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POPULATION DOSE FROM LWR FUEL REPROCESSING

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DISCLAIMER

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ABSTRACT

The inhalation, submersion, and food ingestion dose to the regional and U.S. population are calculated for estimated releases of radionuclides from a hypothetical LWR nuclear fuel reprocessing plant located in southeastern United States. A mathematical transport, diffusion, and deposition model was used to obtain the air concentrations and ground deposition of the various radionuclides emitted to the atmosphere from the reprocessing facility.

The global population dose from atmospheric submersion was also calculated for ^{3}H, ^{14}C, and ^{85}Kr.

The total exposure to persons living in the region of the plant would be 0.2% of background.

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INTRODUCTION

The reference facility is a hypothetical reprocessing plant for spent fuel from light water reactors. For this study, it is assumed to be located at the Savannah River Plant in the southeastern U.S., 40 km (25 miles) southeast of Augusta, GA (Figure 1). The reference facility is assumed to have an operating lifetime of 40 years with annual discharges to the atmosphere as shown in Table I.

During the 40-year operating period, the dose rate from airborne radionuclides is assumed to be constant, but the dose rate from material deposited on the ground is assumed to continuously increase. Material deposited is assumed to be depleted only by radioactive decay. Shielding by terrain and buildings and the effects of weathering is not taken into account, to be conservative.

To calculate the dose to the population, the air concentrations and the amount deposited on the ground is calculated. These data are then also used to calculate the population dose from the agricultural pathway. The expertise of several other laboratories supported by the U.S. Department of Energy was used for these calculations. Lawrence Livermore Laboratory (LLL) [1], Pacific Northwest Laboratory (PNL) [2], and the Air Resources Laboratory (ARL) of NOAA [3] calculated the regional air transport diffusion and deposition. PNL and ARL calculated the U.S.-scale transport, and ARL calculated the global doses. LLL also prepared the data

for the dose from the agricultural pathway. Oak Ridge National Laboratory (ORNL) provided data on the building shielding effects. Calculations by the Hanford Engineering Development Laboratory provided data on the population dose from the aquatic pathway. Because the dose from this pathway is small, the more-conservative tritium equilibrium concept developed by SRL is used to calculate the population dose from drinking water (HTO in the water and air are in equilibrium). Doses are calculated for 50 years, including 10 years after shutdown.

ATMOSPHERIC TRANSPORT AND DISPERSION MODELS

Two models of atmospheric transport, diffusion, and dispersion were used: one for the regional and continental scale air concentration and surface deposition and one for the global scale.

The regional-continental model used was developed by PNL and is a plume element model [2]. This model approximates a continuous release by dividing a plume into a sufficient number of plume elements to represent a continuous plume. These elements are released at specific intervals and tracked over the region of interest. Concentration and ground deposition averages are calculated by determining the contribution each element makes to the grid of points over which it passes using meteorological data and real time precipitation [4] for the year 1975.

The global computational model used in the study was developed by ARL of NOAA [5]. The model is a reservoir model that assumes uniform mixing for 10° latitudinal bands around the

globe. Each band is sliced into 2-km-thick vertical sections with the exception of the lowest layer which is 1 km thick. The vertical sections extend up to 40 km in altitude. The global transport model does not consider ground deposition or removal of ^{85}Kr. For HTO, there are two mechanisms for loss: precipitation scavenging and molecular exchange with bodies of water. For $^{14}CO_2$, uptake and release by the biosphere and oceans are taken into account.

ATMOSPHERIC SUBMERSION CALCULATIONS

The estimated man-rem exposure rate per year to various populations will change because of natural growth. Because the proposed fuel reprocessing facility is expected to operate for 40 years and the starting date is uncertain, the annual dose rate may be significantly different at the beginning and end of operations. To account for total man-rem exposure over the operating period, population projections were used to make adjustments as a function of time.

U.S. population projections are based on U.S. Department of Commerce statistical abstracts [6] with the Series II fertility projection, which assumes 2.1 births per woman. This method results in a near linear growth in population through 2025. The linear growth assumed in this study is shown in Figure 2. The global population was assumed to increase exponentially at a rate of 2.0% per year.

Whole body dose estimates for this southeastern region from individual isotopes are given Tables II and III for conditions

with and without precipitation. Data are given for two assumed startup times in each table so that the effect of delayed startup may be estimated. These tables show that ^{3}H and ^{85}Kr account for about 90% of the total 50-year cumulative dose. All of the ^{3}H is assumed to tritiated water vapor. Also, surface water is assumed to be in equilibrium with the atmospheric HTO.

Because ^{3}H and ^{85}Kr were excluded from rainout effects, the total doses in these two tables are about the same. Doses from some other nuclides are different.

The total dose rate is about 54 man-rem per year in the first year for a 1980 startup, and 64 man-rem per year in the first year for a 2000 startup. The increase in first-year dose results from population growth. At the end of a 40-year operating period these dose rates have increased to 72 man-rem and 86 man-rem, respectively. The cumulative 40-year dose is about 2600 man-rem for startup in 1980 and 3100 man-rem for startup in 2000, a dose increase of about 18%.

Results for the total U.S. dose estimates from atmospheric submersion are similar (Tables IV and V). These data show a 40-fold increase from the regional dose to total U.S. dose, with a maximum of 122,300 man-rem for a year 2000 startup.

Tables II through V show that if no precipitation is assumed, larger doses are estimated from atmospheric submersion because nuclides other than ^{14}C, ^{3}H, and ^{85}Kr remain airborne longer. It is normally conservative to ignore precipitation effects for whole

body dose due to atmospheric submersion. However, precipitation is a significant mechanism for depositing material on the ground; the dose from deposits more than offset the dose from airborne nuclide. Results in this report include precipitation.

Global dose estimates resulting from recirculation in the atmosphere are shown in Table VI (effects of rainout are ignored). The total dose is assumed to result from ^{3}H, ^{85}Kr, and ^{14}C. ^{85}Kr is the major contributor (54.5) because it can be removed only through radioactive decay (half-life: 10.7 years). Whole body global dose estimates over a period of 50 years (includes 10 years following plant shutdown) are 329,600 man-rem for a 2000 startup. A delay from 1980 to 2000 results in an increase in global dose of about 50% over that for a 1980 startup. This percentage increase for the global dose is greater than the U.S. percentage increase because of the assumed larger growth rate for the global population (1% per annum U.S., 2% per annum world population growth).

Whole body dose estimates from atmospheric submersion to the southeastern U.S., the U.S., and the rest of the world are summarized in Table VII for 50-year dose commitments from facility operations. The total world 50-year dose from atmospheric submersion is 324,000 man-rem for a 1980 start and 452,000 man-rem for a year 2000 start. In contrast, a one-year dose to the world population in the year 2000 from natural or background radiation is 630,000,000 man-rem.

TRITIUM MODELING

In the past, the dose from tritium was calculated from inhalation and skin absorption. Tritium (HTO) in the air exchanges very rapidly with the free water in vegetation and surface water. A more-appropriate dose calculation method is the equilibrium hypothesis in which the whole body contains the same average tritium concentration as the moisture in the air. Literature references support this theory [7]. Tritium in the body water of a person ingesting food and water will come into equilibrium with the water in the ingested material.

TRITIUM EQUILIBRIUM DOSE

The tritium dose was calculated by assuming that the human body contains the same concentration of tritium per unit volume of water as the air moisture. This is appropriate only for chronic releases. All tritium released is assumed to be tritiated water (HTO). Rapid exchange between air moisture and surface moisture and between air moisture and free water in vegetation has been demonstrated as an initial step in attaining equilibrium. When both food and water intakes are at a particular tritium concentration, the total body will attain that concentration rapidly because of the short 10-day biological half-life of tritium in body water.

The dose calculated when equilibrium is assumed is conservative. This dose is appropriate for calculating the maximum individual dose commitment, but is conservative for the overall population. Most of the drinking water is obtained from wells

where tritium concentration is lower than in surface water which is in equilibrium with atmospheric moisture. The equilibrium hypothesis assumes that all food consumed is locally grown. No reduction in concentration is considered for exchange between food and domestic water used during preparation and cooking. The tritium concentration of precipitation is less than atmospheric moisture because all rain water does not originate locally. The lower level in precipitation may result in lower concentrations in vegetation because of dilution of soil water by water of lower HTO concentration.

A similar model was used for calculation of radiation dose from ^{14}C. Carbon as carbon dioxide is thoroughly mixed in man's ecosystem by natural processes. The mass of carbon added by the fuel reprocessing plant is minute compared with the mass of carbon available naturally. The model assumes all ^{14}C is carbon dioxide and the ratio of ^{14}C to ^{12}C is identical in the atmosphere, terrestrial food, and man.

GROUND DEPOSITION

Dose from material deposited on the ground results from exposure to cumulative deposits building up over the total operating period. Dose contribution from this deposited material continues after operations have ceased. Thus, a 50-year dose commitment from facility operations is calculated: 40 years of operation and 10 years following shutdown. These estimates are conservative, because the material assumed to remain deposited is actually depleted by weathering and resuspension.

Table VIII shows that ^{106}Ru dominates the dose estimate by accounting for greater than 99% of the total from this pathway. (Table 8 does not include effects of population growth.) Although the dose for the first year is only 97 man-rem, the cumulative effect results in a total dose of 13,600 man-rem over a 40-year period, an increase of a factor of 140. When the population growth is taken into account, this ratio increases to 170 for an assumed 1980 startup.

Figures 3 and 4 show cumulative whole body gamma dose estimates from deposited material for 50 years for the Southeast and U.S. without precipitation effects. Accounting for precipitation results in a computed increase of about 20% in the 50-year dose estimate over results which do not include precipitation. This compares to a decrease of 1.0% for air submersion dose (Tables 2 and 3) when precipitation is taken into account. The cumulative whole body gamma dose estimate for the U.S. from deposited material is seen to be 31,100 man-rem for a 1980 startup and 36,700 man-rem for a year 2000 startup (Table IX). The regional dose is 74% of the U.S. total.

Similar data for beta exposure (primarily skin dose) from ground deposition in the Southeast are shown in Figure 5. The beta dose from deposited material is 23,000 and 27,000 man-rem for startup in 1980 and 2000, respectively. This dose is biologically insignificant relative to the whole body dose discussed above.

POTABLE WATER CONSUMPTION

Separate population dose estimates from water consumption were not made because ^{3}H and ^{14}C in water are included in the equilibrium calculation. It was our judgment that the doses from the other radionuclides in Table 1 via this pathway would be small [8].

TERRESTRIAL FOOD PATHWAY

The methods used for estimating the dose commitment to individuals and populations are those recommended by the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 for estimating doses from routine releases from reactor effluents. These evolved from the computer code HERMES, which assessed the radiological effects of nuclear power facilities in the upper Mississippi Basin [9].

Radionuclides may reach man via the terrestrial food chain in several ways: (1) deposition of atmospheric released radionuclides on the above ground parts of the plant, (2) deposition of radionuclides on ground surfaces and subsequent uptake via the plant root system, (3) use of water from aqueous waste streams for irrigation, and (4) consumption of radionuclide containing vegetation or water as foodstuffs for livestock and thence to man. In the southeastern region, irrigation is minimal so that pathway was not considered.

The concentration of radionuclides in beef, pork, chicken, milk, eggs, or lamb results from the animal consuming foodstuffs

containing the radionuclide. The concentration in the animal product is proportional to the amount of foodstuff consumed and concentration of radionuclide in foodstuff. The fraction consumed which is transferred to the human food is both food and radionuclide specific.

The dose assessment consists of calculating the radionuclide intakes for each year of interest, calculating the dose commitments from each year, and summing. The dose commitments were calculated over a period of 50 years, the 40 years of operation plus 10 years following shutdown. The ingestion dose is calculated for the whole body, bone, liver, kidneys, thyroid, and the lower large intestine (LLI) of the gastrointestinal tract. The average dose to an individual in each county in the southeastern region is given. The maximum dose to an individual, the regional population dose, and the total population dose are also given. The maximum dose to an individual is the dose commitment to a hypothetical individual who resides at the site boundary, where offsite deposition rates are the highest, who derives his entire terrestrial diet from the immediate area, and whose rates of food consumption are maximal. The regional population dose is based on the intake of radionuclides by the regional population. The total population dose includes the regional population dose and also takes into account the ingestion of foods exported in excess of regional population needs.

The average and maximum doses to an individual are computed as the 50-year dose commitment from the beginning of plant operation. A 50-year dose commitment for the first year's intake, a 49-year dose commitment for the second year's intake, a (51-n)-yr dose commitment for the nth year's intake, and an 11-year dose commitment for the 40th year's intake are calculated, and then the sum is computed. The average individual dose from each year is the product of radionuclide concentration in food, amount of food consumed, and dose conversion factor summed over each food-radionuclide combination. The food consumption rates were computed from the USDA Household Food Consumption Survey and are the average of all urban areas of the U.S. South. The dose to the maximum individual is computed in a similar manner except that higher food consumption rates are assumed.

The average radionuclide concentrations in human food are calculated for each county as a first step in regional population dose assessment. These values are used to calculate average concentrations for the region. The food production and population consumption are compared to ensure that regional food production is adequate for the population. The 50-year dose commitment is calculated for each year of operation because, unlike an individual, the population is a mixture of different age groups and will change during the plant lifetime.

DOSE ESTIMATE SUMMARY

Table 9 presents a summary of whole body population dose by pathway and region. Dose estimates are given for annual rates and 50-year total dose commitments for facility operations. Relative contributions to the dose commitment in various categories by isotope are given in Tables X through XVII. Table X, which gives the whole body dose commitment, shows that ^{85}Kr is the largest dose contributor with 30.8% of the total followed closely by ^{3}H with 28.3%. Four of the six isotopes considered are prominent for some pathway. As shown in Table X, ^{3}H is prominent for regional and U.S. atmospheric submersion, ^{85}Kr for global atmospheric submersion, ^{14}C for global atmospheric submersion and agricultural production, and ^{106}Ru for dose for ground deposition. ^{239}Pu is the major contributor to bone dose (Table XI).

The 50-year total whole body dose commitment from the proposed facility, shown in Table IX, is 397,730 man-rem for a 1980 startup and 538,210 man-rem for a year 2000 startup. Natural radiation processes, assuming an average of 100 man-rem per person per year over the entire globe, contribute 4×10^{8} man-rem per year, or 2×10^{10} man-rem for the 50-year period. The dose commitment over the 50-year period of interest for this hypothetical fuel reprocessing plant is thus only 2×10^{-3}% of natural background.

FACTORS INFLUENCING DOSE ESTIMATES

There are several factors which would reduce the dose estimates from direct radiation from deposited material given above, particularly the doses to the southeastern U.S. region and to the total U.S. The primary factors are building shielding, shielding of ground depositions due to ground roughness and terrain irregularities, and the weathering of activity deposited on the ground. (Inhalation and equilibrium dose from ^{3}H, ^{85}Kr, and ^{14}C will not be affected.) The above dose reduction factors are discussed in the Rasmussen Reactor Safety Study [10].

As shown in Table X, direct radiation from deposited material contributes only 14% of the total dose commitment. Thus, it is reasonable to ignore shielding and weathering effects.

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TABLE I

Atmospheric Releases

Radionuclide	*Form*	*Releases, Ci/yr*
^{3}H	HTO	2.42×10^{4}
^{14}C	CO_2	1.33×10^{-1}
^{85}Kr		3.94×10^{4}
^{129}I	I_2	1.39×10^{-3}
^{90}Sr		2.83×10^{-2}
^{137}Cs		3.84×10^{-2}

TABLE II

Southeast Whole Body Dose from Atmospheric Submersion, With Precipitation

Nuclide	*Annual Dose - 1980, man-rem*	*50 Year Dose Commitment, man-rem*		*Dose, % of total*
		1980 Startup	*2000 Startup*	
^{3}H	37.0	1810	2140	69.5
^{14}C	0.6	31	37	1.1
^{85}Kr	12.2	590	690	22.9
^{129}I	0.08	5	6	0.2
^{106}Ru	0.51	25	30	1.0
^{239}Pu	2.84	138	160	5.3
Total	53.23	2599	3063	100.0

TABLE III

Southeast Whole Body Dose from Atmospheric Submersion, Without Precipitation

Nuclide	*Annual Dose - 1980, man-rem*	*50-Year Dose Commitment, man-rem*		*Dose, % of Total*
		1980 Startup	*2000 Startup*	
^{3}H	37.0	1810	2140	68.8
^{14}C	0.6	31	37	1.1
^{85}Kr	12.2	590	690	22.7
^{129}I	0.08	5	6	0.2
^{106}Ru	0.58	28	35	1.1
^{239}Pu	3.25	158	185	6.1
Total	53.7	2622	3093	100.0

TABLE IV

U.S. Whole Body Dose from Atmospheric Submersion, Without Precipitation

Nuclide	*Annual Dose - 1980, man-rem*	*50 Year Dose Commitment, man-rem*		*Dose, % of total*
		1980 Startup	*2000 Startup*	
^{3}H	1880	90,800	106,600	87.1
^{14}C	225	10,930	12,850	10.5
^{85}Kr	44.5	2,170	2,550	2.08
^{129}I	<0.25	<10	<12	<0.01
^{106}Ru	0.92	44.5	52.2	0.04
^{239}Pu	5.12	248	292	0.24
Total	2156	104,192	122,340	100.00

TABLE V

U.S. Whole Body Dose from Atmospheric Submersion, With Precipitation

Nuclide	*Annual Dose - 1980, man-rem*	*50-Year Dose Commitment, man-rem*		*Dose, % of total*
		1980 Startup	*2000 Startup*	
^{3}H	1880	90,800	106,600	87.1
^{14}C	225	10,900	12,850	10.5
^{85}Kr	44.5	2,170	2,550	2.08
^{129}I	<0.25	<10	<12	<0.01
^{106}Ru	0.61	30	40	0.03
^{239}Pu	3.61	175	210	0.17
Total	2154	104,075	122,250	100

TABLE VI

Whole Body Dose from Global Recirculation

Nuclide	*50-Year Dose Commitment, man-rem*	
	1980 Startup	*2000 Startup*
^{3}H	6,800	10,200
^{85}Kr	120,100	179,600
^{14}C	93,400	139,800
Total	220,300	329,600

TABLE VII

Whole Body Dose from Atmospheric Submersion

Region	*50-Year Dose Commitment, man-rem*	
	1980 Startup	*2000 Startup*
Southeastern U.S.	2,600	3,060
Total U.S.	104,100	122,300
Global	220,300	329,600
Total[a]	324,400	451,900

a. Does not include doses for Southeastern U.S. which are included in the total U.S. doses.

TABLE VIII

Whole Body Doses from Ground Depositions to Southeastern U.S. Population, man-rem

Time from Startup, years	^{129}I	^{106}Ru	^{239}Pu
1	0.0546	97.3	0.0004
5	1.37	1,270	0.0102
10	5.46	3,010	0.0410
20	21.8	6,540	0.163
30	49.2	10,000	0.368
40	87.2	13,600	0.652

TABLE IX

Whole Body Population Doses, man-rem

	Annual Dose	*50-year Total Dose Commitment*	
		1980 Startup	*2000 Startup*
Atmospheric Submersion SE Regional	50	2,600	3,060
Atmospheric Submersion U.S. Total	2150	104,100	122,300
Atmospheric Submersion Global Recirculation	4410[a]	220,300	329,600
Ground Deposition SE Regional	460[a]	23,160	27,300
Ground Deposition U.S. Total	630[a]	31,300	36,700
Water Consumption SE Regional	120[a]	6,050	7,150
Agricultural Production SE Regional	200[a]	10,220	12,100
Total Dose	8020	397,730	538,210

a. Annual average over total 50-year period.

TABLE X

50-Year Whole Body Doses by Isotope and Pathway, 1980 Startup

	Dose, man-rem	*Percent of Total Dose*					
		^{3}H	^{14}C	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	2,600	69.8	1.2	22.6	0.19	0.97	5.3
Atmospheric Submersion U.S. Total	104,100	87.2	10.5	2.08	<0.01	0.03	0.17
Atmospheric Submersion Global Recirculation	220,300	3.1	42.4	54.5	<0.01	<0.01	<0.01
Ground Deposition SE Regional	23,160	<0.01	<0.01	<0.01	0.7	99.3	<0.01
Ground Deposition U.S. Total	31,300	<0.01	<0.01	<0.01	0.7	99.3	<0.01
Water Consumption SE Regional	6,050	<100.0	<0.01	<0.01	<0.01	<0.01	<0.01
Agricultural Production SE Regional	10,200	70.8	28.8	<0.01	<0.01	0.36	<0.01
Total Dose	395,130	28.1	27.2	30.9	0.10	13.7	0.04

TABLE XI

50-Year Bone Doses by Isotope and Pathway

	Dose, man, rem	*Percent of Total Dose*					
		^{3}H[a]	^{14}C[a]	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	8,300	21.9	0.16	7.1[b]	0.061[b]	2.1	68.6
Atmospheric Submersion U.S. Total	100,550	90.3	0.02	2.2[b]	-[c]	0.23	7.3
Atmospheric Submersion Global Recirculation	128,010	5.3	0.92	93.7[b]	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,000	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	9,170	66.0	5.4	-	-	23.3	5.4
Agricultural Products SE Regional	56,400	12.8	86.6	-	0.01	0.58	-
Total Dose	348,390	31.7	14.5	35.1	0.11	16.3	2.3

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

TABLE XII

50-Year Lung Doses by Isotope and Pathway

	Dose, man-rem	*Percent of Total Dose*					
		^{3}H[a]	^{14}C	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	12,940	14.0[b]	2.6	4.5[b]	0.01	77.7	1.2
Atmospheric Submersion U.S. Total	106,620	85.1[b]	0.41	2.0[b]	-[c]	12.2	0.19
Atmospheric Submersion Global Recirculation	157,630	4.4[b]	19.5	76.1	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,100	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	6,440	94.0	1.6[b]	-	-	4.3[b]	0.19[b]
Agricultural Products SE Regional	17,000	42.6	57.4	-	-	-	-
Total Dose	341,950	32.5	12.0	35.7	0.11	19.6	0.06

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

TABLE XIII

50-Year Thyroid Doses by Isotope and Pathway

	Dose, man-rem	*Percent of Total Dose*					
		^{3}H[a]	^{14}C	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	2,600	69.4[b]	0.09[b]	22.4[b]	1.9	0.94[b]	5.3[b]
Atmospheric Submersion U.S. Total	93,220	97.4[b]	-[c]	2.3[b]	0.07	0.03[b]	0.19[b]
Atmospheric Submersion Global Recirculation	127,050	5.4[b]	0.17[b]	94.5[b]	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,100	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	6,480	93.3	1.5	-	0.86	4.3[b]	0.02[b]
Agricultural Products	25,150	28.8	38.8	-	32.4	-	-
Total Dose	306,160	36.3	3.2	40.0	2.7	17.7	0.06

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

TABLE XIV

50-Year Kidney Doses by Isotope and Pathway

	Dose, man-rem	*Percent of Total Dose*					
		H[a]	*C*	*Kr*	*I*	*Ru*	*Pu*
Atmospheric Submersion SE Regional	3,330	54.5[b]	0.07[b]	17.6[b]	-[c]	10.3	17.6
Atmospheric Submersion U.S. Total	94,150	96.4[b]	-	2.3[b]	-	0.47	0.81
Atmospheric Submersion Global Recirculation	127,050	5.4[b]	0.17[b]	94.5[b]	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,100	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	10,320	58.7	0.97[b]	-	-	39.9	0.45
Agricultural Products SE Regional	17,650	41.0	55.4	-	0.04	3.5	-
Total Dose	303,430	36.5	3.3	40.3	0.13	19.5	0.27

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

TABLE XV

50-Year Liver Dose by Isotope and Pathway

	Dose, man-rem	*Percent of Total Dose*					
		^{3}H[a]	^{14}C	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	3,200	56.7[b]	0.07[b]	18.3[b]	-[c]	0.77[b]	24.3
Atmospheric Submersion U.S. Total	94,000	96.6[b]	-	2.3[b]	-	0.03[b]	1.1
Atmospheric Submersion Global Recirculation	127,050	5.4[b]	0.17[b]	94.5[b]	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,100	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	6,500	93.3	1.5[b]	-	-	4.3[b]	0.94
Agricultural Products SE Regional	17,000	42.6	57.4	-	0.02	-	-
Total Dose	298,810	37.1	3.4	40.9	0.13	18.1	0.37

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

TABLE XVI

50-Year GI Tract Doses by Isotope and Pathway

	Dose, man-rem	*Percent of Total Dose*					
		^{3}H[a]	^{14}C	^{85}Kr	^{129}I	^{106}Ru	^{239}Pu
Atmospheric Submersion SE Regional	3,360	54.0[b]	0.91	17.4[b]	-[c]	27.6	-
Atmospheric Submersion U.S. Total	105,000	86.5[b]	0.04	2.1[b]	-	11.4	-
Atmospheric Submersion Global Recirculation	157,630	4.3[b]	19.5	76.1[b]	-	-	-
Ground Deposition SE Regional	23,160	-	-	-	0.70	99.3	0.01
Ground Deposition U.S. Total	31,100	-	-	-	0.70	99.3	0.01
Water Consumption SE Regional	176,800	3.4	0.96	-	-	95.6	0.02
Agricultural Products SE Regional	195,440	3.7	85.8	-	-	10.5	-
Total Dose	692,490	16.2	29.0	17.6	0.05	37.1	0.01

a. ^{3}H and ^{14}C dose estimates assume equilibrium model applies.

b. Assumed to be the same as whole body dose.

c. <0.01%.

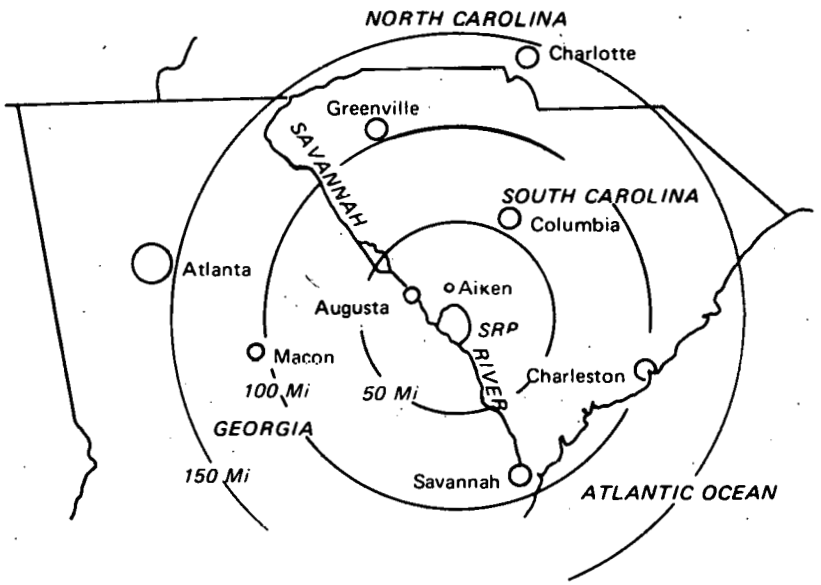

FIGURE 1. Population centers surrounding the Savannah River Plant

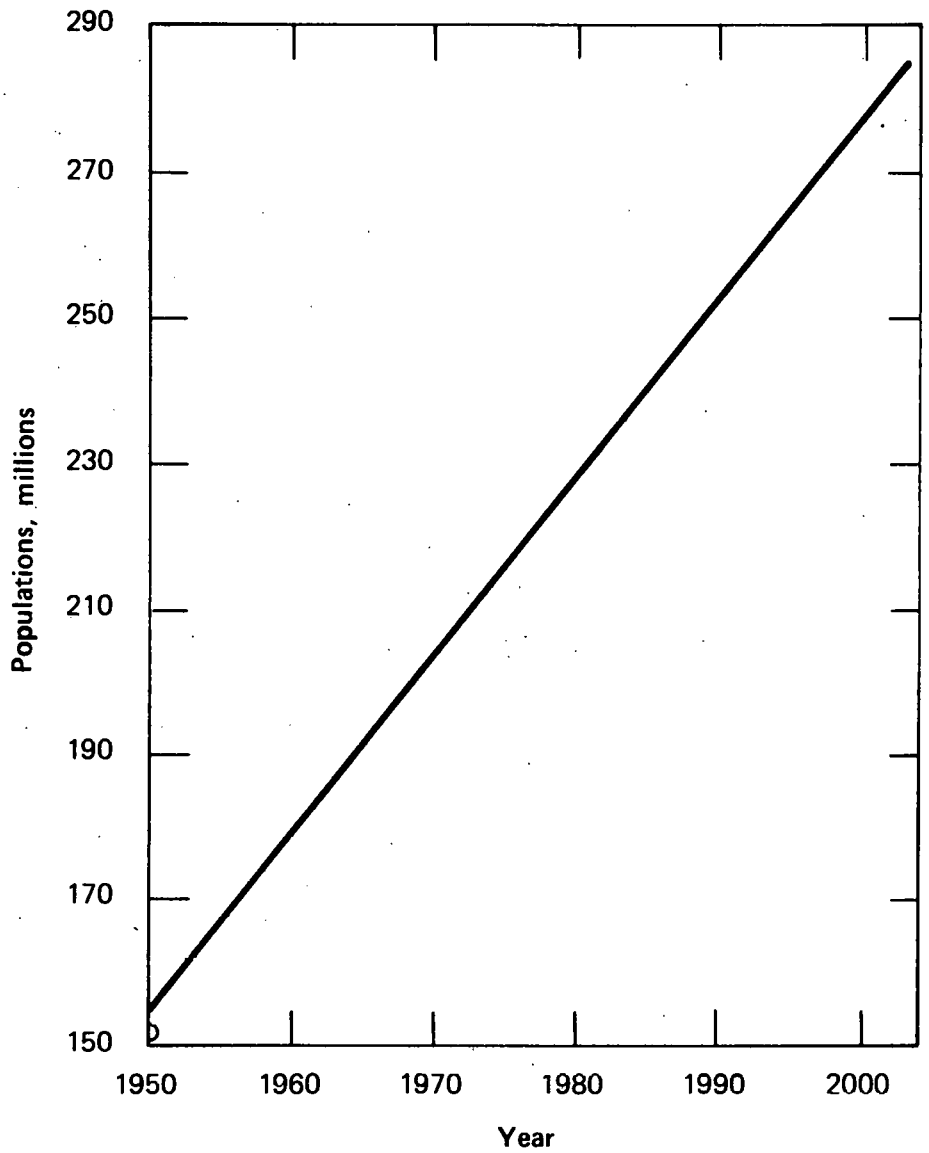

FIGURE 2. U.S. population growth

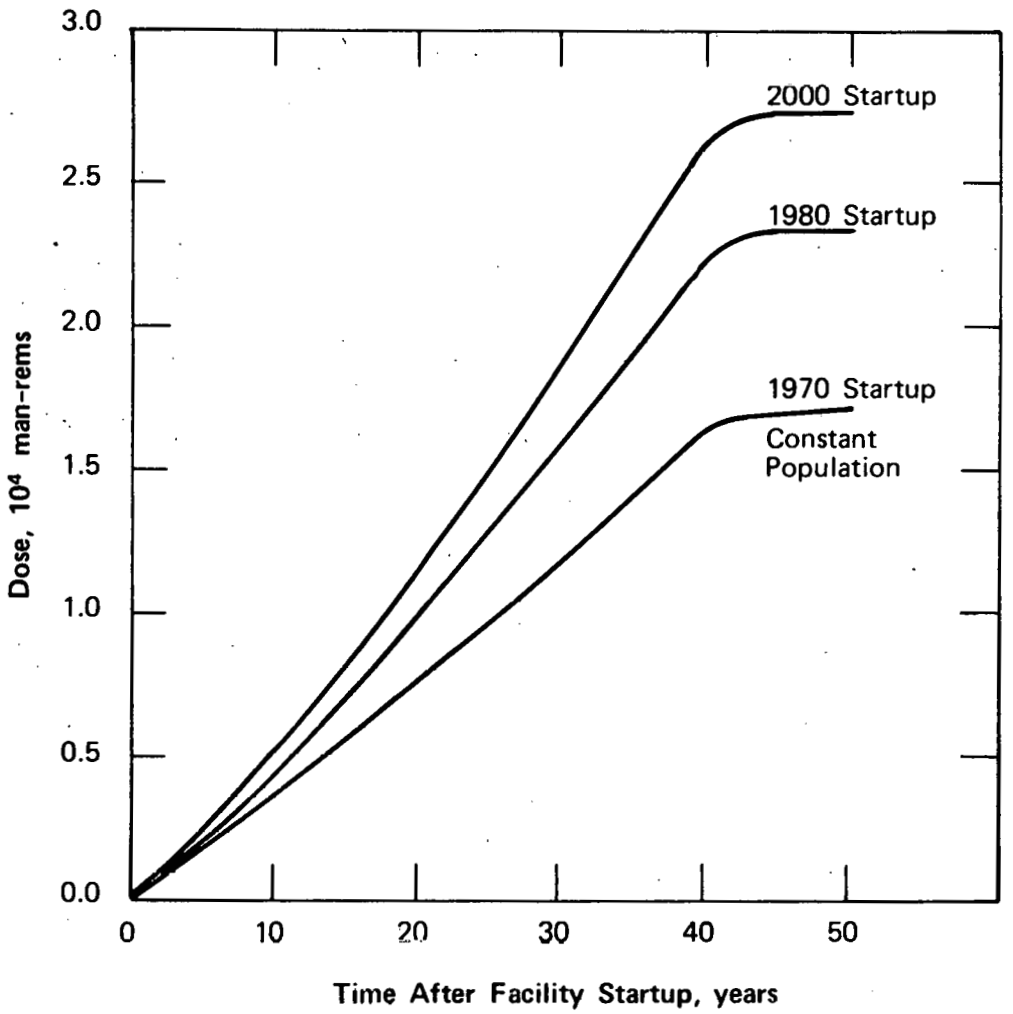

FIGURE 3. Cumulative whole body gamma dose from ground deposition to the population in the southeastern U.S.

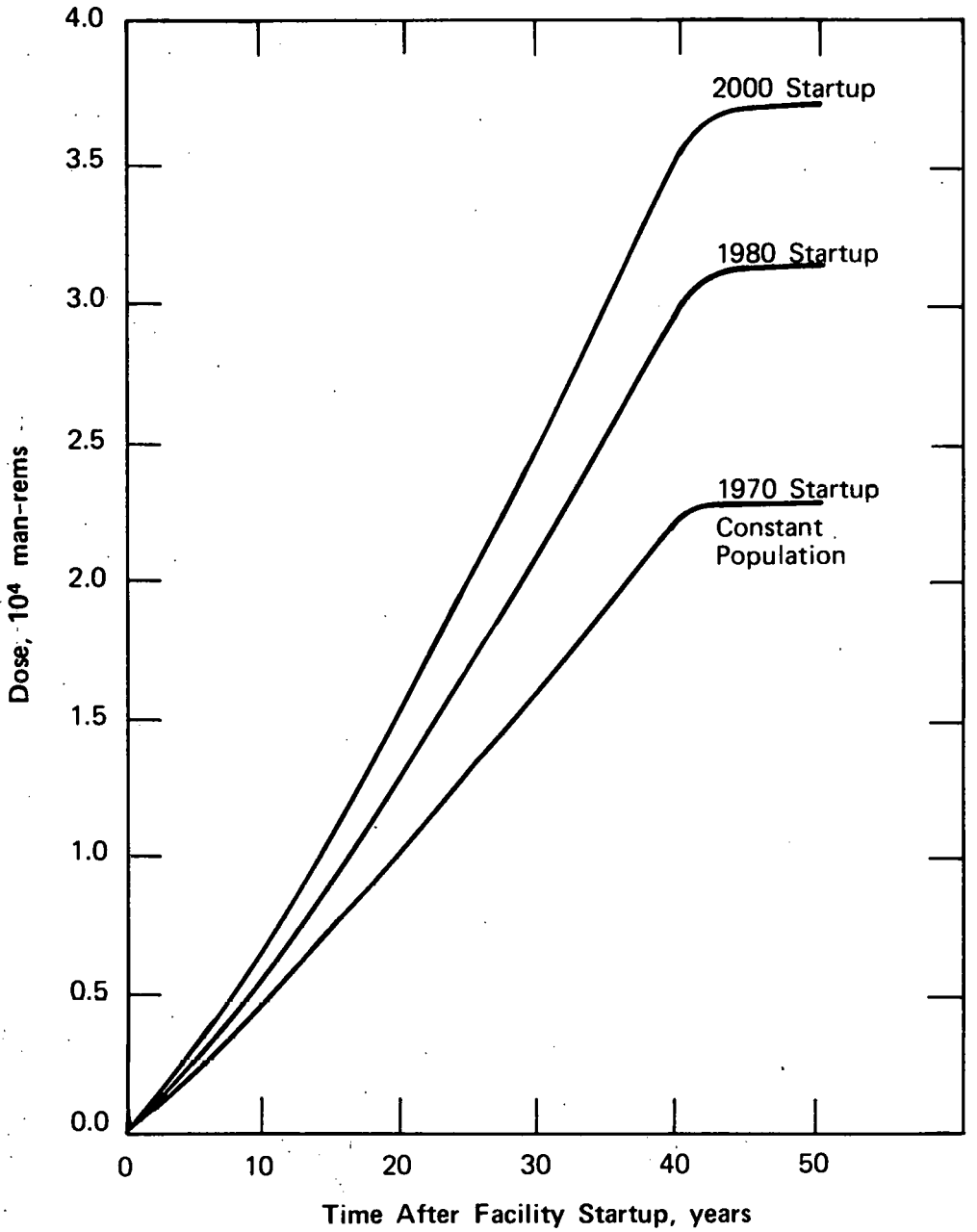

FIGURE 1. Cumulative whole body gamma dose from ground deposition to the U.S. population

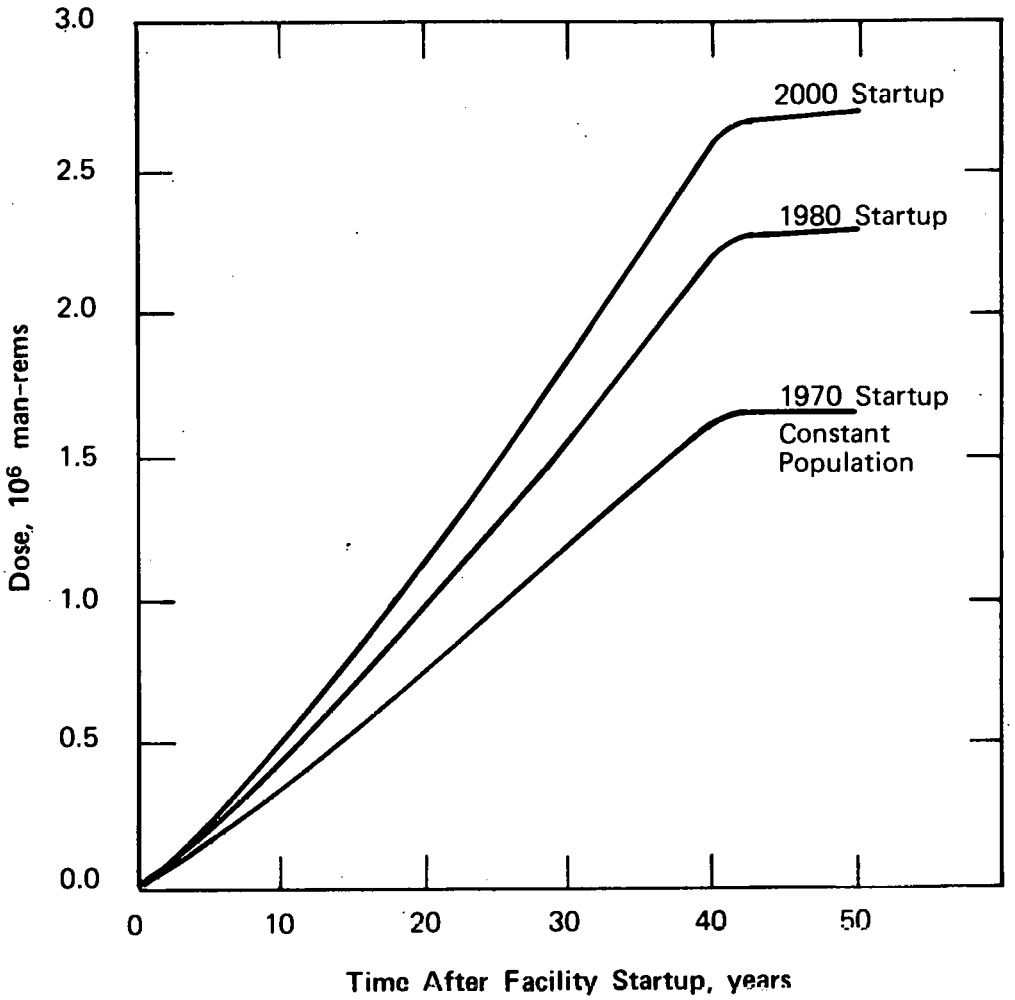

FIGURE 5. Cumulative beta skin dose from ground deposition to the population in the southeastern U.S.