upstream contribution of tritium and ^{90}Sr of fallout origin as well as the SRP contribution. Consumption of river fish was banned in 1970 because of mercury contamination from an upstream source. However, this ban was lifted in 1972, and it is conceivable that some person or persons might have eaten 0.5 lb of fish per week (26 lb/yr). However, it is highly unlikely that anyone regularly consumed untreated river water.

TABLE III-9

Individual Dose Commitment to Consumers of
Downstream River Water, 1957-1975

<i>Period</i>	<i>Dose Commitment, millirem</i>		
	<i>Whole Body</i>	<i>Bone^a</i>	<i>Thyroid^a</i>
1975	0.24	0.07 (0.31)	-
1965-1975 ^b	6.3	2.5 (8.4)	2.1 (8.4)
1957-1975 ^c	10.8	6.5 (17.3)	15.3 (26.1)

- a.* Numbers in parentheses are organ doses plus the whole body dose.
- b.* The period of operation of the Beaufort-Jasper Water Treatment Plant.
- c.* Port Wentworth Water Treatment Plant was in operation during this entire period.

TABLE III-10

Comparison of Tritium Dose Calculations

<i>Year</i>	<i>Individual Dose Commitment, millirem</i>		
	<i>Dilution Calculations^a</i>	<i>Port Wentworth Water Analysis</i>	<i>Beaufort-Jasper Water Analysis</i>
1970	0.48	0.38	0.17
1971	0.34	0.47	0.13
1972	0.36	0.31	0.23
1973	0.42	0.52	0.37
1974	0.53	0.45	0.27
1975	0.36	0.29	0.19

- a.* Based on measured flow rates.

TABLE III-11

Population Dose Commitment from Liquid Releases

Period	Population Size	Dose Commitment, man-rem			
		Natural Sources ^a	Artificial Sources ^a	SRP Sources	Total
1975	70,000	8,200	7,400	15.5 ^b	15,600
1957-1975 ^c }	70,000 ^d	109,000	99,000	531	208,500

- a. Based on an average annual dose to an individual of 0.117 rem from natural sources and 0.106 rem from artificial sources.
- b. Based on dilution calculations (measured data for tritium) and release information.
- c. Includes dose from tritium releases starting in 1954.
- d. Assumes a constant population of 20,000 for 1957-1964 and increasing to 70,000 in 1965 as a result of startup of the Beaufort-Jasper Water Treatment Plant in 1965.

TABLE III-12

Hypothetical Doses to Individuals Consuming River Water and Fish - 1975

Vector	Nuclide	Concentration, $\mu\text{Ci}/(\text{ml or g})$	Critical Organ Dose, ^a mrem	
			Body	Bone ^b
River Water, Untreated	³ H	3.5×10^{-6} ^c	0.31	-
	⁹⁰ Sr	2.0×10^{-11}	0.00003	0.013
	¹³⁷ Cs	5×10^{-12}	0.00014	-
River Fish	³ H	3.5×10^{-6}	0.0084	-
	¹³⁷ Cs ^d	2.5×10^{-7}	0.18	-
Total			0.5	0.013

- a. Doses calculated from analysis of environmental samples.
- b. Does not include contribution from whole body dose.
- c. $10^{-6} = 0.000001$, $10^{-9} = 0.000000001$, etc.
- d. Average concentration in bream and catfish.

RELATIONSHIP OF DOSE COMMITMENT TO HEALTH EFFECTS

Radiation doses to individuals and to population groups from SRP releases are small compared to the range of doses from natural background radiation and medical diagnostic radiation within 100 km of the plant (Table III-13). It is assumed that effects caused by radiation are proportional to radiation dose. Cumulative offsite effects beyond the year of actual release are discussed in the following section.

TABLE III-13

Comparison of Radiation Doses

	<i>Hypothetical Maximum Individual at Plant Boundary (millirem)</i>	<i>Population Within 100-km radius (668,000) (man-rem) (p. III-31)</i>	<i>Users of Water from River Near Savannah, Ga. (70,000) (man-rem) (p. III-35)</i>
SRP atmospheric releases, 1975	0.92 (Table III-6)	115 ^a	--
SRP aqueous releases, 1975	0.5 (Table III-12)	--	15.5
Total	1.4		
Natural radiation sources, avg.	117 (Table II-26)	78,000	8,200
Range	61 - 450	--	--
Artificial radiation sources, avg. (Primarily medical diagnostic x-rays)	106 (Table II-26) Range highly variable	71,000	7,400
SRP contribution as % of average from natural radiation sources	1.2%	0.15%	0.2%

^a. Does not include dose from tritium evaporation, estimated to be less than 3.0 man-rem.

4. MAXIMUM HEALTH EFFECTS

BASIS OF CALCULATIONS

For analysis of the maximum number of health effects to the surrounding population that might occur as a result of the 1975 environmental radiation dose commitment due to Savannah River Plant waste management operations, the conversion factors for calculating maximum potential health effects from population dose, as published in the BEIR Report¹² and as summarized by the Environmental Protection Agency (EPA),¹³ were used. The pessimistic assumption of a no-threshold, linear response through