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Subtask: HISTORICAL OFFSITE SPENT NUCLEAR FUEL SHIPMENTS

Title: SUMMARY OF DOSES AND HEALTH EFFECTS FROM HISTORICAL OFFSITE SPENT NUCLEAR FUEL SHIPMENTS TO THE SAVANNAH RIVER SITE

Summary:

Based on data contained in the Nuclear Materials Management and Safeguards System (NMMSS) data base, incident-free doses and health effects were established for historical offsite spent nuclear fuel shipments to the Savannah River Site. Onsite spent nuclear fuel shipments were not considered in this analysis because the public does not reside on the Savannah River Site. Consequently, doses to the population from onsite shipments would be very small when compared to doses to the general population from offsite shipments.

Spent nuclear fuel shipment data was available for 1970 through 1993. This data was linearly extrapolated to account for spent nuclear fuel shipments to the Savannah River Site for 1953 through 1969. 1953 was the start of operations at the Savannah River Site.

For workers, historical shipments yielded a collective dose of 49 person-rem or 0.019 cancer fatalities. For the general population, historical shipments yielded a collective dose of 25 person-rem or 0.013 cancer fatalities. Historical shipments also yielded 0.015 nonradiological fatalities.

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The number of shipments to the Savannah River Site was obtained from the Nuclear Materials Management and Safeguards System (NMMSS) (see Table 1). The NMMSS is responsible for maintaining and providing information regarding production and materials management, nuclear materials safeguards, and physical accountability for the U.S. Department of Energy, and for providing the U.S. Nuclear Regulatory Commission with information concerning nuclear materials control and accountability. Each facility that shipped or received spent nuclear fuel is assigned a code in the NMMSS; these codes are known as RIS codes in the NMMSS. Each kind of material that is shipped between facilities is also assigned a code in the NMMSS; these codes are known as COEI codes in the NMMSS. The COEI codes for various materials are at a finer level of detail than "spent nuclear fuel", therefore it was necessary to use several COEI codes to adequately capture spent nuclear fuel shipments in the NMMSS (see Table 2). The RIS codes, facilities, and locations are contained in Appendix A.

The distance traveled for each shipment was determined using the HIGHWAY computer code (Johnson et al. 1993), based on using the location identified by the RIS code as the origin and using the Savannah River Site, South Carolina as the destination. The output for the HIGHWAY computer code is contained in Appendix A.

The total shipment distance was used to calculate the occupational and general population (members of the public) doses and cancer fatalities and nonradiological deaths from the spent nuclear fuel shipments to the Savannah River Site. The total shipment distance was first divided into three components: (1) the total distance traveled in rural population zones, (2) the total distance traveled in suburban population zones, and (3) the total distance traveled in urban population zones. This was done by multiplying the total shipment distance by 80%, 17%, and 3% for rural, suburban, and urban, respectively. These percentages were based on average population statistics calculated for numerous transportation routes across the United States.

Radiological impacts were determined for crew workers and the general population during normal, incident-free transportation. For truck shipments, the crew were the drivers of the shipment vehicle. The general population was persons within 800 meters (2,625 feet) of the road (off-link), persons sharing the road (on-link), and persons at stops. It was assumed that all shipments were made by truck, since relatively few non-naval spent nuclear fuel shipments are made by train and truck shipments yield larger incident-free doses. Based on the analyses presented in Transportation of Naval Spent Nuclear Fuel (Attachment A to Appendix D of Volume 1 of the SNF and INEL EIS), the historical spent nuclear fuel shipments were assigned a dose rate of 1 mrem/hr at 1 m (3.28 ft) from the shipping container.

The calculation of the doses was based on the development of unit risk factors (URFs). URFs provide an estimate of the dose to an exposure group from transporting one shipment of radioactive material over a unit distance of travel in a given population density zone (rural, suburban, and urban). URFs have units of person-rem/km and may be combined with routing information, such as the total shipment distances in various population density zones, to determine the dose for a series of shipments between a given origin and destination.

The total distances traveled in the rural, suburban, and urban zones were then multiplied by unit risk factors (URFs) to provide an estimate of the dose from transporting the spent nuclear fuel over the total distance. URFs were developed based on travel within rural, suburban, and urban population zones, using RADTRAN 4 (Neuhauser and Kanipe 1992). Table 3 contains the URFs for truck and rail shipments for various exposure groups and population zones.

Occupational doses to the crew were calculated using the equations:

Dose (rural zone) = Occupational URF (rural zone) × Total Distance (rural zone)
Dose (suburban zone) = Occupational URF (suburban zone) × Total Distance (suburban zone)
Dose (urban zone) = Occupational URF (urban zone) × Total Distance (urban zone)
Total Dose = Dose (rural zone) + Dose (suburban zone) + Dose (urban zone)

For members of the public, doses were evaluated in the same manner:

Dose (rural zone) = General Population URF (rural zone) × Total Distance (rural zone)
Dose (suburban zone) = General Population URF (suburban zone) × Total Distance (suburban zone)
Dose (urban zone) = General Population URF (urban zone) × Total Distance (urban zone)
Total Dose = Dose (rural zone) + Dose (suburban zone) + Dose (urban zone)

Nonradiological health effects were also evaluated using URFs. The nonradiological URF for truck transport used in this analysis was 1.0E-7 health effects/km (Rao et al. 1982). This URF accounts for the health effects associated with emission of particulates and SO_2 and is only applicable to the urban population zone (Rao et al. 1982). The distance used in the nonradiological analyses must be doubled to reflect the round trip distance, because these impacts occur whether or not the shipment contains radioactive material:

Nonradiological Health Effects = Nonradiological URF × 2 × Total Distance (urban zone)

Radiological doses were converted to cancer fatalities using risk conversion factors of 5.0E-4 fatal cancers/person-rem for members of the public and 4.0E-4 cancer fatalities/person-rem for workers. These risk conversion factors are from Publication 60 of the International Commission on Radiological Protection (ICRP 1991).

Table 3 presents the results of the analyses for 1970 through 1993 for radiological and nonradiological impacts.

SUMMARY OF DOSES AND HEALTH EFFECTS

Occupational

The analyses in Table 3 estimated a dose of 28.0 person-rem for shipments of SNF to the Savannah River Site for 1970 through 1993 or 23 years (the data for 1993 did not extend to the end of the calendar year). To extrapolate this data back to 1953, the start of operations at the Savannah River Site, the doses for 1970 through 1993 were used to calculate the doses for 1953 through 1969.

28.0 person-rem ÷ 23 yr = 1.22 person-rem/yr
1.22 person-rem/yr × 17 yr = 20.7 person-rem
28.0 person-rem (1970-1993) + 20.7 person-rem (1953-1969) = 49 person-rem (1953-1993)
49 person-rem × 4E-4 cancer fatalities/person-rem = 0.019 cancer fatalities

General Population

The analyses in Table 3 estimated a dose of 14.5 person-rem for shipments of SNF to the Savannah River Site for 1970 through 1993 or 23 years (the data for 1993 did not extend to the end of the calendar year). To extrapolate this data back to 1953, the start of operations at the Savannah River Site, the doses for 1970 through 1993 were used to calculate the doses for 1953 through 1969.

14.5 person-rem ÷ 23 yr = 0.630 person-rem/yr
0.630 person-rem/yr × 17 yr = 10.7 person-rem
14.5 person-rem (1970-1993) + 10.7 person-rem (1953-1969) = 25 person-rem (1953-1993)
25 person-rem × 5E-4 cancer fatalities/person-rem = 0.013 cancer fatalities

Nonradiological

The analyses in Table 3 estimated 0.00884 nonradiological fatalities for shipments of SNF to the Savannah River Site for 1970 through 1993 or 23 years (the data for 1993 did not extend to the end of the calendar year). To extrapolate this data back to 1953, the start of operations at the Savannah River Site, the doses for 1970 through 1993 were used to calculate the doses for 1953 through 1969.

0.00884 fatalities ÷ 23 yr = 3.80E-4 fatalities/yr
3.80E-4 fatalities/yr × 17 yr = 0.00653 fatalities
0.00884 fatalities (1970-1993) + 0.00653 fatalities (1953-1969) = 0.015 fatalities (1953-1993)

References:

ICRP (International Commission on Radiological Protection), 1991, 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of the ICRP, Volume 21, No. 1-3, Pergamon Press, NY.

Johnson, P. E., D. S. Joy, D. B. Clarke, J. M. Jacobi, 1993, HIGHWAY 3.1 - An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual, ORNL/TM-12124.

Neuhauser, K. S., F. L. Kanipe, 1992, RADTRAN 4 User Guide, SAND89-2370.

Rao, R. K., E. L. Wilmot, R. E. Luna, 1982, Non-Radiological Impacts of Transporting Radioactive Material, SAND81-1703.

Table 1. OFFSITE SPENT NUCLEAR FUEL SHIPMENTS TO SAVANNAH RIVER BY YEAR AND GENERATOR[a] FOR 1970 THROUGH 1993

CODE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	NUMBER OF SHIPMENTS	DISTANCE PER SHIPMENT (KM)	SHIPMENT DISTANCE (KM)
RFP						3	4																		7	2618.3	18328.1
RFP	1			5	7	4																			17	2618.3	44511.1
ALE			1																						1	1450.0	1450.0
BCL						2																			2	1173.2	2346.4
ALISU						4		3	3																10	1905.4	19054.0
B&WVA			1																						1	700.0	700.0
ALE							3					4													7	1450.0	10150.0
BNL						12	6																		18	1458.0	26244.0
NFSNY		4																							4	1660.8	6643.2
NBL		1																							1	1300.3	1300.3
ORNL						17	21	12	25	17	21	21	20	12	39	2			1						208	614.8	127878.4
ORNL															10	14	53	4	22						103	614.8	63324.4
HEDL						4																			4	4404.7	17618.8
ICPP			5	15	8	4	1																		33	3733.6	123208.8
ICPP						2																			2	3733.6	7467.2
ICPP																			1						1	3733.6	3733.6
RRI							20	8	8	9	4			88	1										138	3947.6	544768.8
RRI									2																2	3947.6	7895.2
USA			3	1		8	2	4																	18	931.8	16772.4
WNTC													1						1						2	1543.3	3086.6
MIT																								6	6	1688.2	10129.2
AARL				1																					1	1688.2	1688.2
B&WVA													3												3	700.0	2100.0
USIS							2		2										9						13	960.8	12490.4
B&WVA																			1						1	700.0	700.0
BMI						1	2																		3	1153.9	3461.7
GIT						1																			1	331.5	331.5
IRL						4																			4	1248.8	4995.2
UKEA																	2								2	1689.8	3379.6
MIT						3																			3	1688.2	5064.6
UMES						1																			1	962.4	962.4
UMPML						1	1	1							5		1		2						11	1467.7	16144.7
MURR						1	1	1		5	3				3		3	3	3						23	1395.3	32091.9
NCSU										2									2						4	526.2	2104.8
OSUE																						1			1	1153.9	1153.9
RINSC						2											2								4	1638.3	6553.2
SFR								3			4	4	5	4	6	7	5	8	4	5	6	4	4	2	71	1419.4	100777.4
UVNE																	2		4						6	783.7	4702.2
VPI																	1								1	582.6	582.6
WPI																						1			1	1627.0	1627.0
FWSMFL							4	7	3																14	1179.6	16514.4
FSNNVA										5	1														6	846.5	5079.0
FWSNVA								3	44	25	33	32	22	2											161	803.0	129283.0
FWSONY							4		10		14		8												36	1675.3	60310.8
FWSRVA											1	1	2												4	758.0	3032.0
FWSSGA							1	2	1																4	426.5	1706.0
TOTAL	1	5	10	22	15	74	72	44	98	63	81	62	61	106	64	23	69	15	50	5	6	6	4	8	964		1473447.0

a. The generator codes are contained in Appendix A.

Table 2. COEI Codes Used to Denote Spent Nuclear Fuel in the NMMSS

COEI Code	Physical Description
253	Alloyed rough machined items feed
254	Unalloyed finish machined items feed
255	Alloyed finish machined items feed
256	In canning and cladding process
286	Finished machined items feed
290	In fuel element and target fabrication process, aluminum process, irradiated material
291	Fabricated fuel elements and targets, production, zirconium process
292	Electrolytic process, irradiated material
293	Graphite combined process, irradiated material
294	U-233 process, irradiated material
295	Combined aqueous process, irradiated material
296	Custom or special process, irradiated material
297	No planned process, irradiated material
352	Nitrate solutions
353	Acetate solutions
375	Irradiated recyclable fuel
385	Aluminum process, irradiated
386	Zirconium process, irradiated
387	Electrolytic process, irradiated
388	Graphite combined process, irradiated
389	U-233 process, irradiated
390	Fluorinel process, irradiated
391	Custom or special process, irradiated
392	No planned process, irradiated
405	In cooling, product feed
408	In separation process
409	Nitrate solutions product
410	Nitrate compounds product

Table 3. ESTIMATED DOSES AND DEATHS FROM HISTORICAL OFFSITE SPENT NUCLEAR FUEL SHIPMENTS[a] TO SAVANNAH RIVER

CALCULATED OCCUPATIONAL AND PUBLIC DOSES FOR 1970 TO 1993

	SHIPMENT DISTANCE (KM)	FRACTION PER AREA	FRACTIONAL DISTANCE (KM)	OCCUPATIONAL UNIT RISK FACTOR (PERSON-REM/KM)	PUBLIC UNIT RISK FACTOR (PERSON-REM/KM)	OCCUPATIONAL DOSE (PERSON-REM)	PUBLIC DOSE (PERSON-REM)
RURAL	1473447.0	0.80	1.179E+06	1.48E-05	8.96E-06	1.74E+01	1.06E+01
SUBURBAN	1473447.0	0.17	2.505E+05	3.26E-05	1.08E-05	8.17E+00	2.71E+00
URBAN	1473447.0	0.03	4.420E+04	5.43E-05	2.70E-05	2.40E+00	1.19E+00
TOTAL						2.80E+01	1.45E+01

CALCULATED NONRADIOLOGICAL DEATHS FOR 1970 TO 1993

	SHIPMENT DISTANCE (KM)	FRACTION FOR AREA	FRACTIONAL DISTANCE (KM)	UNIT RISK FACTOR (DEATHS/KM)	TRUCK ROUND TRIP[a]	NONRAD DEATHS
URBAN	1473447.0	0.03	4.420E+04	1.0E-07	2	8.84E-03

a. For nonradiological fatalities, the distance must be doubled to reflect the round trip distance.