

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	<u>1.4</u>		
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

zero effects at zero dose was made. This assumption implies that when population doses (sum of the dose received by each member of a population group) for population groups of various sizes are equal, the number of health effects are the same for each group; it does not matter whether population doses are small and populations are large or vice versa. The EPA values are given in Table III-14.

These dose-effect estimates are subject to error and probably overestimate the actual effects considerably. The following is a quote from Reference 14, the EPA analysis of the uranium fuel cycle:

"The numerical risk estimates used are primarily from the BEIR report.¹² What must be emphasized is that though these numbers may be used as the best available for the purpose of risk-cost benefit analyses, they cannot be used to accurately predict the number of casualties. For a given dose equivalent, the BEIR report estimates a range for the health impact per million exposed persons. For example, the BEIR results from a study of the major sources of cancer mortality data yield an absolute risk* estimate of 54 to 123 deaths annually per 10^6 persons per rem for a 27-year followup period. Depending on the details of the risk model used, the BEIR Committee's relative risk** estimate is 160-450 deaths per 10^6 persons per rem. It is seen that the precision of these estimates is at best about a factor of 3 to 4, even when applied to sample populations studied on the basis of the same dose rates. The application of the BEIR risk estimates to exposures at lower dose rates and to population groups more heterogeneous than those studied increases the uncertainty in the risk estimates. Considering the limitations of presently available data and the lack of an accepted theory of radiocarcinogenesis, emphasis should be placed on the difference in risk estimates between the various procedures and countermeasures discussed in this report rather than on the absolute numbers. Where the absolute numbers must be used for risk-cost-benefit balancing, it should be remembered that these risk estimates are likely to be revised as new information becomes available. Notwithstanding these disclaimers, it is also pertinent to note that we are in a better position to evaluate the true risks and the accompanying uncertainties from low levels of radiation than from low concentrations of other environmental pollutants which might affect populations in the vicinity of a fuel reprocessing plant."

* Absolute risk estimates are based on the reported number of cancer deaths per rad that have been observed in exposed population groups, e.g., Hiroshima, Nagasaki, etc.

** Relative risk estimates are based on the percentage increase of the ambient cancer mortality per rem.

TABLE III-14

Conversion Factors

Population Dose to Maximum Potential Number of Health Effects

<i>Mortality</i>	<i>Conversion Factors</i>
Total Body	200 cancer deaths/10 ⁶ man-rem
Lung	50 cancer deaths/10 ⁶ man-rem
Thyroid ^a	5 cancer deaths/10 ⁶ man-rem
<i>Morbidity</i>	
Total Body	400 cancer cases/10 ⁶ man-rem
Thyroid ^a	20 cancer cases/10 ⁶ man-rem
Genetic Effects	300 effects/10 ⁶ man-rem

a. Weighted for an assumed population age distribution given by EPA.¹³

The population doses and maximum potential health effects due to 1975 Savannah River Plant waste management operations are summarized in Table III-15. For this calculation, the genetic dose was conservatively estimated to be the same as the whole body dose. The population thyroid dose from atmospheric releases of ¹²⁹I, as given in Table G-1 of Appendix G, was adjusted to exclude total body contribution. For actinide elements the critical organ is the lung assuming, as in the EPA report,¹³ that these elements are insoluble. On this basis, the lung population dose commitment from the actinides released in 1975, if all were insoluble, was calculated to be about 0.04 man-lung-rem. This is the dose value used in Table III-15.

Death rate statistics¹⁶ for South Carolina and Georgia show that the death rate from all malignancies is about 116.3 per 100,000 population per year. Thus, in a population of 738,000, there would be 858 expected cancer deaths per year. [K.11] The calculated number of eventual cancer deaths from release of radioactive materials from SRP during 1975 is 0.026 deaths (Table III-15), or 0.003% of the annual cancer deaths in the same population.

The lung dose is calculated with the assumption of uniform distribution of actinides in the lung. This is the method adopted by the International Commission on Radiological Protection.¹⁷ However, it has been proposed^{18,19} that summing the energy released from radioactive material in the lung over the entire lung may not

be a proper assessment of consequences. Particulate radioactive materials (hot particles) are considered in that proposal to produce a much larger health effect than would be expected from the total organ dose because of the very high dose delivered to small volumes of tissue by alpha particles from the deposited material.

TABLE III-15

Maximum Potential Number of Health Effects for 1975 Population Dose Commitment^a

<i>Mortality</i>	<i>Population Dose, man-rem</i>	<i>Maximum Potential Number^b of Health Effects</i>
Total Body	131 ^c	2.6×10^{-2} cancer deaths
Lung	0.04	2×10^{-6} cancer deaths
Thyroid	73.2	3.7×10^{-4} cancer deaths
	Total Mortality	2.6×10^{-2}
<i>Morbidity</i>		
Total Body	131	5.2×10^{-2} cancer cases
Thyroid	73.2	1.5×10^{-3} cancer cases
Genetic Damage	131	3.9×10^{-2} genetic effects
	Total Morbidity	9.3×10^{-2}

- a. For population in an annular ring, 50-miles wide (100 km from center of plant) around SRP (668,000 people) and two population groups downstream from SRP who use Savannah River water for drinking (70,000 people).
- b. This column gives the total number of potential health effects for population dose commitment received in 1975 from SRP operations.
- c. Includes 115.3 man-rem from atmospheric releases and 15.5 man-rem from liquid releases.

The position of the National Council on Radiation Protection is given below, quoted from Reference 15.

"The linear dose-effect hypothesis has been coming into frequent use in analyses in which population exposures are expressed in the form of person-rem, including doses of 1 mrem/year or less to population groups and doses to individual organs, with linear extrapolation to damage estimates through the use of the NAS-BEIR committee report values. The indications of a significant dose rate influence on radiation effects would make completely inappropriate the current practice of summing of doses at all levels of dose and dose rate in the form of total person-rem for purposes of calculating risks to the population on the basis of extrapolation of risk estimates derived from data at high doses and dose rates.

The NCRP wishes to caution governmental policy-making agencies of the unreasonableness of interpreting or assuming "upper limit" estimates of carcinogenic risks at low radiation levels, derived from linear extrapolation from data obtained at high doses and dose rates as actual risks, and of basing unduly restrictive policies on such an interpretation or assumption. The NCRP has always endeavored to ensure public awareness of the hazards of ionizing radiation but it is equally determined to ensure that such hazards are not greatly overestimated. Undue concern, as well as carelessness with regard to radiation hazards, is considered detrimental to the public interest."

A recent review²⁰ of experiments with animals and health studies of plutonium workers exposed thirty years ago to airborne plutonium in the early days of the Manhattan Project discounts a "hot particle" effect. It concludes that the mean dose lung model on which occupational radiation protection standards for plutonium are based is not grossly in error and does not lead to hazardous practices. Currently available data from occupationally exposed persons indicate that the nonhomogeneous dose distribution from inhaled plutonium does not result in demonstrably greater risk than that assumed for a uniform dose distribution.

The Radiation Alert Network of the Division of Atmospheric Surveillance, EPA, routinely collects airborne particles from eleven stations across the U.S. for plutonium analysis.²¹ The high value (Austin, Texas), low value (Anchorage, Alaska), and values for three other locations in the southeastern U.S. are:

Austin, Texas	$44 \times 10^{-18} \text{ Ci/m}^3$
Anchorage, Alaska	$14 \times 10^{-18} \text{ Ci/m}^3$
New Orleans, Louisiana	$28 \times 10^{-18} \text{ Ci/m}^3$
Gastonia, North Carolina	$26 \times 10^{-18} \text{ Ci/m}^3$
Baltimore, Maryland	$33 \times 10^{-18} \text{ Ci/m}^3$

These concentrations are the result of fallout from previous nuclear weapons tests. The concentration of total plutonium at the Savannah River Plant perimeter from plant operations in 1975 was calculated to be $1.5 \times 10^{-19} \text{ Ci/m}^3$, about 0.5% of the concentration of fallout background in the southeast.

CUMULATIVE OFFSITE EFFECTS

Should SRP production operations be shut down, offsite effects to the surrounding population would decrease to a small fraction of the present values. The effects of previous releases continue to become smaller because of the following factors:

- Radioactive decay of the released nuclides.
- Dispersion of gases released to the atmosphere.
- Dilution of tritium and other nuclides released to plant streams.

[K.11] It should be realized that SRP dose commitments given in preceding years have largely accounted for the effects from persistence of released radioactivity (see Appendix G).

Atmospheric Releases

Estimated population radiation exposures (doses) within 50 miles (80 km) of the Plant perimeter from SRP atmospheric releases were 219, 163, and 116 man-rem, respectively, for the years 1973, 1974, and 1975. Average contributions to this exposure for these years were as follows:

Tritium	81%
⁴¹ Ar	10%
¹⁴ C	7%
Other	2%

Each of these contributions is discussed below.

Tritium

After shutdown of production operations, tritium releases to the atmosphere would cease except for the small amounts associated with continued waste storage operations (estimated releases are initially about 4000 Ci/year resulting in an estimated population dose of 1.3 man-rem). Exposure of the surrounding population from some of the previously released tritium would continue for a short period of time because various foodstuffs, such as vegetable crops, milk, etc., contain tritium that is in dynamic equilibrium with tritium in the atmosphere. The concentrations of tritium in these foodstuffs in areas near the plant are measurably higher than the tritium background at greater distances from the plant, showing that there is some residual effect from SRP tritium releases. However, the exchange of the tritiated water contained

in plants with that contained in the atmosphere is relatively rapid (half-life less than 1 month). Therefore, residual effects from previous tritium releases would be small and would diminish by dilution in the atmosphere and eventual distribution throughout the hydrosphere.²²

Argon-41

After shutdown of production operations, the generation of ⁴¹Ar would cease and there would be no residual effects (half-life 1.8 hours).

Carbon-14

After shutdown of production operations, release of ¹⁴C would cease. Based on the assumptions and techniques for estimating doses from ¹⁴C reported in Appendix G (page G-17), residual effects to the surrounding population from previously released ¹⁴C (half-life 5700 years) could continue for perhaps another year. The principal assumption is that any SRP-released ¹⁴C instantaneously reaches equilibrium in man at the same ratio as exists in the local atmosphere, but, after the SRP source is removed, the return to equilibrium with naturally occurring ¹⁴C is slower than the half-life in the body of ¹⁴C ingested in food or inhaled as CO and CO₂. For purposes of estimating an upper limit on dose for a given release of ¹⁴C, the total dose commitment was arbitrarily assumed to be two times the dose received during the year of release of ¹⁴C from SRP. This is equivalent to assuming a one-year residual effect after the SRP source is removed.

Other

Residual or cumulative effects to the surrounding population from other radionuclides released by SRP are also expected to be extremely small. Of potential concern would be the extremely long-lived materials that are either released as particulates that can settle out (e.g., ^{238,239}Pu) or as reactive species that might concentrate in the biosphere (e.g., ¹²⁹I). Calculated lifetime whole-body doses to the population within 50 miles of the plant perimeter received by exposure from all pathways during the 1975 year of release were 0.02 man-rem for ^{238,239}Pu and 0.12 man-rem for ¹²⁹I. Also, the estimated population bone dose from ^{238,239}Pu was 0.04 man-rem and the conservatively estimated population thyroid dose from ¹²⁹I was 72.3 man-rem.

An intensive soil sampling program was begun in 1972 using improved techniques to detect the extremely low levels of ^{238,239}Pu in the environment. SRP perimeter and offsite soil samples show a deposition level that is well within the range of deposition from weapons test fallout in the southeastern U.S., indicating

that actual offsite deposits due to SRP operations are small compared to background.²³ Increased concentrations are measured onsite, within about a 2-km radius of each of the two chemical separations areas, indicating some SRP contribution. Also, as indicated on page III-39, the airborne concentration of total plutonium calculated from SRP releases at the plant perimeter was about 0.5% of the concentration of plutonium from fallout background in the southeastern U.S.

Not enough is known about ¹²⁹I long-term behavior in the environment to enable detailed calculation of residual effects. A program has been initiated at SRP for the purpose of effluent and environmental monitoring of ¹²⁹I. Because of the limited residence time in the thyroid, dilution with natural stable ¹²⁷I, and downward migration out of plant root zones with rain-water infiltration, residual effects from the estimated releases of ¹²⁹I are believed to be small compared to the estimated effects during the year of release.

Liquid Releases

Estimated radiation exposures (doses) to population groups downriver from SRP were 29.1, 22.9, and 15.5 man rem, respectively for the years 1973, 1974, and 1975. Greater than 98% of this exposure resulted from releases of tritium as tritiated water to plant streams. About 1% resulted from release of ¹³⁷Cs primarily by desorption from plant stream beds. The remainder (<1%) resulted from small releases of other radionuclides.

After shutdown of production operations, tritium releases would consist only of the tritiated water that migrates from seepage basins in F, H, and K Areas through the ground water on the plantsite to Four Mile Creek and Pen Branch. During operations, approximately 17,000 Ci/year migrates offsite in this manner and results in a total calculated population dose of 6.7 man-rem/year. After discharges to the seepage basins are stopped, this migration rate will decrease slowly as a function of radioactive decay (half-life 12 years) and decreased liquid head in the basins.

After shutdown of plant production operations, the release of ¹³⁷Cs would continue as cesium continues to desorb from the stream beds of Four Mile Creek and Steel Creek. This release would result in a continuing population dose calculated to be about 0.2 man-rem/year initially and then would decrease based on the radioactive half-life of 30 years and the slow depletion of the material available to be desorbed. The only significant individual contributor among the remainder of the nuclides released during normal operation is ⁹⁰Sr. Release of ⁹⁰Sr is mostly from migration to Four Mile Creek from the F and H Area seepage basins. This release results in an offsite dose of approximately 0.01 man-rem/year and would decrease slowly after shutdown of production operations.