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OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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UPDATED PROJECTIONS OF RADIOACTIVE WASTES TO BE GENERATED BY THE U.S. NUCLEAR POWER INDUSTRY

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ABSTRACT

Eleven types of radioactive wastes to be generated within the fuel cycle operations of the U.S. nuclear power industry are defined, and projections are presented of their annual generation rates, shipping requirements, and accumulated characteristics over the remainder of this century. The power reactor complex is assumed to consist of uranium- and plutonium-fueled LWRs, HTGRs, and LMFBRs, and the installed nuclear electric capacity of the U.S. is taken as 68.1, 252, and 510 GW at the ends of calendar years 1980, 1990, and 2000, respectively.

1. INTRODUCTION

Projections of the industrial radioactive wastes from the nuclear fuel cycle are useful in the planning and design of methods and facilities that will be needed for their future management, and for the assessment of potential environmental effects. Until recently, many design and planning studies were based on the waste projections published in Projections of Radioactive Wastes to be Generated by the U.S. Nuclear Power Industry, ORNL-TM-3965 (February 1974).[1] However, as a result of changes in the projected growth of installed nuclear electric capacity and in the types and characteristics of the reactors, of changes in fuel cycle strategies and waste management technology, and of increased interest in waste types not included in previous projections (viz., ^{14}C), more current and comprehensive projections are required. The present study was made to fulfill this need.

In this study, the "Mid Case" forecast[2] of nuclear power growth in the United States as developed by ERDA's Office of Assistant Administrator for Planning and Analysis (APA) was used (Table 1.1). This case assumes a kilowatt-hour growth-rate of 5.8% per year through 1985, and 4.75% per year through 2000. Additional APA assumptions are as follows:

1. Fast breeder reactors will be commercially introduced in 1995 and will achieve 6% of the installed nuclear capacity by 2000.
2. HTGRs will increase to 2% of the non-breeder market during the 1990's.
3. LWRs will constitute the remainder of the market with two-thirds as PWRs and one-third as BWRs.
4. Fuel reprocessing begins in 1981.
5. Plutonium recycle begins in 1983 with 25% of the plutonium inventory, increases to 50% of the inventory in 1984, and to 75% in 1985. It is recycled without constraint thereafter.
6. Nuclear reactor capacity factors are:
   1st year of operation - 40%
   2nd and 3rd year of operation - 65%
   4th through 15th years of operation - 70%
   16th through 40th years of operation - declines 2 percentage points per year to 40%.

Six types of nuclear reactors are considered in these projections: uranium-enriched PWR (PWR-U); plutonium-enriched PWR (PWR-Pu); uranium-enriched BWR (BWR-U); plutonium-enriched BWR (BWR-Pu); LMFBR; and HTGR.

To estimate the future magnitude of waste management operations, fuel cycle process flowsheets were constructed, assuming present and near-future technology, and eleven types of radioactive wastes were defined on the basis of their packaging, shipping, and probable disposal requirements. Finally, annual rates of generation, annual numbers of shipments, and accumulations of each type of waste through the end of

Table 1.1. Projected nuclear operating capacity, GW(e)

YEAR	LWR	HTGR	LMFBR	TOTAL
1970	5.0	0.0	0.0	5.0
1971	8.0	0.0	0.0	8.0
1972	10.0	0.0	0.0	10.0
1973	15.0	0.0	0.0	15.0
1974	23.0	0.0	0.0	23.0
1975	32.1	0.0	0.0	32.1
1976	44.0	0.0	0.0	44.0
1977	49.2	0.3	0.0	49.5
1978	55.4	0.3	0.0	55.7
1979	59.8	0.3	0.0	60.1
1980	67.8	0.3	0.0	68.1
1981	78.4	0.3	0.0	78.7
1982	90.2	0.3	0.0	90.5
1983	105.6	0.3	0.0	105.9
1984	126.4	0.3	0.0	126.7
1985	146.1	0.3	0.4	146.8
1986	166.1	0.3	0.4	166.8
1987	186.1	0.3	0.4	186.8
1988	207.1	0.3	0.4	207.8
1989	229.1	0.3	0.4	229.8
1990	250.2	0.3	1.3	251.8
1991	273.2	0.3	1.3	274.8
1992	296.2	0.3	1.3	297.8
1993	320.2	0.3	1.3	321.8
1994	344.2	0.3	1.3	345.8
1995	367.2	1.3	2.3	370.8
1996	389.2	2.3	4.3	395.8
1997	409.5	4.0	8.3	421.8
1998	429.5	6.0	14.0	449.5
1999	449.5	8.0	22.0	479.5
2000	468.1	10.0	32.0	510.1

this century were calculated. A summary of these projections for the year 2000 is presented in Table 1.2.

As a matter of possible interest, the characteristics of the principal fuel cycle wastes on the basis of the production of 1000 MW-years of electricity by LWRs (50% PWRs and 50% BWRs) fueled with approximately 1/3 mixed (U-Pu) oxide elements and 2/3 enriched UO_2 elements are given in Table 1.3.

2. ASSUMED NUCLEAR REACTOR CHARACTERISTICS

Tables 2.1 and 2.2 present the major reactor characteristics which were assumed in these waste projections. These two tables represent middle-of-reactor-life mass flows only. Beginning- and end-of-reactor-life mass flows are accounted for in the projections of nuclear fuel management that are presented in Section 3, but are not taken into account here.

2.1 Light Water Reactors

The physical and operational (e.g., specific power) characteristics of the reference light water reactors were taken from PWR and BWR standard safety analysis reports.[3,4] Isotopic buildup and depletion in the four types of LWRs are based on charge and discharge data given in Ref. 5 for the following isotopes: ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{242}Am, ^{243}Am, ^{242}Cm, ^{243}Cm, and ^{244}Cm. This represents a substantial improvement over the LWRs used in previous waste projections, which were based on charge and discharge data for only ^{235}U, ^{238}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu.

An additional improvement over previous waste projections is the explicit inclusion of both uranium- and plutonium-enriched BWRs. Pertinent reactor and fuel cycle characteristics were obtained from Refs. 4 and 5.

The fractions of the plutonium-recycle LWRs (PWR-Pu and BWR-Pu) that are assumed to be plutonium-enriched are based on equating the second-cycle fissile plutonium discharged to the third-cycle fissile

Table 1.2. Fuel cycle wastes projected for the year 2000

Category of wastes	Annual generation		Annual shipments	Total accumulated at repository		
	Volume (10^3 m^3)	Activity (MCi)		Volume (10^3 m^3)	Activity (MCi)	Metric tons of actinides
High-level solidified	0.88	24,000	200[a,b]	2.2	5,900	150
Transuranium wastes						
Cladding hulls	0.78	86	450[b,c]	4.5	260	31
Int.-level solid	3.9	1.3	1,350[c,d]	20	5.8	0.16
Low-level solid	12	10	250[c,b]	58	37	4.5
Non-TRU wastes						
Noble gases	0.029[f]	73	110[b,e]	0.29[f]	550	—
Iodine	0.013	0.00034	49[e,d]	0.13	0.0033	—
Carbon-14	—	0.005	—	—	0.058	—
LWR tritium (water)	65	0.3	4,100[e,d]	730	2.4	—
FP tritium (solidified)	0.094	4.9	350[e,d]	0.91	36	—
Low-level solid	260	0.92	19,000[e,d]	2,700	3.2	—
Ore tailings	20,000	0.24	—	300,000	3.4	48,000

[a] Shipped 10 years after generation.

[b] Rail shipments are assumed.

[c] Shipped 5 years after generation.

[d] Truck shipments are assumed.

[e] Shipped 1 year after generation.

[f] Pressurized at 2200 psi.

Table 1.3. Fuel cycle wastes from the production of 1000 MW-years of electricity[a]

Category of waste	Volume (m^3)	Activity[b] (MCi)	Thermal power[b] (kW)	Number of shipments
Transuranium wastes				
High-level solidified	3.1	170	960	2
Cladding hulls	2.7[c]	2.0	10.1	2
Int.-level solid	140[d]	0.012	0.057	66
Low-level solid	480[d]	0.049	0.04	17
Non-TRU wastes				
Noble gases	0.1	0.25	0.37	0.4
Iodine	0.05	1×10^{-6}	—	0.2
Carbon-14	—	2×10^{-5}	—	—
LWR tritium (water)	140	6×10^{-4}	—	9
FP tritium (solidified)	0.35	0.018	7×10^{-4}	1
Low-level solid	2400[d]	0.002	0.007	180
Ore tailings	42,000	5×10^{-4}	0.011	—

[a] Mixed (U-Pu) oxide-fueled LWRs.

[b] Activity and thermal power at time of waste generation.

[c] Compacted to 70% of theoretical density.

[d] Uncompacted volume.

Table 2.1 Assumed characteristics of light water reactors

	PWR-U	PWR-Pu			BWR-U	BWR-Pu		
		U fraction	Pu fraction	Total		U fraction	Pu fraction	Total
Electric power, MW(e)	1250	811	439	1250	1250	776	474	1250
Thermal power, MW(t)	3800	2465	1335	3800	3800	2359	1441	3800
Avg. specific power[a], MW(t)/ton heavy metal	37.5	37.5	37.5	37.5	25.9	25.9	25.9	25.9
Avg. fuel burnup, MWd/ton heavy metal	33,000	33,000	33,000	33,000	27,500	27,500	27,500	27,500
Irradiation duration, full-power days	880	880	880	880	1062	1062	1062	1062
Steady-state charge, kg								
^{235}U	1081	701	81	782	943	585	95	680
Total U	33,778	21,915	11,323	33,238	36,680	22,771	13,364	36,135
Fissile Pu[b]	0	0	345	345	0	0	338	338
Total Pu[c]	0	0	539	539	0	0	546	546
Total heavy metal	33,778	21,915	11,862	33,777	36,680	22,771	13,910	36,681
Steady-state discharge, kg								
^{235}U	272	176	37	213	244	151	46	197
Total U	32,261	20,931	11,031	31,962	35,278	21,901	13,077	34,978
Fissile Pu[b]	222	144	201	345	220	137	201	338
Total Pu[c]	316	205	378	583	315	196	389	585
Total (U + Pu)	32,577	21,136	11,409	32,545	35,593	22,097	13,466	35,563

[a]Based upon full power and fuel charged.

[b]$^{239}Pu + {}^{241}Pu$.

[c]$^{238}Pu + {}^{239}Pu + {}^{240}Pu + {}^{241}Pu + {}^{242}Pu$.

Table 2.2 Assumed characteristics of the HTGR and the A.I. Follow-On LMFBR

	HTGR				A.I. Follow-On LMFBR			
	Th-^{233}U	Fresh ^{235}U makeup	Recycled ^{235}U makeup	Total	Core	Axial blanket	Radial blanket	Total
Electric power, MW(e)	807	409	34	1250	1147	39	64	1250
Thermal power, MW(t)	2087	1058	87	3232	2748	94	153	2995
Avg. specific power[a], MW(t)/ton heavy metal	55.1	584	203	80.5	115	5.71	7.90	50.25
Avg. fuel burnup, MWd/ton heavy metal	64,210	682,260	238,040	93,972	67,100	3330	13,270	37,137
Irradiation duration, full-power days	1167	1167	1167	1167	583	583	1680	—
Steady-state charge, kg								
Th	9087	0	0	9087	0	0	0	0
^{233}U	234	0	0	234	0	0	0	0
^{235}U	32	419	23	474	20	16	6.7	43
Total U	386	453	107	946	9850	8213	3352	21,415
Fissile Pu[b]	0	0	0	0	1461	0	0	1461
Total Pu[c]	0	0	0	0	2077	0	0	2077
Total heavy metal	9473	453	107	10,033	11,927	8213	3352	23,492
Steady-state discharge, kg								
Th	8427	0	0	8427	0	0	0	0
^{233}U	211	0	0	211	0	0	0	0
^{235}U	40	23	1.4	64	11	14	4.4	29
Total U	384	108	65	557	9037	8049	3165	20,251
Fissile Pu[b]	0	1.6	1.6	3.1	1344	129	132	1605
Total Pu[c]	0	7.0	7.3	14	2017	132	139	2288
Total (Th + U + Pu)	8811	115	72	8998	11,054	8181	3304	22,539

[a] Based on full power and fuel charged.

[b] $^{239}Pu + ^{241}Pu$.

[c] $^{238}Pu + ^{239}Pu + ^{240}Pu + ^{241}Pu + ^{242}Pu$.

plutonium charged (i.e., equilibrium fissile plutonium recycle is assumed). Then, given a required fissile plutonium enrichment (2.91 wt % fissile plutonium in PWRs and 2.43 wt % fissile plutonium in BWRs), the percentage of the fuel which is plutonium-enriched was calculated to be 35.1% for the PWR-Pu and 37.9% for the BWR-Pu. This procedure results in the total plutonium discharged in the second cycle being slightly greater than the total plutonium charged in the third cycle for both the PWR-Pu and BWR-Pu. This effect is unavoidable since the second and third plutonium recycles are not equilibrium recycles, and the total plutonium (including the fissile fraction) discharge is increasing with each cycle.

2.2 High-Temperature Gas-Cooled Reactor

The reference HTGR is based upon design studies of an 1160-MW(e) HTGR that uses annual refueling (at 80% capacity factor) of approximately one-fourth of the core.[6,7] Recycle of ^{235}U is assumed to begin in the third reload. The ^{235}U from the fissile makeup particles is assumed to be reprocessed separately from the ^{233}U-thorium particles and recycled one time before discard. This recycle of partially burned ^{235}U particles is also assumed to begin in the third reload.

2.3 A. I. Follow-On LMFBR

The assumed characteristics of the Atomics International (A. I.) Follow-On LMFBR are taken from normalized data developed by Argonne National Laboratory.[8]

3. PROJECTIONS OF NUCLEAR FUEL MANAGEMENT

The nuclear generating capacity and mass flow information presented in the previous sections were employed in the KWIKPLAN code[9] to derive a schedule of requirements for the nuclear fuel cycle. The assumed processing steps, lag times, and losses were the same as those employed by the Fuel Recycle Task Force[10] with exceptions that the LWR, HTGR, and LMFBR fuels were assumed to be reprocessed after post-irradiation decay times of 160, 250, and 90 days, respectively. The data used by

KWIKPLAN were schedules of installed nuclear power capacity, on-stream fuel reprocessing plant capacity, and the fuel mass flows for the reference reactors. The installed capacities and reprocessing rates were taken from the APA study,[2] while the fuel mass-flow data were taken from the reactor models presented in Tables 2.1 and 2.2.

The reactor models were described in KWIKPLAN as a year-by-year schedule of reactor operating capacity factors, and the fuel charged and discharged from each reactor during its 40-year operating life. The code then calculated the uranium and thorium mining requirements, the utilization of fissile materials, and reactor fuel fabrication and reprocessing loads. The increased fabrication and reprocessing requirements that result from the initial startup and final shutdown of each reactor were taken into account.

Table 3.1 presents a summary of the computed annual requirements for mining of uranium and thorium and the production and utilization of fissile plutonium, ^{233}U, and highly enriched uranium. The requirements for mining of uranium are based upon a tails assay in uranium enrichment of 0.3% ^{235}U and makes allowance for the recycle for reenrichment of uranium that contains greater than 0.4% ^{235}U. The annual "production" of fissile materials is defined as the annual quality that is placed in a stockpile following reprocessing. The quantities in the columns labeled "used" are the annual quantities withdrawn from this stockpile. Also included with the ^{233}U are relatively small quantities of ^{235}U that are produced in HTGR fertile particles.

Table 3.2 presents the derived annual loads of the several types of fuel fabrication plants expressed in terms of metric tons of total heavy metal. The fabrication load for plutonium recycle to light water reactors includes only those portions of the fuel assemblies that are fueled with mixed oxide (about 35 to 38% of the total in the core).

Table 3.1 Metric tons of U, Th, and Pu consumed, produced, and stockpiled annually

Year	Ore Mined		Fissile Plutonium			* * * * U-233 * * * *			93 Percent	40 Percent U-235		
	U	Th	Prod.	Used	Net	Prod.	Used	Net	U-235 Used	Prod.	Used	Net
1970	2636	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	2488	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	4605	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	7371	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	8815	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	11540	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	9462	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	10505	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	10400	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	13431	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	16112	2	0.0	0.0	0.0	0.03	0.0	0.03	0.0	0.0	0.0	0.0
1981	17679	2	2.38	0.0	2.38	0.06	0.03	0.06	0.0	0.0	0.0	0.0
1982	21193	2	7.28	2.40	7.26	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1983	25871	2	7.97	5.60	9.63	0.05	0.06	0.06	0.0	0.0	0.0	0.0
1984	28085	2	8.69	13.11	5.20	0.06	0.05	0.06	0.0	0.0	0.0	0.0
1985	30536	2	12.19	13.88	3.51	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1986	32765	2	19.26	13.88	8.89	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1987	36255	2	20.21	17.50	11.59	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1988	39178	2	25.58	14.80	22.37	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1989	39837	2	31.74	20.65	33.46	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1990	41822	2	34.76	33.38	34.84	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1991	43646	2	42.59	44.57	32.86	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1992	47038	2	45.31	50.09	28.08	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1993	50994	2	53.68	49.52	32.24	0.06	0.06	0.06	0.0	0.0	0.0	0.0
1994	53366	35	61.69	43.16	50.77	0.06	0.06	0.06	1.00	0.0	0.0	0.0
1995	54370	40	72.77	51.10	72.44	0.05	0.06	0.06	2.00	0.0	0.0	0.0
1996	55588	69	78.21	64.42	86.22	0.05	0.05	0.06	3.00	0.0	0.0	0.0
1997	58069	89	88.07	72.48	101.80	0.05	0.05	0.06	5.00	0.0	0.0	0.0
1998	60964	102	94.63	79.76	116.68	0.13	0.05	0.14	6.00	0.0	0.0	0.0
1999	63806	114	93.66	85.52	124.82	0.30	0.13	0.31	7.00	1.00	0.0	1.00
2000	65358	127	97.95	85.97	136.80	0.53	0.30	0.53	7.00	1.00	1.00	1.00

Table 3.2. Metric tons of fuel fabricated annually

Year	PWR-U	PWR-Pu	BWR-U	BWR-Pu	HTGR	LMFBR	Total
1970	139	0	231	0	0	0	370
1971	156	0	281	0	0	0	437
1972	220	0	387	0	0	0	607
1973	357	0	668	0	0	0	1026
1974	587	0	770	0	0	0	1357
1975	1014	0	620	0	0	0	1635
1976	1120	0	565	0	6	0	1691
1977	1109	0	527	0	7	0	1642
1978	1209	0	541	0	2	0	1752
1979	1244	0	805	0	2	0	2052
1980	1436	0	1113	0	2	0	2552
1981	1785	0	1109	0	2	0	2896
1982	2125	56	1137	32	2	0	3352
1983	2464	132	1490	73	2	0	4161
1984	2548	293	1881	160	2	18	4902
1985	2812	315	2066	184	2	5	5383
1986	3200	312	2117	188	2	5	5824
1987	3458	394	2275	237	2	5	6372
1988	3895	332	2542	200	2	5	6977
1989	4119	447	2666	269	2	27	7529
1990	4192	732	2711	439	2	33	8108
1991	4306	1000	2790	600	2	17	8716
1992	4552	1127	2936	676	2	18	9310
1993	4941	1113	3171	668	2	18	9913
1994	5437	945	3457	567	19	42	10467
1995	5594	1076	3544	645	39	96	10995
1996	5632	1292	3550	775	58	187	11493
1997	5838	1361	3643	816	84	298	12039
1998	6081	1334	3826	799	102	486	12628
1999	6402	1263	3998	756	115	670	13203
2000	6724	1028	4274	616	129	887	13658

Table 3.3 gives the projected fuel reprocessing load, or the quantity of spent fuel that will be discharged each year. The projected schedule of fuel actually reprocessed is given in Table 3.4. The indicated backlog of 1365 tons of heavy metal as spent fuel in inventory at the end of 1975 (Table 3.4) was taken from a recent survey.[11] This table includes the estimated low-exposure fuels from reactor startup cycles as well as scrap that is recycled from fuel fabrication. According to this schedule, the backlog of unreprocessed spent fuel will not be worked off until near the end of this century.

In considering the delay in reprocessing, it was assumed that fuels from demonstration HTGRs and LMFBRs would be reprocessed by ERDA pilot plant facilities. Since mixed oxide LWR fuels contain greater amounts of fissile plutonium, they were assumed to be reprocessed preferentially to UO_2 fuels. The UO_2 fuels were reprocessed from the backlog on a first-in, first-out basis since this would allow reprocessing plants to work with older feedstocks during the earlier years of operation.

Table 3.5 is essentially a table of megawatt-days of exposure represented by the fuel reprocessed in a given year since it presents the equivalent tons of fuel having the rated steady-state exposures. These data were used to develop estimates of the radiation properties of aggregates of spent fuel and wastes based upon calculated properties of the spent fuel at the rated steady-state exposures as determined with the ORIGEN[12] code.

Since spent fuel may be stored for an extended time before reprocessing occurs, calculations were made of the number of LWR fuel assemblies to be discharged and accumulated (if reprocessing was not available) through the year 2000 (Table 3.6). This calculation assumes 461.4 kg of heavy metal and 183.35 kg of heavy metal per PWR and BWR assembly, respectively.[3,4] Again, the number of assemblies accumulated by the end of 1975 were taken from ERDA-76-25.[11]

Table 3.3. Annual reprocessing load (Metric Tons)

YEAR	LWR	HTGR	LMFBR	TOTAL
1970	59	0	0	59
1971	95	0	0	95
1972	156	0	0	156
1973	217	0	0	217
1974	301	0	0	301
1975	459	0	0	459
1976	663	0	0	663
1977	897	0	0	897
1978	1088	0	0	1088
1979	1228	2.2	0	1230
1980	1356	2.2	0	1358
1981	1507	2.3	0	1509
1982	1733	2.3	0	1735
1983	1991	2.1	0	1993
1984	2296	2.1	0	2298
1985	2717	2.1	0	2719
1986	3197	2.1	4.8	3203
1987	3675	2.1	4.7	3681
1988	4141	2.1	5.1	4148
1989	4620	2.1	5.1	4628
1990	5124	2.1	5.1	5131
1991	5620	2.1	16.5	5639
1992	6121	2.1	16.2	6140
1993	6640	2.1	17.1	6659
1994	7166	2.0	17.1	7185
1995	7700	2.0	17.1	7719
1996	8220	1.9	26.6	8249
1997	8712	8.6	48.5	8769
1998	9167	14.9	93.1	9275
1999	9595	26.6	157.1	9779
2000	9993	40.0	256.6	10290

Table 3.4. Fuel reprocessed (Metric Tons)

YEAR	LWR	HTGR	LMFBR	TOTAL	BACKLOG
1975	0	0	0	0	1365
1976	0	0	0	0	2029
1977	0	0	0	0	2926
1978	0	0	0	0	4014
1979	0	2	0	2	5241
1980	0	2	0	2	6597
1981	500	2	0	502	7603
1982	1500	2	0	1502	7836
1983	1500	2	0	1502	8327
1984	1500	2	0	1502	9123
1985	2000	2	0	2002	9840
1986	3000	2	5	3007	10036
1987	3000	2	5	3007	10711
1988	3500	2	5	3507	11352
1989	4500	2	5	4507	11472
1990	5000	2	5	5007	11597
1991	6000	2	17	6019	11217
1992	6500	2	16	6518	10838
1993	7500	2	17	7519	9978
1994	8000	2	17	8019	9143
1995	9100	2	17	9119	7743
1996	9600	2	27	9628	6364
1997	11000	9	49	11057	4076
1998	12000	15	93	12108	1242
1999	10838	27	157	11021	0
2000	9993	40	257	10290	0

Table 3.5. Metric tons of fuel reprocessed annually at rated exposure

Year	PWR-U	PWR-Pu	BWR-U	BWR-Pu	HTGR	LMFBR
1979	0	0	0	0	1	0
1980	0	0	0	0	1	0
1981	182	0	166	0	2	0
1982	494	0	574	0	2	0
1983	628	0	543	0	2	0
1984	772	0	533	0	2	0
1985	1162	0	675	0	2	0
1986	1704	53	929	31	2	3
1987	1602	126	865	70	2	3
1988	1757	280	923	154	2	4
1989	2286	301	1191	177	2	5
1990	2551	298	1369	181	2	5
1991	3058	377	1685	229	2	12
1992	3436	318	1917	193	2	13
1993	3950	427	2211	259	2	15
1994	4015	699	2257	423	2	18
1995	4420	956	2484	578	2	18
1996	4598	1076	2582	651	2	23
1997	5462	1063	3081	643	4	37
1998	6264	903	3562	546	8	67
1999	5490	1028	3139	622	15	115
2000	4800	1235	2753	746	25	191

Table 3.6. Number of LWR spent fuel assemblies discharged

Year	Annual number discharged			Total number discharged		
	BWR	PWR	Total	BWR	PWR	Total
1975	1494	401	1896	4404	1321	5725
1976	1814	555	2370	6218	1877	8095
1977	2124	979	3104	8342	2856	11198
1978	2435	1390	3825	10777	4247	15023
1979	2524	1657	4181	13301	5904	19205
1980	2596	1906	4502	15896	7810	23707
1981	2933	2100	5033	18830	9910	28740
1982	3548	2346	5894	22377	12256	34633
1983	4024	2717	6741	26401	14972	41374
1984	4445	3210	7654	30846	18182	49028
1985	5231	3809	9040	36077	21991	58068
1986	6391	4388	10779	42467	26379	68847
1987	7520	4976	12496	49987	31355	81343
1988	8453	5616	14069	58441	36971	95412
1989	9422	6270	15692	67863	43241	111104
1990	10445	6955	17400	78308	50196	128504
1991	11436	7637	19072	89744	57833	147576
1992	12441	8323	20764	102185	66155	168340
1993	13498	9026	22524	115683	75181	190864
1994	14575	9739	24313	130258	84920	215178
1995	15669	10462	26131	145927	95382	241308
1996	16730	11168	27897	162656	106549	269206
1997	17729	11837	29566	180386	118386	298772
1998	18656	12454	31109	199041	130840	329881
1999	19519	13040	32559	218560	143880	362440
2000	20361	13567	33928	238921	157447	396368

4. ORIGIN, NATURE, AND PROJECTIONS OF FUEL CYCLE WASTES

There are many important aspects bearing on waste management that are in evolutionary stages of development. While much research and development work has been done, there remains a shortage of commercial plant operating experience upon which estimates of future performance can be reliably based. This is especially true of those operations that will generate most of the wastes: fuel preparation, fabrication, and reprocessing. We have nevertheless attempted in this section to derive definitions of "typical" wastes and estimate their generation rates by drawing on available operating experience at both ERDA and commercial facilities, and from the results of research and development work, much of which is still in progress.

The characteristics of radioactive wastes from the nuclear fuel cycle, the factors that influence their generation, and the bases used for projecting future quantities were discussed in ORNL/TM-3965.[1] This information is summarized below with our new projections. For comparative purposes, the principal assumptions used for the waste projections of ORNL/TM-3965 and those used for this study are listed in Table 4.1.

4.1 High-Level Wastes

High-level wastes are defined in federal regulations[13] as "those aqueous wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, in a facility for reprocessing irradiated reactor fuels." These wastes contain virtually all of the nonvolatile fission products, several tenths of one percent of the uranium and plutonium originally in the spent fuels, and all the other actinides formed by transmutation of the uranium and plutonium in the reactors. They can be generally characterized by their very intense, penetrating radiation and their high heat-generation rates. Regulations call for these wastes to be solidified within 5 years after they are generated and for the resultant stable solids to be shipped to a federal repository within 10 years after the liquids are generated.[13]

Table 4.1. Comparison of principal assumptions used for waste projections

Category of waste	ORNL/TM-3965 (Ref. 1)	This report
High-level solidified waste	2 ft^3/ton[a] heavy metal (LWR) 6 ft^3/ton heavy metal (HTGR) 3 ft^3/ton heavy metal (LMFBR)	3 ft^3/ton heavy metal (LWR) 6 ft^3/ton heavy metal (HTGR) 3 ft^3/ton heavy metal (LMFBR)
Cladding hulls (compacted)	2.3 ft^3/ton heavy metal (LWR) 8.7 ft^3/ton heavy metal (LMFBR)	2.3 ft^3/ton heavy metal (PWR) 2.9 ft^3/ton heavy metal (BWR) 8.7 ft^3/ton heavy metal (LMFBR)
Intermediate-level solid TRU	10,000 ft^3/ton Pu (reprocessing)	10,000 ft^3/ton Pu (reprocessing)
Low-level solid TRU	10,000 ft^3/ton Pu (preparation) 20,000 ft^3/ton Pu (fabrication) 4,000 ft^3/ton Pu (reprocessing)	10,000 ft^3/ton Pu (preparation) 20,000 ft^3/ton Pu (fabrication) 4,000 ft^3/ton Pu (reprocessing)
Noble gases (Kr + Xe)	693 g-atoms/cylinder	693 g-atoms/cylinder
Iodine	Storage as KI, 587 g-atoms/ft^3	Storage in concrete, 40.4 g-atoms/ft^3
Carbon-14	—	25 ppm nitrogen in oxide fuels 30 ppm nitrogen in HTGR graphite
LWR tritiated water	20,000 gal/year per GW(e) installed capacity	36,600 gal/year per GW(e) installed capacity
FP tritium	Fixed as $Ca(OH)_2$, ~1500 Ci/ft^3	Fixed as $Ca(OH)_2$, ~1500 Ci/ft^3
Low-level solid non-TRU	40,000 ft^3/ton Pu (preparation) 80,000 ft^3/ton Pu (fabrication) 16,000 ft^3/ton Pu (reprocessing) 4,000 ft^3/year per GW(e), LWRs, HTGRs 2,000 ft^3/year per GW(e), LMFBRs Prep., fab., reproc., wastes: 0.001 Ci/ft^3 Reactor wastes: 1 Ci/ft^3	40,000 ft^3/ton Pu (preparation) 80,000 ft^3/ton Pu (fabrication) 16,000 ft^3/ton Pu (reprocessing) 15,000 ft^3/year per GW(e) Prep., fab., reproc., wastes: 0.001 Ci/ft^3 Reactor wastes: 1971-85, 0.1 Ci/ft^3 1986-90, 0.2 Ci/ft^3 1991-2000, 0.3 Ci/ft^3
Ore Tailings	Mining requirements based on U enrichment tails 0.2% ^{235}U Mill tailings: 0.16 yd^3/lb U_3O_8 or ThO_2	Mining requirements based on U enrichment tails 0.3% ^{235}U Mill tailings: 0.16 yd^3/lb U_3O_8 or ThO_2

[a] In this table, "ton" is used to mean metric ton.

4.1.1 Fuel Reprocessing[1]

In the reprocessing of LWR fuels, a chop-leach head-end method was used, followed by a standard Purex solvent extraction procedure for separating the uranium and plutonium and subsequently purifying the uranium, followed by an amine extraction for the final purification of plutonium. Soluble poisons were not used for criticality control during dissolution.

The flowsheet for reprocessing HTGR fuel was based on methods being developed at Gulf General Atomic, Allied Chemical Corporation at Idaho Falls, Idaho, and ORNL.[14] The fuel block is crushed prior to burning the graphite in a fluidized bed. The burning step is carried out in two parts: (1) an exothermic burning mode with heat evolution, and (2) an endothermic mode with heat addition. The residual fuel particles are separated from each other by screening, and the ^{235}U (recycle) particles constitute a solid waste which is not processed further. The fertile ThO_2-$^{233}UO_2$ (recycle) particles are dissolved and, after clarification, are purified by a modified Thorex solvent-extraction process.[15] The ^{235}U (makeup) particles are crushed in a roll grinder to fracture the silicon carbide coating, and the residual carbon is burned off in an exothermic burner. After dissolution and clarification, the ^{235}U is recovered using a TBP-25 solvent-extraction process flowsheet.[16]

The flowsheet for reprocessing LMFBR mixed core and blanket fuel was also based on developmental work still in progress. Following a mechanical disassembly of the fuel element and separation of hardware that has only induced activity associated with it, the fuel tubes are sheared and heated to about 400°C in an oxygen atmosphere for removal of volatile fission products (voloxidation).[17] The oxide fuel is then leached from the stainless steel cladding with nitric acid, and the uranium and plutonium are then recovered by a modified Purex solvent extraction process. The primary flowsheet relied on concentration and geometry for criticality control, and an alternative flowsheet used boron as a soluble poison for this purpose.

4.1.2 Waste Volumes

Estimated characteristics of the residues obtained from evaporating and heating aqueous wastes to 900°C are given in Ref. 1. In addition to the solids obtained from solidifying the individual waste streams derived from the flowsheets, solidification of several combinations of these streams is considered. Based on the flowsheets described above, the combined volumes of solidified reprocessing wastes (excluding cladding) should lie in the neighborhood of 1 to 2 ft^3 per ton of LWR fuel, 4 to 6 ft^3 per ton of HTGR fuel, and 1 to 3 ft^3 per ton of LMFBR fuel. Recent development work indicates that the volume of solidified high-level waste from LWR fuel reprocessing will probably be between 1 and 3 ft^3 per ton of fuel.[18] Although waste management economics will tend to force the final volumes toward smaller values, additional wastes not considered here arising from maloperations, equipment decontamination, etc., will tend to increase them. Similarly, possible future requirements for higher-quality waste products (less leachable in water, more radiation-resistant) will also probably result in higher volumes of waste per ton of fuel processed. It is for these reasons that we believe the upper-limit volumes of 3 ft^3, 6 ft^3, and 3 ft^3 of solidified high-level waste per ton of fuel processed are the most realistic and, consequently, should be used for planning and design studies at this time.

4.1.3 Radiation Characteristics of High-Level Wastes

Appendix A presents the calculated radioactivity and thermal power in high-level wastes generated by reprocessing one metric ton of each of the six types of spent reactor fuels. The tables summarize the curies of fission-product and actinide isotopes as a function of time (years) following reprocessing. In these tables, the columns labeled "discharge" refer to the times when the wastes are first generated at the reprocessing plant and correspond to post-irradiation decay times of 160, 250, and 90 days for the spent LWR, HTGR, and LMFBR fuels, respectively. All of the tritium and noble-gas fission products, and 99.9% of the iodine and bromine fission products are excluded from the tables on the basis that these

elements will be separated from the high-level wastes during the head-end reprocessing steps. Also, the levels of actinides in the wastes are based on the assumption that 0.5% of the uranium and plutonium in the LWR and LMFBR fuels, 0.5% of the thorium and uranium in the HTGR fuel, and 100% of all other actinides in the fuels at the time of reprocessing report to the high-level waste.

4.1.4 High-Level Waste Projections

The activity of fission product and actinide isotopes, the thermal power from radioactive decay, and the volumes (assuming immediate solidification) of the high-level wastes generated annually by LWRs, HTGRs, and LMFBRs through the year 2000 are presented in Tables 4.2 through 4.4.

The volume, mass, radioactivity, and toxicity of all high-level wastes accumulated annually through the year 2000 are given in Table 4.5. The activity and thermal power added annually in this table are those at the end of the year. This table includes wastes in storage at reprocessing plants as well as any which have been shipped to federal repositories. The toxicity of the mixture is determined by summing the amount of water or air required to dilute each individual isotope to the maximum level specified in the Radiation Concentration Guide[19] as acceptable for unrestricted use.

Although solidification of industrial high-level wastes has not as yet been practiced, indications are that these materials may be packaged in steel canisters typically 1 ft in diam by 10 ft long and then shipped to a repository after having first been stored at the reprocessing plants for 10 years. Studies of conceptually designed shipping systems for these wastes[20,21] show that as many as 12 such canisters (each containing 6.28 ft^3 of 10-year-old solidified waste) could be shipped by rail in iron- or lead-shielded casks weighing in the neighborhood of 100 tons. Based on these assumptions, the activity, thermal power, and volume of the 10-year-old wastes that will be shipped annually are given in Tables 4.6, 4.7, and 4.8, respectively. The number of solidified waste containers to be

Table 4.2. Radioactivity (MCi) in high-level wastes generated annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1979	0	4	0	4
1980	0	8	0	8
1981	1535	12	0	1546
1982	4709	14	0	4723
1983	5167	13	0	5180
1984	5753	13	0	5766
1985	8105	13	0	8118
1986	12031	13	26	12070
1987	11849	13	32	11894
1988	13957	13	41	14012
1989	17686	13	50	17750
1990	19644	13	50	19707
1991	23898	13	113	24024
1992	26118	13	126	26258
1993	30548	13	148	30709
1994	33184	12	169	33365
1995	37997	12	169	38178
1996	40161	12	221	40393
1997	46075	25	353	46454
1998	50471	47	642	51160
1999	46178	92	1103	47373
2000	43054	155	1840	45049

Table 4.3. Thermal power (kW) in high-level wastes generated annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1979	0	20	0	20
1980	0	37	0	37
1981	7219	54	0	7273
1982	22151	66	0	22216
1983	24305	60	0	24364
1984	27062	60	0	27122
1985	38126	60	0	38186
1986	57579	60	113	57751
1987	58032	60	138	58229
1988	70729	60	179	70968
1989	88780	60	217	89057
1990	97993	60	217	98270
1991	119484	60	488	120032
1992	128821	60	547	129428
1993	151712	60	643	152414
1994	169205	57	730	169992
1995	196651	57	730	197438
1996	209092	54	955	210101
1997	236666	114	1531	238311
1998	254344	217	2783	257343
1999	236490	422	4781	241692
2000	225660	710	7973	234342

Table 4.4. Cubic meters of solidified high-level wastes generated annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1979	0	0.4	0	0.4
1980	0	0.4	0	0.4
1981	42	0.4	0	43
1982	127	0.4	0	128
1983	127	0.4	0	128
1984	127	0.4	0	128
1985	170	0.4	0	170
1986	255	0.4	0.4	256
1987	255	0.4	0.4	256
1988	297	0.4	0.4	298
1989	382	0.4	0.4	383
1990	425	0.4	0.4	425
1991	509	0.4	1.4	511
1992	552	0.4	1.4	554
1993	637	0.4	1.5	639
1994	679	0.3	1.5	681
1995	773	0.3	1.5	774
1996	815	0.3	2.3	818
1997	934	1.5	4.1	940
1998	1019	2.5	7.9	1029
1999	920	4.5	13.3	938
2000	848	6.8	21.8	877

Table 4.5. Projected annual accumulations of solidified high-level wastes without shipment

Year	* * * * Annual Addition * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	* * * * * Accumulation Through End of Year * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	Hazard, Cubic Meters at RCG Air	Water
1979	0.00	0.0	3	0	0.00	0.0	3	0	1.8E 16	8.5E 11
1980	0.00	0.0	5	0	0.00	0.1	7	0	4.7E 16	2.3E 12
1981	0.04	2.8	788	4	0.04	2.9	792	4	5.6E 18	1.2E 14
1982	0.13	8.4	2359	12	0.17	11.3	2757	13	2.1E 19	4.5E 14
1983	0.13	8.5	2644	13	0.30	19.8	4086	20	3.6E 19	7.8E 14
1984	0.13	8.5	2991	15	0.43	28.4	5275	25	5.2E 19	1.1E 15
1985	0.17	11.4	4260	21	0.60	39.8	7338	35	7.5E 19	1.6E 15
1986	0.26	17.3	6361	31	0.85	57.0	10687	51	1.3E 20	2.4E 15
1987	0.26	17.5	6276	31	1.11	74.5	12575	60	1.9E 20	3.0E 15
1988	0.30	20.8	7410	38	1.41	95.4	15104	73	3.1E 20	3.8E 15
1989	0.38	26.6	9383	48	1.79	122.0	18771	91	4.3E 20	4.7E 15
1990	0.43	29.4	10397	53	2.22	151.4	22115	107	5.6E 20	5.8E 15
1991	0.51	35.4	12653	64	2.73	186.8	26674	129	7.2E 20	7.0E 15
1992	0.55	38.1	13817	69	3.28	224.8	30802	148	8.6E 20	8.4E 15
1993	0.64	44.1	16158	82	3.92	268.9	36045	172	1.0E 21	1.0E 16
1994	0.68	47.8	17557	90	4.60	316.7	40964	197	1.3E 21	1.2E 16
1995	0.77	54.9	20095	104	5.38	371.6	46997	227	1.7E 21	1.3E 16
1996	0.82	58.2	21263	111	6.19	429.8	52285	253	2.0E 21	1.5E 16
1997	0.94	66.3	24441	126	7.13	496.1	59365	287	2.4E 21	1.8E 16
1998	1.03	71.8	26892	137	8.16	567.9	66663	320	2.7E 21	2.0E 16
1999	0.94	66.2	24894	128	9.10	634.1	69818	334	3.0E 21	2.2E 16
2000	0.88	62.8	23665	123	9.98	696.9	71809	343	3.4E 21	2.4E 16
TIME AFTER SHUTDOWN, YEARS										
100					9.98	696.9	3042.3	11.9	5.6E 20	1.8E 15
300					9.98	696.9	95.6	1.7	3.1E 20	2.5E 13
1000					9.98	696.9	27.2	0.7	1.3E 20	4.9E 12
3000					9.98	696.9	13.8	0.3	6.8E 19	1.8E 12
10000					9.98	696.9	8.7	0.2	4.5E 19	1.1E 12
30000					9.98	696.9	3.9	0.1	2.1E 19	4.7E 11
100000					9.98	696.9	2.0	0.0	4.1E 18	3.7E 11
300000					9.98	696.9	1.5	0.0	2.6E 18	4.6E 11
1000000					9.98	696.9	0.8	0.0	2.7E 18	2.7E 11

Table 4.6. Radioactivity (MCi) in 10-year-old high-level wastes shipped annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1989	0	1	0	1
1990	0	1	0	1
1991	109	2	0	111
1992	336	2	0	338
1993	368	2	0	370
1994	410	2	0	412
1995	578	2	0	580
1996	859	2	1	862
1997	848	2	1	851
1998	1003	2	1	1006
1999	1270	2	2	1273
2000	1409	2	2	1413
2001	1715	2	4	1721
2002	1871	2	4	1877
2003	2190	2	5	2197
2004	2386	2	6	2394
2005	2737	2	6	2744
2006	2895	2	7	2904
2007	3316	4	12	3332
2008	3624	8	21	3653
2009	3322	15	36	3373
2010	3106	25	61	3191

Table 4.7. Thermal power (kW) in 10-year-old high-level wastes shipped annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1989	0	3	0	3
1990	0	5	0	5
1991	379	7	0	386
1992	1164	9	0	1172
1993	1277	8	0	1285
1994	1422	8	0	1429
1995	2003	8	0	2011
1996	3233	8	3	3243
1997	3534	8	3	3545
1998	4789	8	4	4801
1999	5845	8	5	5858
2000	6331	8	5	6343
2001	7773	8	11	7791
2002	8028	8	12	8048
2003	9666	8	14	9688
2004	11663	7	16	11687
2005	14122	7	16	14146
2006	15254	7	21	15282
2007	16650	15	34	16699
2008	16944	28	62	17034
2009	16502	55	107	16663
2010	16751	92	178	17021

Table 4.8. Cubic meters of 10-year-old high-level wastes shipped annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1989	0	0.4	0	0.4
1990	0	0.4	0	0.4
1991	42	0.4	0	43
1992	127	0.4	0	128
1993	127	0.4	0	128
1994	127	0.4	0	128
1995	170	0.4	0	170
1996	255	0.4	0.4	256
1997	255	0.4	0.4	256
1998	297	0.4	0.4	298
1999	382	0.4	0.4	383
2000	425	0.4	0.4	425
2001	509	0.4	1.4	511
2002	552	0.4	1.4	554
2003	637	0.4	1.5	639
2004	679	0.3	1.5	681
2005	773	0.3	1.5	774
2006	815	0.3	2.3	818
2007	934	1.5	4.1	940
2008	1019	2.5	7.9	1029
2009	920	4.5	13.3	938
2010	848	6.8	21.8	877

shipped annually and the number of shipments are presented in Tables 4.9 and 4.10. The annual and cumulative properties (volume, mass, radioactivity, thermal power, and toxicity) of the solidified high-level wastes accumulated at one or more federal repositories are presented in Table 4.11. The number of annual shipments is also shown.

The accumulated mass, radioactivity, thermal power, and ingestion toxicity of the solidified high-level wastes as a function of time following the year 2010 are summarized in Tables 4.12 through 4.15 for actinides, and in Tables 4.16 through 4.19 for fission products.

4.2 Fuel Element Structural Materials (Cladding Wastes)

Fuel element structural materials are comprised of the Zircaloy, stainless steel, Inconel, and other miscellaneous materials which comprise the structure of a fuel assembly. These materials remain in the fuel dissolver after the fuel itself has been as completely dissolved as is possible. Although their radioactivity arises mainly from neutron-induced isotopes, the structural materials are similar in some respects to high-level waste in that they may contain up to 0.1% of the plutonium originally in the spent fuel, need biological shielding equivalent to several inches of lead, and have heat-generation rates of 50 to 100 W/ft^3.

The mass, volume, and assumed exposure of the residual structural materials from one metric ton of PWR, BWR, and LMFBR fuel are summarized in Table 4.20. The percentage exposure reflects the fact that the structural material, which is not in close proximity to the fuel itselt, (e.g., the stainless steel end fittings in LWRs) is exposed to a reduced flux level as compared to the cladding. This results in less activation of these components.

The neutron-induced radioactivity and thermal power of the major nuclides in the irradiated structural materials associated with one metric ton of LWR and LMFBR fuels are given in Appendix B for the five reactor types assumed. In addition to induced activity, the cladding

Table 4.9. Number of 10-year-old high-level waste canisters shipped annually

YEAR	LWR	HTGR	LMFBR	TOTAL
1989	0	2	0	2
1990	0	2	0	2
1991	239	2	0	241
1992	717	2	0	719
1993	717	2	0	719
1994	717	2	0	719
1995	955	2	0	957
1996	1433	2	2	1437
1997	1433	2	2	1437
1998	1672	2	2	1676
1999	2150	2	2	2154
2000	2389	2	2	2393
2001	2866	2	8	2876
2002	3105	2	8	3115
2003	3583	2	8	3593
2004	3822	2	8	3832
2005	4347	2	8	4357
2006	4586	2	13	4600
2007	5255	8	23	5286
2008	5732	14	45	5791
2009	5177	25	75	5278
2010	4774	38	123	4935

Table 4.10. Number of annual 10-year-old high-level waste shipments

YEAR	LWR	HTGR	LMFBR	TOTAL
1989	0.0	0.2	0.0	0.2
1990	0.0	0.2	0.0	0.2
1991	19.9	0.2	0.0	20.1
1992	59.7	0.2	0.0	59.9
1993	59.7	0.2	0.0	59.9
1994	59.7	0.2	0.0	59.9
1995	79.6	0.2	0.0	79.8
1996	119.4	0.2	0.2	119.8
1997	119.4	0.2	0.2	119.8
1998	139.3	0.2	0.2	139.7
1999	179.1	0.2	0.2	179.5
2000	199.0	0.2	0.2	199.4
2001	238.9	0.2	0.7	239.7
2002	258.8	0.2	0.6	259.6
2003	298.6	0.2	0.7	299.4
2004	318.5	0.2	0.7	319.3
2005	362.3	0.2	0.7	363.1
2006	382.2	0.2	1.1	383.4
2007	437.9	0.7	1.9	440.5
2008	477.7	1.2	3.7	482.6
2009	431.4	2.1	6.3	439.8
2010	397.8	3.2	10.2	411.2

Table 4.11. Projected annual accumulation of solidified high-level waste at a federal repository

Year	* * * * Annual Addition * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	Annual Number of Shipments	* * * * * Accumulation Through End of Year * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	Hazard, Cubic Meters at RCG Air	Water
1989	0.00	0.0	0.70	0.0	0	0.00	0.0	1	0.0	1.8E 17	5.7E 11
1990	0.00	0.0	1.30	0.0	0	0.00	0.1	2	0.0	5.2E 17	1.6E 12
1991	0.04	2.8	98.58	0.3	20	0.04	2.9	100	0.3	3.9E 18	6.8E 13
1992	0.13	8.4	295.33	1.0	60	0.17	11.3	392	1.4	1.3E 19	2.6E 14
1993	0.13	8.5	328.36	1.1	60	0.30	19.8	706	2.4	2.3E 19	4.8E 14
1994	0.13	8.5	369.35	1.3	60	0.43	28.4	1052	3.6	3.5E 19	7.1E 14
1995	0.17	11.4	523.62	1.8	80	0.60	39.8	1541	5.3	5.0E 19	1.0E 15
1996	0.26	17.3	776.19	2.8	120	0.85	57.0	2267	7.8	8.4E 19	1.5E 15
1997	0.26	17.5	761.04	2.8	120	1.11	74.5	2955	10.4	1.3E 20	2.0E 15
1998	0.30	20.8	889.91	3.5	140	1.41	95.4	3752	13.5	2.1E 20	2.5E 15
1999	0.38	26.6	1129.59	4.4	180	1.79	122.0	4765	17.4	3.0E 20	3.2E 15
2000	0.43	29.4	1254.50	4.8	199	2.22	151.4	5872	21.6	3.9E 20	3.9E 15
2001	0.51	35.4	1524.95	5.9	240	2.73	186.8	7218	26.8	5.1E 20	4.8E 15
2002	0.55	38.1	1671.22	6.3	260	3.28	224.8	8670	32.1	6.1E 20	5.8E 15
2003	0.64	44.1	1950.81	7.5	299	3.92	268.9	10361	38.5	7.4E 20	6.9E 15
2004	0.68	47.8	2105.11	8.5	319	4.60	316.7	12156	45.6	9.3E 20	8.0E 15
2005	0.77	54.9	2400.41	9.9	363	5.38	371.6	14196	53.9	1.2E 21	9.3E 15
2006	0.82	58.2	2534.48	10.6	383	6.19	429.8	16312	62.7	1.4E 21	1.1E 16
2007	0.94	66.3	2922.20	11.9	441	7.13	496.1	18756	72.5	1.7E 21	1.2E 16
2008	1.03	71.8	3226.40	12.7	483	8.16	567.9	21435	82.7	1.9E 21	1.4E 16
2009	0.94	66.2	2963.86	12.0	440	9.10	634.1	23776	91.9	2.2E 21	1.6E 16
2010	0.88	62.8	2783.93	11.7	411	9.98	696.9	25877	100.6	2.5E 21	1.7E 16
TIME AFTER SHUTDOWN, YEARS											
100						9.98	696.9	2422.5	9.8	5.3E 20	1.4E 15
300						9.98	696.9	88.6	1.7	3.1E 20	2.2E 13
1000						9.98	696.9	27.0	0.7	1.3E 20	4.8E 12
3000						9.98	696.9	13.8	0.3	6.8E 19	1.8E 12
10000						9.98	696.9	8.7	0.2	4.5E 19	1.1E 12
30000						9.98	696.9	3.9	0.1	2.1E 19	4.7E 11
100000						9.98	696.9	2.0	0.0	4.1E 18	3.8E 11
300000						9.98	696.9	1.5	0.0	2.6E 18	4.7E 11
1000000						9.98	696.9	0.8	0.0	2.7E 18	2.8E 11

Table 4.12. Grams of accumulated heavy elements in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
HE	1.05E 05	2.64E 05	3.55E 05	5.21E 05	6.92E 05	9.99E 05	1.79E 06	4.14E 06
TL	3.37E-07	4.39E-07	3.95E-07	3.82E-07	3.73E-07	3.72E-07	1.27E-06	2.77E-06
PB	2.00E 01	2.59E 01	3.35E 01	5.62E 01	1.60E 02	1.41E 03	1.28E 05	1.45E 06
BI	1.36E-02	4.25E-02	2.47E-01	3.30E 00	5.22E 01	1.35E 03	3.56E 05	1.59E 07
PO	1.30E-06	2.95E-05	2.10E-04	3.07E-03	2.48E-02	1.48E-01	1.18E 00	2.45E-01
AT	1.26E-13	7.74E-13	2.41E-12	1.18E-11	6.99E-11	5.51E-10	1.11E-08	2.74E-08
RN	2.95E-07	1.31E-06	7.48E-06	9.00E-05	7.26E-04	4.33E-03	3.44E-02	7.16E-03
FR	1.30E-08	3.34E-08	4.89E-08	1.35E-07	6.66E-07	5.07E-06	1.02E-04	2.51E-04
RA	2.79E-02	1.96E-01	1.16E 00	1.40E 01	1.13E 02	6.75E 02	5.37E 03	1.12E 03
AC	4.47E-01	9.87E-01	1.01E 00	9.93E-01	9.58E-01	8.61E-01	1.08E 00	1.74E 00
TH	3.64E 05	3.64E 05	3.65E 05	3.68E 05	3.78E 05	4.14E 05	7.57E 05	1.02E 06
PA	1.55E 03	1.55E 03	1.54E 03	1.52E 03	1.47E 03	1.30E 03	1.18E 03	1.49E 03
U	5.12E 08	5.12E 08	5.13E 08	5.14E 08	5.17E 08	5.24E 08	5.54E 08	5.58E 08
NP	6.44E 07	6.68E 07	7.06E 07	7.74E 07	8.07E 07	8.12E 07	7.96E 07	5.94E 07
PU	1.18E 07	1.70E 07	1.69E 07	1.74E 07	1.90E 07	2.12E 07	3.12E 06	1.30E 05
AM	4.35E 07	4.11E 07	3.66E 07	2.80E 07	2.07E 07	1.09E 07	3.19E 03	1.33E 00
CM	7.89E 06	1.87E 06	1.70E 06	1.60E 06	1.34E 06	7.23E 05	3.58E 03	2.94E 03
BK	1.20E-04	1.80E-14	1.78E-14	1.73E-14	1.60E-14	1.21E-14	3.36E-16	9.02E-32
CF	4.69E 00	3.71E 00	2.55E 00	7.16E-01	3.94E-02	1.28E-04	1.19E-11	3.21E-27
TOTALS	6.40E 08	6.40E 08	6.40E 08	6.40E 08	6.40E 08	6.40E 08	6.40E 08	6.40E 08

Table 4.13. Curies of accumulated heavy isotopes in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
TL207	3.33E 01	7.18E 01	7.32E 01	7.22E 01	6.95E 01	6.15E 01	5.60E 01	7.06E 01
TL209	4.49E-03	2.77E-02	8.62E-02	4.23E-01	2.50E 00	1.97E 01	3.99E 02	9.81E 02
PB209	2.04E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
PB210	6.22E-03	1.33E-01	9.49E-01	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
PB211	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
PB214	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
BI210	6.23E-03	1.33E-01	9.49E-01	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
BI211	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
BI213	2.04E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
BI214	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
PO210	5.88E-03	1.33E-01	9.49E-01	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
PO213	2.00E-01	1.23E 00	3.83E 00	1.88E 01	1.11E 02	8.76E 02	1.77E 04	4.36E 04
PO214	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
PO215	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
PO218	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
AT217	2.04E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
RN219	3.34E.01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
RN222	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
FR221	2.04E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
RA223	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
RA225	2.03E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
RA226	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
AC225	2.04E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
AC227	3.26E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
TH227	3.27E 01	7.10E 01	7.24E 01	7.14E 01	6.88E 01	6.08E 01	5.53E 01	6.98E 01
TH229	2.00E-01	1.26E 00	3.92E 00	1.92E 01	1.14E 02	8.96E 02	1.81E 04	4.46E 04
TH230	2.77E 00	5.80E 00	1.85E 01	7.94E 01	2.60E 02	8.60E 02	5.28E 03	1.10E 03
TH231	7.92E 00	7.94E 00	7.99E 00	8.19E 00	9.08E 00	1.46E 01	6.57E 01	7.08E 01
TH234	1.70E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02
PA231	7.38E 01	7.36E 01	7.33E 01	7.24E 01	6.97E 01	6.17E 01	5.61E 01	7.08E 01
PA233	4.59E 04	4.71E 04	4.98E 04	5.46E 04	5.69E 04	5.73E 04	5.61E 04	4.19E 04
PA234M	1.70E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02
U233	1.02E 02	1.22E 02	1.63E 02	3.20E 02	7.97E 02	2.46E 03	1.98E 04	4.45E 04
U234	1.34E 03	5.27E 03	8.74E 03	1.05E 04	1.06E 04	1.04E 04	8.08E 03	8.02E 02
U235	7.92E 00	7.94E 00	7.99E 00	8.19E 00	9.08E 00	1.46E 01	6.57E 01	7.08E 01
U236	1.14E 02	1.21E 02	1.36E 02	1.88E 02	3.18E 02	6.09E 02	8.85E 02	8.62E 02
U238	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02	1.69E 02
NP237	4.54E 04	4.71E 04	4.98E 04	5.46E 04	5.69E 04	5.73E 04	5.61E 04	4.19E 04
NP239	5.19E 06	5.14E 06	5.04E 06	4.73E 06	3.95E 06	2.09E 06	6.10E 02	2.56E-01
PU238	1.86E 07	1.03E 07	3.41E 06	1.10E 05	1.17E 01	1.60E-13		
PU239	2.07E 05	2.21E 05	2.49E 05	3.40E 05	5.60E*05	9.81E 05	1.50E 05	2.56E-01
PU240	1.40E 06	2.68E 06	2.65E 06	2.47E 06	2.01E 06	9.82E 05	9.64E 01	3.51E-03
PU241	4.72E 07	6.83E 05	2.72E 05	2.56E 05	2.17E 05	1.20E 05	6.35E 01	
PU242	2.11E 03	2.26E 03	2.42E 03	2.56E 03	2.70E 03	2.94E 03	2.62E 03	5.05E 02
AM241	5.49E 07	4.82E 07	3.51E 07	1.16E 07	6.88E 05	1.20E 05	6.35E 01	
AM242M	5.16E 06	3.27E 06	1.31E 06	5.39E 04	5.90E 00	8.08E-14		
AM242	5.16E 06	3.27E 06	1.31E 06	5.39E 04	5.90E 00	8.08E-14		
AM243	5.18E 06	5.14E 06	5.04E 06	4.73E 06	3.95E 06	2.09E 06	6.10E 02	2.56E-01
CM242	4.24E 06	2.68E 06	1.08E 06	4.42E 04	4.85E 00	6.64E-14		
CM243	4.36E 05	5.00E 04	6.57E 02	1.71E-04	2.62E-23			
CM244	4.97E 08	1.08E 07	5.09E 03	2.33E-08	3.26E-08	1.05E-07	9.54E-07	4.57E-06
CM245	2.78E 05	2.76E 05	2.71E 05	2.56E 05	2.16E 05	1.20E 05	6.32E 01	
CM246	5.28E 04	5.20E 04	5.05E 04	4.56E 04	3.40E 04	1.21E 04	2.15E-02	4.78E-25
TOTAL	6.45E 08	9.29E 07	5.59E 07	2.48E 07	1.18E 07	6.67E 06	4.94E 05	4.99E 05

Table 4.14. Watts of accumulated heavy isotopes in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
TL207	1.01E-01	2.17E-01	2.21E-01	2.18E-01	2.10E-01	1.86E-01	1.69E-01	2.13E-01
TL209	7.35E-05	4.53E-04	1.41E-03	6.91E-03	4.09E-02	3.22E-01	6.52E 00	1.60E 01
PB209	2.35E-04	1.45E-03	4.51E-03	2.21E-02	1.31E-01	1.03E 00	2.08E 01	5.13E 01
PB210	2.58E-07	5.52E-06	3.94E-05	5.75E-04	4.64E-03	2.77E-02	2.20E-01	4.57E-02
PB211	1.12E-01	2.41E-01	2.45E-01	2.42E-01	2.33E-01	2.06E-01	1.88E-01	2.37E-01
PB214	5.60E-05	4.68E-04	2.80E-03	3.38E-02	2.72E-01	1.63E 00	1.29E 01	2.6°E 00
BI210	1.64E-05	3.50E-04	2.50E-03	3.65E-02	2.94E-01	1.76E 00	1.40E 01	2.90E 00
BI211	1.30E 00	2.80E 00	2.86E 00	2.82E 00	2.72E 00	2.40E 00	2.19E 00	2.76E 00
BI213	1.26E-03	7.73E-03	2.41E-02	1.18E-01	6.99E-01	5.51E 00	1.11E 02	2.74E 02
BI214	3.20E-04	2.67E-03	1.60E-02	1.93E-01	1.56E 00	9.30E 00	7.39E 01	1.54E 01
PO210	1.85E-04	4.19E-03	2.99E-02	4.36E-01	3.52E 00	2.10E 01	1.67E 02	3.47E 01
PO213	9.92E-03	6.11E-02	1.90E-01	9.33E-01	5.52E 00	4.35E 01	8.80E 02	2.16E 03
PO214	1.05E-03	8.75E-03	5.24E-02	6.32E-01	5.09E 00	3.04E 01	2.42E 02	5.02E 01
PO215	1.46E 00	3.15E 00	3.21E 00	3.17E 00	3.05E 00	2.70E 00	2.46E 00	3.10E 00
PO218	8.33E-04	6.96E-03	4.17E-02	5.02E-01	4.05E 00	2.42E 01	1.92E 02	3.99E 01
AT217	8.56E-03	5.27E-02	1.64E-01	8.05E-01	4.76E 00	3.75E 01	7.59E 02	1.87E 03
RN219	1.35E 00	2.91F 00	2.97E 00	2.93E 00	2.82E 00	2.50E 00	2.27E 00	2.87E 00
RN222	7.49E-04	6.26E-03	3.75E-02	4.52E-01	3.64E 00	2.18E 01	1.73E 02	3.59E 01
FR221	7.60E-03	4.68E-02	1.46E-01	7.14E-01	4.23E 00	3.33E 01	6.74E 02	1.66E 03
RA223	1.16E 00	2.50E 00	2.55E 00	2.52E 00	2.42E 00	2.14E 00	1.95E 00	2.46E 00
RA225	1.33E-04	8.28E-04	2.58E-03	1.26E-02	7.48E-02	5.89E-01	1.19E 01	2.93E 01
RA226	6.50E-04	5.44E-03	3.25E-02	3.92E-01	3.16E 00	1.89E 01	1.50E 02	3.12E 01
AC225	7.01E-03	4.32E-02	1.34E-01	6.59E-01	3.90F 00	3.07E 01	6.22E 02	1.53E 03
AC227	1.64E-02	3.63E-02	3.70E-02	3.65E-02	3.51E-02	3.11E-02	2.83E-02	3.57E-02
TH227	1.12E 00	2.44E 00	2.49E 00	2.46E 00	2.37E 00	2.09E 00	1.90E 00	2.40E 00
TH229	6.06E-03	3.80E-02	1.18E-01	5.81E-01	3.44E 00	2.71E 01	5.48E 02	1.35E 03
TH230	7.83E-02	1.64E-01	5.22E-01	2.24E 00	7.34E 00	2.43E 01	1.49E 02	3.11E 01
TH231	6.25E-03	6.26E-03	6.30E-03	6.46E-03	7.16E-03	1.15E-02	5.18E-02	5.58E-02
TH234	6.05E-02	6.00E-02	6.00E-02	6.00E-02	6.00E-02	6.00E-02	6.00E-02	6.00E-02
PA231	2.25E 00	2.25E 00	2.24E 00	2.21E 00	2.13E 00	1.88E 00	1.71E 00	2.16E 00
PA233	6.20E 01	6.37E 01	6.73E 01	7.38E 01	7.69E 01	7.74E 01	7.58E 01	5.67E 01
PA234M	8.75E-01	8.67E-01	8.67E-01	8.67E-01	8.67E-01	8.67E-01	8.68E-01	8.68E-01
U233	2.98E 00	3.55E 00	4.76E 00	9.32E 00	2.32E 01	7.16E 01	5.77E 02	1.29E 03
U234	3.84E 01	1.52E 02	2.52E 02	3.04E 02	3.04E 02	2.98E 02	2.33E 02	2.31E 01
U235	2.20E-01	2.20E-01	2.22E-01	2.27E-01	2.52E-01	4.05E-01	1.82E 00	1.97E 00
U236	3.09E 00	3.27E 00	3.69E 00	5.10E 00	8.62E 00	1.65E 01	2.40E 01	2.34E 01
U238	4.26E 00	4.26E 00	4.26E 00	4.26E 00	4.26E 00	4.26E 00	4.27E 00	4.27E 00
NP237	1.33E 03	1.38E 03	1.46E 03	1.60E 03	1.67E 03	1.68E 03	1.65E 03	1.23E 03
NP239	7.01E 03	6.94E 03	6.82E 03	6.40E 03	5.34E 03	2.83E 03	8.24E-01	3.46E-04
PU238	6.15E 05	3.41E 05	1.13E 05	3.65E 03	3.88E-01	5.31E-15		
PU239	6.42E 03	6.88E 03	7.74E 03	1.06E 04	1.74E 04	3.05E 04	4.66E 03	7.97E-03
PU240	4.37E 04	8.35E 04	8.27E 04	7.70E 04	6.27E 04	3.06E 04	3.00E 00	1.09E-04
PU241	1.96E 03	2.84E 01	1.13E 01	1.06E 01	8.98E 00	5.00E 00	2.63E-03	
PU242	6.23E 01	6.66E 01	7.13E 01	7.57E 01	7.98E 01	8.67E 01	7.74E 01	1.49E 01
AM241	1.83E 06	1.61E 06	1.17E 06	3.88E 05	2.30E 04	4.02E 03	2.12E 00	
AM242M	1.47E 03	9.30E 02	3.74E 02	1.53E 01	1.68E-03	2.30E-17		
AM242	6.88E 03	4.36E 03	1.75E 03	7.19E 01	7.87E-03	1.08E-16		
AM243	1.89E 05	1.87E 05	1.84E 05	1.73E 05	1.44E 05	7.64E 04	2.23E 01	9.36E-03
CM242	1.56E 05	9.88E 04	3.97E 04	1.63E 03	1.79E-01	2.45E-15		
CM243	1.60E 04	1.84E 03	2.41E 01	6.27E-06	9.61E-25			
CM244	1.74E 07	3.77E 05	1.78E 02	8.14E-10	1.14E-09	3.68E-09	3.34E-08	1.60E-07
CM245	8.73E 03	8.65E 03	8.51E 03	8.02E 03	6.78E 03	3.77E 03	1.98E 00	
CM246	1.73E 03	1.71E 03	1.66E 03	1.50E 03	1.11E 03	3.98E 02	7.06E-04	1.57E-26
TOTAL	2.03E 07	2.73E 06	1.62E 06	6.72E 05	2.63E 05	1.51E 05	1.22E 04	1.19E 04

Table 4.15. Ingestion toxicity (m^3 water) of accumulated fission product isotopes in high-level wastes at a federal repository in the year 2010 as a function of time

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
TL207	4.17E 03	8.97E 03	9.14E 03	9.03E 03	8.69E 03	7.69E 03	7.00E 03	8.83E 03
TL209	4.49E-01	2.77E 00	8.62E 00	4.23E 01	2.50E 02	1.97E 03	3.99E 04	9.81E 04
PB209	6.81E 01	4.19E 02	1.31E 03	6.40E 03	3.79E 04	2.99E 05	6.04E 06	1.49E 07
PB210	6.22E 04	1.33E 06	9.49E 06	1.39E 08	1.12E 09	6.68E 09	5.31E 10	1.10E 10
PB211	8.36E 04	1.80E 05	1.83E 05	1.81E 05	1.74E 05	1.54E 05	1.40E 05	1.77E 05
PB214	4.60E 01	3.84E 02	2.30E 03	2.77E 04	2.24E 05	1.34E 06	1.06E 07	2.20E 06
BI210	1.56E 02	3.33E 03	2.37E 04	3.46E 05	2.79E 06	1.67E 07	1.33E 08	2.76E 07
BI211	4.78E 03	1.03E 04	1.05E 04	1.03E 04	9.96E 03	8.81E 03	8.02E 03	1.01E 04
BI213	4.09E 02	2.52E 03	7.84E 03	3.84E 04	2.27E 05	1.79E 06	3.62E 07	8.92E 07
BI214	3.83E 01	3.20E 02	1.92E 03	2.31E 04	1.86E 05	1.11E 06	8.84E 06	1.84E 06
PO210	8.40E 03	1.90E 05	1.36E 06	1.98E 07	1.60E 08	9.54E 08	7.58E 09	1.57E 09
PO213	2.00E-01	1.23E 00	3.83E 00	1.88E 01	1.11E 02	8.76E 02	1.77E 04	4.36E 04
PO214	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
PO215	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
PO218	5.75E 00	4.80E 01	2.87E 02	3.46E 03	2.79E 04	1.67E 05	1.33E 06	2.76E 05
AT217	3.40E-01	2.10E 00	6.53E 00	3.20E 01	1.89E 02	1.49E 03	3.02E 04	7.43E 04
RN219	3.34E 01	7.20E 01	7.34E 01	7.24E 01	6.98E 01	6.17E 01	5.61E 01	7.08E 01
RN222	2.30E-02	1.92E-01	1.15E 00	1.39E 01	1.12E 02	6.68E 02	5.31E 03	1.10E 03
FR221	2.55E 02	1.57E 03	4.90E 03	2.40E 04	1.42E 05	1.12E 06	2.26E 07	5.57E 07
RA223	4.78E 07	1.03E 08	1.05E 08	1.03E 08	9.96E 07	8.81E 07	8.02E 07	1.01E 08
RA225	4.05E 05	2.52E 06	7.84E 06	3.84E 07	2.27E 08	1.79E 09	3.62E 10	8.92E 10
RA226	7.65E 05	6.40E 06	3.83E 07	4.62E 08	3.73E 09	2.23E 10	1.77E 11	3.67E 10
AC225	4.09E 04	2.52E 05	7.84E 05	3.84E 06	2.27E 07	1.79E 08	3.62E 09	8.92E 09
AC227	1.63E 07	3.60E 07	3.67E 07	3.62E 07	3.49E 07	3.08E 07	2.81E 07	3.54E 07
TH227	1.63E 06	3.55E 06	3.62E 06	3.57E 06	3.44E 06	3.04E 06	2.77E 06	3.49E 06
TH229	5.01E 05	3.15E 06	9.79E 06	4.80E 07	2.84E 08	2.24E 09	4.53E 10	1.11E 11
TH230	1.39E 06	2.90E 06	9.23E 06	3.97E 07	1.30E 08	4.30E 08	2.64E 09	5.51E 08
TH231	3.96E 04	3.97E 04	3.99E 04	4.09E 04	4.54E 04	7.30E 04	3.29E 05	3.54E 05
TH234	8.50E 06	8.43E 06	8.43E 06	8.43E 06	8.43E 06	8.43E 06	8.43E 06	8.44E 06
PA231	8.20E 07	8.18E 07	8.15E 07	8.04E 07	7.75E 07	6.85E 07	6.24E 07	7.87E 07
PA233	4.59E 08	4.71E 08	4.98E 08	5.46E 08	5.69E 08	5.73E 08	5.61E 08	4.19E 08
PA234M	8.50E 03	8.43E 03	8.43E 03	8.43E 03	8.43E 03	8.43E 03	8.43E 03	8.44E 03
U233	3.41E 06	4.07E 06	5.45E 06	1.07E 07	2.66E 07	8.20E 07	6.61E 08	1.48E 09
U234	4.45E 07	1.76E 08	2.91E 08	3.52E 08	3.52E 08	3.45E 08	2.69E 08	2.67E 07
U235	2.64E 05	2.65E 05	2.66E 05	2.73E 05	3.03E 05	4.87E 05	2.19E 06	2.36E 06
U236	3.79E 06	4.02E 06	4.54E 06	6.28E 06	1.06E 07	2.03E 07	2.95E 07	2.87E 07
U238	4.21E 06	4.21E 06	4.21E 06	4.21E 06	4.21E 06	4.21E 06	4.22E 06	4.22E 06
NP237	1.51E 10	1.57E 10	1.66E 10	1.82E 10	1.90E 10	1.91E 10	1.87E 10	1.40E 10
NP239	5.19E 10	5.14E 10	5.04E 10	4.73E 10	3.95E 10	2.09E 10	6.10E 06	2.56E 03
PU238	3.72E 12	2.06E 12	6.81E 11	2.20E 10	2.34E 06	3.21E-08		
PU239	4.13E 10	4.43E 10	4.98E 10	6.80E 10	1.12E 11	1.96E 11	3.00E 10	5.13E 04
PU240	2.81E 11	5.36E 11	5.31E 11	4.94E 11	4.02E 11	1.96E 11	1.93E 07	7.03E 02
PU241	2.36E 11	3.42E 09	1.36E 09	1.28E 09	1.08E 09	6.02E 08	3.17E 05	
PU242	4.22E 08	4.51E 08	4.83E 08	5.13E 08	5.41E 08	5.88E 08	5.24E 08	1.01E 08
AM241	1.37E 13	1.21E 13	8.78E 12	2.91E 12	1.72E 11	3.01E 10	1.59E 07	
AM242M	1.29E 12	8.17E 11	3.28E 11	1.35E 10	1.48E 06	2.02E-08		
AM242	5.16E 10	3.27E 10	1.31E 10	5.39E 08	5.90E 04	8.08E-10		
AM243	1.30E 12	1.28E 12	1.26E 12	1.18E 12	9.87E 11	5.24E 11	1.52E 08	6.41E 04
CM242	2.12E 11	1.34E 11	5.38E 10	2.21E 09	2.43E 05	3.32E-09		
CM243	8.72E 10	1.00E 10	1.31E 08	3.41E 01	5.23E-18			
CM244	7.09E 13	1.54E 12	7.27E 08	3.33E-03	4.66E-03	1.50E-02	1.36E-01	6.52E-01
CM245	6.95E 10	6.89E 10	6.78E 10	6.39E 10	5.40E 10	3.00E 10	1.58E 07	
CM246	1.32E 10	1.30E 10	1.26E 10	1.14E 10	8.49E 09	3.03E 09	5.38E 03	1.19E-19
TOTAL	9.20E 13	1.87E 13	1.18E 13	4.83E 12	1.80E 12	1.06E 12	3.77E 11	2.76E 11

Table 4.16. Grams of accumulated fission product elements in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
GE	4.25E 04	4.25E 04	4.25E 04	4.25E 04	4.25E 04	4.25E 04	4.25E 04	4.25E 04
AS	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04
SE	5.59E 06	5.59E 06	5.58E 06	5.58E 06	5.57E 06	5.53E 06	5.22E 06	5.03E 06
BR	2.33E 03	2.92E 03	4.12E 03	8.28E 03	2.00E 04	5.91E 04	3.70E 05	5.63E 05
RB	3.24E 07	3.24E 07	3.24E 07	3.24E 07	3.24E 07	3.24E 07	3.24E 07	3.24E 07
SR	6.70E 07	3.58E 07	3.29E 07	3.29E 07	3.29E 07	3.29E 07	3.29E 07	3.29E 07
Y	4.35E 07	4.35E 07	4.35E 07	4.35E 07	4.35E 07	4.35E 07	4.35E 07	4.35E 07
ZR	3.67E 08	3.98E 08	4.01E 08	4.01E 08	4.01E 08	4.00E 08	3.98E 08	3.75E 08
NB	6.42E 02	3.89E 03	1.04E 04	3.31E 04	9.79E 04	3.24E 05	3.17E 06	2.60E 07
MO	3.47E 08	3.47E 08	3.47E 08	3.47E 08	3.47E 08	3.47E 08	3.47E 08	3.47E 08
TC	8.55E 07	8.55E 07	8.54E 07	8.53E 07	8.47E 07	8.28E 07	6.17E 07	3.25E 06
RU	2.28E 08	2.28E 08	2.28E 08	2.28E 08	2.29E 08	2.31E 08	2.52E 08	3.10E 08
RH	4.86E 07	4.86E 07	4.86E 07	4.86E 07	4.86E 07	4.86E 07	4.86E 07	4.86E 07
PD	1.66E 08	1.66E 08	1.66E 08	1.66E 08	1.66E 08	1.66E 08	1.66E 08	1.64E 08
AG	7.22E 06	7.22E 06	7.22E 06	7.22E 06	7.23E 06	7.25E 06	7.48E 06	9.67E 06
CD	1.03E 07	1.03E 07	1.03E 07	1.03E 07	1.03E 07	1.03E 07	1.03E 07	1.03E 07
IN	1.45E 05	1.53E 05	1.53E 05	1.53E 05	1.53E 05	1.53E 05	1.53E 05	1.53E 05
SN	5.47E 06	5.47E 06	5.47E 06	5.46E 06	5.42E 06	5.32E 06	4.32E 06	3.18E 06
SB	9.78E 05	9.54E 05	9.54E 05	9.54E 05	9.54E 05	9.54E 05	9.54E 05	9.54E 05
TE	5.07E 07	5.07E 07	5.07E 07	5.07E 07	5.08E 07	5.09E 07	5.18E 07	5.30E 07
I	9.06E 04	9.06E 04	9.06E 04	9.06E 04	9.06E 04	9.05E 04	9.04E 04	8.94E 04
XE	2.30E-02	1.45E-01	3.88E-01	1.24E 00	3.67E 00	1.22E 01	1.21E 02	1.19E 03
CS	2.34E 08	1.56E 08	1.47E 08	1.47E 08	1.47E 08	1.47E 08	1.46E 08	1.39E 08
BA	2.04E 08	2.82E 08	2.91E 08	2.91E 08	2.91E 08	2.91E 08	2.92E 08	2.99E 08
LA	1.24E 08	1.24E 08	1.24E 08	1.24E 08	1.24E 08	1.24E 08	1.24E 08	1.24E 08
CE	2.43E 08	2.43E 08	2.43E 08	2.43E 08	2.43E 08	2.43E 08	2.43E 08	2.43E 08
PR	1.16E 08	1.16E 08	1.16E 08	1.16E 08	1.16E 08	1.16E 08	1.16E 08	1.16E 08
ND	4.07E 08	4.07E 08	4.07E 08	4.07E 08	4.07E 08	4.07E 08	4.07E 08	4.07E 08
PM	2.36E 05	7.63E-07						
SM	9.02E 07	8.81E 07	8.66E 07	8.63E 07	8.63E 07	8.63E 07	8.63E 07	8.63E 07
EU	1.62E 07	1.61E 07	1.76E 07	1.80E 07	1.80E 07	1.80E 07	1.80E 07	1.80E 07
GD	1.35E 07	1.59E 07	1.59E 07	1.59E 07	1.59E 07	1.59E 07	1.59E 07	1.59E 07
TB	2.16E 05	2.16E 05	2.16E 05	2.16E 05	2.16E 05	2.16E 05	2.16E 05	2.16E 05
DY	1.54E 05	1.54E 05	1.54E 05	1.54E 05	1.54E 05	1.54E 05	1.54E 05	1.54E 05
HO	1.45E 04	1.45E 04	1.45E 04	1.45E 04	1.44E 04	1.44E 04	1.44E 04	1.44E 04
ER	3.82E 03	3.83E 03	3.83E 03	3.85E 03	3.87E 03	3.88E 03	3.88E 03	3.88E 03
TOTALS	2.91E 09	2.91E 09	2.91E 09	2.91E 09	2.91E 09	2.91E 09	2.91E 09	2.91E 09

Table 4.17. Curies of accumulated fission product isotopes in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	3.91E 04	3.90E 04	3.89E 04	3.87E 04	3.78E 04	3.51E 04	1.35E 04	9.13E-01
SR 90	4.83E 09	4.10E 08	2.96E 06	9.37E-02	3.51E-23			
Y 90	4.84E 09	4.10E 08	2.96E 06	9.37E-02	3.51E-23			
ZR 93	1.80E 05	1.80E 05	1.80E 05	1.80E 05	1.80E 05	1.79E 05	1.72E 05	1.13E 05
NB 93M	1.12E 05	1.80E 05	1.80E 05	1.80E 05	1.80E 05	1.79E 05	1.72E 05	1.13E 05
TC 99	1.46E 06	1.46E 06	1.46E 06	1.45E 06	1.44E 06	1.41E 06	1.05E 06	5.54E 04
RU106	6.01E 06							
RH106	6.01E 06							
PD107	1.24E 04	1.24E 04	1.24E 04	1.24E 04	1.24E 04	1.24E 04	1.23E 04	1.12E 04
SB125	2.53E 07	1.80E-04						
TE125M	1.05E 07	7.44E-05						
SN126	6.51E 04	6.50E 04	6.49E 04	6.46E 04	6.37E 04	6.07E 04	3.25E 04	6.36E 01
SB126M	6.51E 04	6.50E 04	6.49E 04	6.46E 04	6.37E 04	6.07E 04	3.25E 04	6.36E 01
SB126	6.47E 04	6.44E 04	6.43E 04	6.40E 04	6.31E 04	6.01E 04	3.22E 04	6.30E 01
I129	4.86E 00	4.86E 00	4.86E 00	4.86E 00	4.86E 00	4.86E 00	4.84E 00	4.67E 00
CS134	1.95E 08	4.03E-07						
CS135	3.50E 04	3.50E 04	3.50E 04	3.50E 04	3.50E 04	3.49E 04	3.42E 04	2.78E 04
CS137	7.56E 09	7.50E 08	7.38E 06	6.98E-01	5.96E-21			
BA137M	7.07E 09	7.01E 08	6.90E 06	6.53E-01	5.57E-21			
PM147	2.19E 08	7.09E-04						
SM151	1.13E 08	5.11E 07	1.04E 07	3.90E 04	4.69E-03			
EU152	6.03E 05	1.87E 03	1.80E-02	4.96E-20				
EU154	3.43E 08	4.51E 06	7.79E 02	5.26E-11				
EU155	3.95E 06	9.21E-11						
HO166M	1.03E 02	9.74E 01	8.68E 01	5.79E 01	1.82E 01	3.20E-01	8.46E-24	
TOTAL	2.52E 10	2.33E 09	3.27E 07	2.13E 06	2.08E 06	2.03E 06	1.55E 06	3.21E 05

Table 4.18. Watts of accumulated fission product isotopes in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	1.48E 01	1.48E 01	1.48E 01	1.47E 01	1.44E 01	1.33E 01	5.10E 00	3.46E-04
SR 90	6.33E 06	5.37E 05	3.87E 03	1.23E-04	4.60E-26			
Y 90	2.85E 07	2.41E 06	1.74E 04	5.51E-04	2.07E-25			
ZR 93	2.13E 01	2.13E 01	2.13E 01	2.13E 01	2.13E 01	2.12E 01	2.04E 01	1.34E 01
NB 93M	1.99E 01	3.19E 01	3.20E 01	3.20E 01	3.20E 01	3.19E 01	3.06E 01	2.02E 01
TC 99	9.85E 02	9.85E 02	9.84E 02	9.82E 02	9.75E 02	9.53E 02	7.10E 02	3.74E 01
RU106	3.56E 02							
RH106	6.32E 04							
PD107	1.03E 00	1.03E 00	1.03E 00	1.03E 00	1.03E 00	1.03E 00	1.02E 00	9.31E-01
SB125	1.03E 05	7.28E-07						
TE125M	1.80E 04	1.28E-07						
SN126	7.02E 01	7.02E 01	7.01E 01	6.97E 01	6.88E 01	6.55E 01	3.51E 01	6.86E-02
SB126M	4.40E 02	4.39E 02	4.39E 02	4.37E 02	4.31E 02	4.10E 02	2.20E 02	4.30E-01
SB126	8.42E 02	8.38E 02	8.36E 02	8.32E 02	8.21E 02	7.82E 02	4.19E 02	8.19E-01
I129	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.19E-03	3.07E-03
CS134	2.07E 06	4.27E-09						
CS135	1.70E 01	1.70E 01	1.70E 01	1.70E 01	1.70E 01	1.70E 01	1.66E 01	1.35E 01
CS137	1.24E 07	1.23E 06	1.21E 04	1.14E-03	9.75E-24			
BA137M	2.78E 07	2.76E 06	2.71E 04	2.57E-03	2.19E-23			
PM147	1.13E 05	3.65E-07						
SM151	1.98E 05	8.91E 04	1.81E 04	6.80E 01	8.17E-06			
EU152	1.08E 04	3.36E 01	3.23E-04	8.88E-22				
EU154	2.82E 06	3.70E 04	6.39E 00	4.32E-13				
EU155	3.32E 03	7.75E-14						
HO166M	1.11E 00	1.05E 00	9.33E-01	6.23E-01	1.96E-01	3.44E-03	9.09E-26	
TOTAL	8.04E 07	7.06E 06	8.10E 04	2.48E 03	2.38E 03	2.30E 03	1.46E 03	8.68E 01

Table 4.19. Ingestion toxicity (m^3 water) of accumulated fission product isotopes in high-level wastes at a federal repository in the year 2010 as a function of age

	Year	Years following close of the repository						
	2010	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	3.91E 04	3.90E 04	3.89E 04	3.87E 04	3.78E 04	3.51E 04	1.35E 04	9.13E-01
SR 90	1.61E 16	1.37E 15	9.85E 12	3.12E 05	1.17E-16			
Y 90	2.42E 14	2.05E 13	1.48E 11	4.68E 03	1.76E-18			
ZR 93	2.25E 08	2.25E 08	2.25E 08	2.25E 08	2.25E 08	2.24E 08	2.15E 08	1.42E 03
NB 93M	2.80E 08	4.49E 08	4.50E 08	4.50E 08	4.49E 08	4.48E 08	4.30E 08	2.83E 08
TC 99	7.29E 09	7.29E 09	7.28E 09	7.26E 09	7.22E 09	7.05E 09	5.26E 09	2.77E 08
RU106	6.01E 11							
RH106	6.01E 06							
PD107	1.24E 07	1.24E 07	1.24E 07	1.24E 07	1.24E 07	1.24E 07	1.23E 07	1.12E 07
SB125	2.53E 11	1.80E 00						
TE125M	1.05E 11	7.44E-01						
SN126	6.51E 04	6.50E 04	6.49E 04	6.46E 04	6.37E 04	6.07E 04	3.25E 04	6.36E 01
SB126M	6.51E 04	6.50E 04	6.49E 04	6.46E 04	6.37E 04	6.07E 04	3.25E 04	6.36E 01
SB126	6.47E 04	6.44E 04	6.43E 04	6.40E 04	6.31E 04	6.01E 04	3.22E 04	6.30E 01
I129	8.10E 07	8.10E 07	8.10E 07	8.10E 07	8.10E 07	8.10E 07	8.07E 07	7.78E 07
CS134	2.17E 13	4.48E-02						
CS135	3.50E 08	3.50E 08	3.50E 08	3.50E 08	3.50E 08	3.49E 08	3.42E 08	2.78E 03
CS137	3.78E 14	3.75E 13	3.69E 11	3.49E 04	2.98E-16			
BA137M	7.07E 09	7.01E 08	6.90E 06	6.53E-01	5.57E-21			
PM147	1.09E 12	3.54E 00						
SM151	2.83E 11	1.28E 11	2.60E 10	9.76E 07	1.17E 01			
EU152	7.54E 09	2.34E 07	2.25E 02	6.20E-16				
EU154	1.72E 13	2.26E 11	3.89E 07	2.63E-06				
EU155	1.97E 10	4.61E-07						
HO166M	1.03E 02	9.74E 01	8.68E 01	5.79E 01	1.82E 01	3.20E-01	8.46E-24	
TOTAL	1.68E 16	1.43E 15	1.04E 13	8.48E 09	8.33E 09	8.17E 09	6.33E 09	1.07E 09

Table 4.20. Mass, composition, and exposure of fuel assembly structural materials

Structural material	PWR		BWR		LMFBR	
	Mass[a] (kg/MTHM[b])	Percentage exposure[c]	Mass[d] (kg/MTHM)	Percentage exposure[c]	Mass[e] (kg/MTHM)	Percentage exposure
Zircaloy	235.0	100	316.0	100	0	—
302 SS	4.2	60	0	—	0	—
304 SS	37.1	40	50.0	50	0	—
316 SS	0	—	0	—	700.0	100
Inconel	12.8	100	3.4	100	0	—
Nicrobraze 50	2.6	100	0	—	0	—
Total	291.7	—	369.4	—	700.0	100

[a] Reference 22.

[b] MTHM is an abbreviation for metric tons of heavy metal.

[c] Reference 23.

[d] Reference 24.

[e] Reference 1.

is assumed to contain 0.05% of the actinides and fission products originally in the spent fuel. The radioactivity and thermal power of the major actinide and fission-product isotopes accompanying the structural materials associated with one metric ton of each type of reactor fuel are also summarized in Appendix B.

The fuel assembly structural materials are assumed to be compacted to 70% of their theoretical density, resulting in final structural material volumes of 2.29 ft^3 per metric ton of PWR fuel, 2.92 ft^3 per metric ton of BWR fuel, and 8.7 ft^3 per metric ton of LMFBR fuel. The compacted structural materials are packaged in canisters 10 in. in diameter by 10 ft long, each of which contains 3.53 ft^3 of waste. After a storage period of five years at the reprocessing plants, the waste is shipped by rail to a repository in casks containing 27 canisters of LWR cladding or 36 canisters of LMFBR cladding.

The properties (volume, mass, radioactivity, thermal power, and toxicity) of the cladding wastes accumulated at one or more federal repositories are presented in Table 4.21. Many of the assumptions used to construct this table are based on an earlier study of cladding wastes.[25]

The accumulated mass, radioactivity, thermal power, and ingestion toxicity of the cladding wastes as a function of time following the year 2005 are summarized in Tables 4.22 through 4.25 for neutron-induced radionuclides, Tables 4.26 through 4.29 for associated actinides, and Tables 4.30 through 4.33 for associated fission products.

4.3 Intermediate-Level TRU Wastes

Intermediate-level transuranic (TRU) wastes are defined as those solid materials, other than high-level and cladding wastes, which contain long-lived alpha activities greater than 10 nCi/g and have gamma radiation levels sufficient to require biological shielding and remote handling techniques (typical surface dose rates lie between 10 and 1000 mrem/hr). The criterion of 10 nCi/g is adopted as a lower activity density for low-level TRU wastes because this corresponds to

Table 4.21. Projected annual accumulation of cladding waste at a federal repository

Year	* * * * Annual Addition * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	Annual Number of Shipments	* * * * * Accumulation Through End of Year * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (MW)	Hazard, Cubic Meters at RCG Air	Water
1986	0.04	0.24	3.3	0.015	30	0.04	0.24	3	0.01	1.6E 16	7.9E 10
1987	0.11	0.72	10.2	0.048	95	0.15	0.97	13	0.06	6.6E 16	3.2E 11
1988	0.11	0.72	10.9	0.050	81	0.26	1.69	21	0.10	1.2E 17	5.5E 11
1989	0.11	0.72	12.0	0.052	75	0.37	2.41	29	0.14	1.7E 17	7.9E 11
1990	0.14	0.97	16.6	0.071	96	0.51	3.38	40	0.18	2.5E 17	1.1E 12
1991	0.22	1.45	24.4	0.102	147	0.72	4.83	57	0.25	3.8E 17	1.6E 12
1992	0.22	1.45	23.7	0.099	146	0.94	6.28	69	0.31	5.4E 17	2.1E 12
1993	0.25	1.69	27.2	0.114	168	1.19	7.98	83	0.37	7.8E 17	2.5E 12
1994	0.32	2.18	34.7	0.145	219	1.51	10.15	102	0.45	1.1E 18	3.2E 12
1995	0.36	2.42	38.8	0.163	247	1.87	12.57	121	0.54	1.4E 18	3.9E 12
1996	0.43	2.91	47.3	0.199	297	2.30	15.48	146	0.65	1.7E 18	4.7E 12
1997	0.47	3.15	52.2	0.220	321	2.77	18.62	171	0.76	2.1E 18	5.6E 12
1998	0.54	3.63	60.8	0.257	370	3.31	22.25	199	0.89	2.5E 18	6.6E 12
1999	0.58	3.87	64.9	0.274	394	3.89	26.13	227	1.01	3.1E 18	7.7E 12
2000	0.65	4.40	73.5	0.311	448	4.55	30.53	258	1.16	3.8E 18	8.9E 12
2001	0.69	4.65	77.4	0.328	474	5.24	35.18	288	1.29	4.6E 18	1.0E 13
2002	0.80	5.34	89.9	0.380	544	6.04	40.52	325	1.46	5.4E 18	1.2E 13
2003	0.88	5.84	100.3	0.423	596	6.92	46.36	366	1.64	6.2E 18	1.3E 13
2004	0.81	5.31	91.9	0.386	543	7.73	51.67	391	1.76	7.0E 18	1.4E 13
2005	0.78	4.95	85.9	0.359	509	8.51	56.62	406	1.83	7.8E 18	1.5E 13
TIME AFTER SHUTDOWN, YEARS											
100						8.51	56.62	22	0.022	3.8E 18	1.6E 12
300						8.51	56.62	5	0.011	2.4E 18	2.2E 11
1000						8.51	56.62	0	0.004	1.3E 18	3.2E 10
3000						8.51	56.62	0	0.002	8.2E 17	1.2E 10
10000						8.51	56.62	0	0.001	5.0E 17	8.1E 09
30000						8.51	56.62	0	0.000	1.9E 17	4.8E 09
100000						8.51	56.62	0	0.000	2.7E 16	4.0E 09
300000						8.51	56.62	0	0.000	7.2E 15	3.8E 09
1000000						8.51	56.62	0	0.000	5.3E 15	1.6E 09

Table 4.22. Grams of accumulated structural materials and impurity elements in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
HE	2.34E 03	2.34E 03	2.34E 03	2.34E 03	2.34E 03	2.34E 03	2.34E 03	2.34E 03
LI	1.80E 03	1.80E 03	1.80E 03	1.80E 03	1.80E 03	1.80E 03	1.80E 03	1.80E 03
BE	1.51E 01	1.51E 01	1.51E 01	1.51E 01	1.51E 01	1.51E 01	1.51E 01	1.48E 01
B	1.16E 04	1.16E 04	1.16E 04	1.16E 04	1.16E 04	1.16E 04	1.16E 04	1.16E 04
C	8.98E 06	8.98E 06	8.98E 06	8.98E 06	8.98E 06	8.98E 06	8.98E 06	8.98E 06
N	6.26E 05	6.26E 05	6.26E 05	6.26E 05	6.27E 05	6.28E 05	6.28E 05	6.28E 05
O	8.62E 07	8.62E 07	8.62E 07	8.62E 07	8.62E 07	8.62E 07	8.62E 07	8.62E 07
F	1.77E 01	1.77E 01	1.77E 01	1.77E 01	1.77E 01	1.77E 01	1.77E 01	1.77E 01
NE	8.03E 00	8.04E 00	8.04E 00	8.04E 00	8.04E 00	8.04E 00	8.04E 00	8.04E 00
NA	6.46E 05	6.46E 05	6.46E 05	6.46E 05	6.46E 05	6.46E 05	6.46E 05	6.46E 05
MG	4.01E 02	4.01E 02	4.01E 02	4.01E 02	4.01E 02	4.01E 02	4.01E 02	4.01E 02
AL	8.58E 06	8.58E 06	8.58E 06	8.58E 06	8.58E 06	8.58E 06	8.58E 06	8.58E 06
SI	3.59E 07	3.59E 07	3.59E 07	3.59E 07	3.59E 07	3.59E 07	3.59E 07	3.59E 07
P	1.95E 07	1.95E 07	1.95E 07	1.95E 07	1.95E 07	1.95E 07	1.95E 07	1.95E 07
S	1.56E 06	1.56E 06	1.56E 06	1.56E 06	1.56E 06	1.56E 06	1.56E 06	1.56E 06
CL	2.13E 01	2.13E 01	2.13E 01	2.13E 01	2.13E 01	2.13E 01	2.12E 01	2.07E 01
AR	1.15E-04	2.55E-04	5.34E-04	1.51E-03	4.29E-03	1.39E-02	1.25E-01	5.58E-01
K	2.43E-06	2.43E-06	2.43E-06	2.43E-06	2.44E-06	2.44E-06	2.44E-06	2.44E-06
CA	3.23E 01	3.23E 01	3.23E 01	3.23E 01	3.23E 01	3.23E 01	3.23E 01	3.23E 01
SC	5.25E-01	5.25E-01	5.25E-01	5.25E-01	5.25E-01	5.25E-01	5.25E-01	5.25E-01
TI	1.22E 07	1.22E 07	1.22E 07	1.22E 07	1.22E 07	1.22E 07	1.22E 07	1.22E 07
V	1.10E 06	1.10E 06	1.10E 06	1.10E 06	1.10E 06	1.10E 06	1.10E 06	1.10E 06
CR	1.20E 09	1.20E 09	1.20E 09	1.20E 09	1.20E 09	1.20E 09	1.20E 09	1.20E 09
MN	6.30E 07	6.30E 07	6.30E 07	6.30E 07	6.30E 07	6.30E 07	6.30E 07	6.30E 07
FE	3.70E 09	3.70E 09	3.70E 09	3.70E 09	3.70E 09	3.70E 09	3.70E 09	3.70E 09
CO	2.50E 06	2.45E 06	2.46E 06	2.48E 06	2.54E 06	2.76E 06	4.66E 06	6.27E 06
NI	1.03E 09	1.03E 09	1.03E 09	1.03E 09	1.03E 09	1.03E 09	1.02E 09	1.02E 09
CU	1.90E 06	2.25E 06	2.50E 06	2.57E 06	2.57E 06	2.57E 06	2.57E 06	2.57E 06
ZN	9.58E 03	9.58E 03	9.58E 03	9.58E 03	9.58E 03	9.58E 03	9.58E 03	9.58E 03
SR	2.56E 04	2.56E 04	2.56E 04	2.56E 04	2.56E 04	2.56E 04	2.56E 04	2.56E 04
Y	1.39E-04	1.18E-05	8.51E-08	2.69E-15	1.01E-36			
ZR	2.76E 10	2.76E 10	2.76E 10	2.76E 10	2.76E 10	2.76E 10	2.76E 10	2.76E 10
NB	4.82E 07	4.82E 07	4.82E 07	4.82E 07	4.82E 07	4.82E 07	4.84E 07	4.99E 07
MO	3.42E 07	3.42E 07	3.42E 07	3.42E 07	3.42E 07	3.42E 07	3.42E 07	3.42E 07
TC	5.23E 04	5.22E 04	5.22E 04	5.21E 04	5.17E 04	5.06E 04	3.76E 04	1.93E 03
RU	1.77E 04	1.77E 04	1.77E 04	1.77E 04	1.77E 04	1.77E 04	1.77E 04	1.77E 04
CD	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02
SN	4.31E 08	4.31E 08	4.31E 08	4.31E 08	4.31E 08	4.31E 08	4.31E 08	4.31E 08
SB	2.50E 07	2.49E 07	2.49E 07	2.49E 07	2.49E 07	2.49E 07	2.49E 07	2.49E 07
TE	3.91E 06	4.05E 06	4.05E 06	4.05E 06	4.05E 06	4.05E 06	4.05E 06	4.05E 06
TA	6.52E 00	6.52E 00	6.52E 00	6.52E 00	6.52E 00	6.52E 00	6.52E 00	6.52E 00
W	2.96E 05	2.96E 05	2.96E 05	2.96E 05	2.96E 05	2.96E 05	2.96E 05	2.96E 05
TOTALS	3.44E 10	3.44E 10	3.44E 10	3.44E 10	3.44E 10	3.44E 10	3.44E 10	3.44E 10

Table 4.23. Curies of accumulated structural materials and impurity isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year 2005	Years following close of the repository						
		100	300	1000	3000	10,000	100,000	1,000,000
C 14	1.15E 04	1.13E 04	1.11E 04	1.02E 04	7.99E 03	3.43E 03	6.40E-02	
MN 54	4.10E 05							
FE 55	6.48E 07	1.71E-04						
CO 60	6.34E 07	1.20E 02	4.29E-10					
NI 59	2.90E 05	2.90E 05	2.89E 05	2.87E 05	2.82E 05	2.66E 05	1.22E 05	5.03E 01
NI 63	4.13E 07	1.95E 07	4.31E 06	2.21E 04	6.30E-03			
ZR 93	1.13E 04	1.13E 04	1.13E 04	1.13E 04	1.13E 04	1.12E 04	1.08E 04	7.11E 03
NB 93M	6.44E 03	1.38E 04	1.38E 04	1.36E 04	1.33E 04	1.24E 04	1.08E 04	7.11E 03
NB 94	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.73E 01	1.68E 01
MO 93	2.97E 03	2.95E 03	2.91E 03	2.75E 03	2.36E 03	1.38E 03	1.34E 00	
TC 99	8.99E 02	8.99E 02	8.98E 02	8.96E 02	8.90E 02	8.70E 02	6.46E 02	3.31E 01
SN121M	3.71E 04	1.49E 04	2.40E 03	3.98E 00	4.76E-08			
SB125	1.51E 08	1.07E-03						
TE125M	6.26E 07	4.44E-04						
TOTAL	3.84E 08	1.98E 07	4.64E 06	3.48E 05	3.18E 05	2.95E 05	1.44E 05	1.43E 04

Table 4.24. Watts of accumulated structural materials and impurity isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
C 14	3.40E 00	3.36E 00	3.28E 00	3.02E 00	2.37E 00	1.02E 00	1.90E-05	
MN 54	3.32E 03							
FE 55	8.46E 04	2.23E-07						
CO 60	9.91E 05	1.87E 00	6.71E-12					
NI 63	6.62E 03	3.11E 03	6.90E 02	3.53E 00	1.01E-06			
ZR 93	1.34E 00	1.34E 00	1.34E 00	1.34E 00	1.34E 00	1.33E 00	1.28E 00	8.43E-01
NB 93M	2.25E 00	4.81E 00	4.81E 00	4.77E 00	4.65E 00	4.34E 00	3.77E 00	2.49E 00
NB 94	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.02E-01	1.96E-01
MO 93	7.40E 00	7.35E 00	7.24E 00	6.86E 00	5.88E 00	3.43E 00	3.35E-03	
TC 99	1.55E 00	1.54E 00	1.54E 00	1.54E 00	1.53E 00	1.50E 00	1.11E 00	5.70E-02
SN121M	3.89E 01	1.56E 01	2.52E 00	4.17E-03	4.99E-11			
SB125	6.12E 05	4.34E-06						
TE125M	5.38E 04	3.81E-07						
TOTAL	1.75E 06	3.15E 03	7.11E 02	2.13E 01	1.60E 01	1.18E 01	6.37E 00	3.59E 00

Table 4.25. Ingestion toxicity (m^3 water) of accumulated structural materials and impurity isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
C 14	1.44E 07	1.42E 07	1.38E 07	1.27E 07	9.99E 06	4.28E 06	8.01E 01	
MN 54	4.10E 09							
FE 55	8.11E 10	2.14E-01						
CO 60	2.11E 12	4.00E 06	1.43E-05					
NI 59	1.45E 09	1.45E 09	1.45E 09	1.44E 09	1.41E 09	1.33E 09	6.09E 08	2.51E 05
NI 63	1.38E 12	6.49E 11	1.44E 11	7.36E 08	2.10E 02			
ZR 93	1.41E 07	1.41E 07	1.41E 07	1.41E 07	1.41E 07	1.41E 07	1.35E 07	8.89E 06
NB 93M	1.61E 07	3.44E 07	3.44E 07	3.41E 07	3.32E 07	3.10E 07	2.70E 07	1.78E 07
NB 94	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.74E 01	1.73E 01	1.68E 01
MO 93	2.97E 03	2.95E 03	2.91E 03	2.75E 03	2.36E 03	1.38E 03	1.34E 00	
TC 99	4.49E 06	4.49E 06	4.49E 06	4.48E 06	4.45E 06	4.35E 06	3.23E 06	1.66E 05
SN121M	3.71E 04	1.49E 04	2.40E 03	3.98E 00	4.76E-08			
SB125	1.51E 12	1.07E 01						
TE125M	6.26E 11	4.44E 00						
TOTAL	5.71E 12	6.50E 11	1.45E 11	2.24E 09	1.47E 09	1.38E 09	6.53E 08	2.71E 07

Table 4.26. Grams of accumulated heavy elements in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
HE	6.58E 01	4.96E 02	1.07E 03	2.13E 03	3.30E 03	5.47E 03	1.12E 04	1.84E 04
TL	1.33E-09	6.22E-10	1.21E-10	9.82E-11	2.82E-10	9.71E-10	7.91E-09	1.19E-08
PB	3.68E-03	3.69E-02	5.54E-02	8.59E-02	6.73E-01	1.34E 01	1.48E 03	2.02E 04
BI	9.82E-08	1.73E-06	2.94E-05	1.24E-03	4.48E-02	1.81E 00	5.74E 02	2.59E 04
PO	7.36E-10	2.06E-07	2.66E-06	3.91E-05	2.94E-04	1.71E-03	1.37E-02	5.81E-03
AT	3.60E-18	5.83E-17	4.28E-16	6.13E-15	7.28E-14	7.98E-13	1.81E-11	4.48E-11
RN	1.31E-09	1.08E-08	9.60E-08	1.14E-06	8.60E-06	5.00E-05	4.02E-04	1.70E-04
FR	2.29E-13	1.56E-12	6.19E-12	6.30E-11	6.86E-10	7.37E-09	1.66E-07	4.11E-07
RA	2.89E-05	1.60E-03	1.49E-02	1.78E-01	1.34E 00	7.78E 00	6.25E 01	2.65E 01
AC	7.35E-06	3.87E-05	8.52E-05	2.55E-04	7.21E-04	2.37E-03	1.70E-02	2.20E-02
TH	4.04E-01	4.26E 00	1.47E 01	5.57E 01	1.74E 02	5.85E 02	4.26E 03	1.15E 04
PA	3.65E-02	7.23E-02	1.44E-01	3.93E-01	1.11E 00	3.60E 00	2.53E 01	3.18E 01
U	5.11E 07	5.12E 07	5.12E 07	5.12E 07	5.12E 07	5.13E 07	5.17E 07	5.17E 07
NP	3.24E 04	4.57E 04	6.97E 04	1.13E 05	1.33E 05	1.33E 05	1.30E 05	9.71E 04
PU	6.25E 05	5.62E 05	5.53E 05	5.34E 05	4.89E 05	3.71E 05	6.43E 04	8.45E 03
AM	5.82E 04	1.02E 05	7.80E 04	3.35E 04	1.12E 04	5.46E 03	1.59E 00	6.66E-04
CM	4.59E 03	9.48E 02	8.51E 02	7.99E 02	6.69E 02	3.62E 02	1.79E 00	1.47E 00
BK	3.38E-06	8.97E-18	8.90E-18	8.65E-18	7.99E-18	6.04E-18	1.68E-19	4.50E-35
CF	2.40E-03	1.87E-03	1.29E-03	3.61E-04	1.98E-05	6.42E-08	5.96E-15	1.60E-30
ES	8.44E-38							
TOTALS	5.19E 07	5.19E 07	5.19E 07	5.19E 07	5.19E 07	5.19E 07	5.19E 07	5.19E 07

Table 4.27. Curies of accumulated heavy isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	5.38E-04	2.81E-03	6.20E-03	1.85E-02	5.23E-02	1.71E-01	1.20E 00	1.51E 00
TL209	1.29E-07	2.09E-06	1.53E-05	2.19E-04	2.60E-03	2.85E-02	6.47E-01	1.60E 00
PB209	5.85E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
PB210	3.65E-06	9.27E-04	1.20E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
PB211	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
PB214	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
BI210	3.65E-06	9.27E-04	1.20E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
BI211	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
BI213	5.85E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
BI214	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
PO210	3.30E-06	9.27E-04	1.20E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
PO213	5.72E-06	9.27E-05	6.80E-04	9.74E-03	1.16E-01	1.27E 00	2.88E 01	7.12E 01
PO214	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
PO215	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
PO218	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
AT217	5.85E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
RN219	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
RN222	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
FR221	5.85E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
RA223	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
RA225	5.84E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
RA226	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
AC225	5.85E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
AC227	5.36E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
TH227	5.31E-04	2.78E-03	6.13E-03	1.83E-02	5.17E-02	1.69E-01	1.19E 00	1.49E 00
TH229	5.82E-06	9.48E-05	6.96E-04	9.96E-03	1.18E-01	1.30E 00	2.94E 01	7.28E 01
TH230	6.45E-03	7.14E-02	2.54E-01	9.77E-01	3.04E 00	9.90E 00	6.16E 01	2.62E 01
TH231	7.92E-01	7.93E-01	7.97E-01	8.11E-01	8.49E-01	9.66E-01	1.47E 00	1.52E 00
TH234	1.70E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01
PA231	1.69E-03	3.37E-03	6.74E-03	1.86E-02	5.24E-02	1.71E-01	1.20E 00	1.52E 00
PA233	2.31E 01	3.22E 01	4.92E 01	7.94E 01	9.35E 01	9.41E 01	9.16E 01	6.84E 01
PA234M	1.70E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01
U233	3.92E-03	1.56E-02	5.08E-02	2.51E-01	1.01E 00	3.76E 00	3.22E 01	7.26E 01
U234	5.51E 01	9.04E 01	1.14E 02	1.21E 02	1.21E 02	1.19E 02	9.59E 01	2.32E 01
U235	7.91E-01	7.93E-01	7.97E-01	8.11E-01	8.49E-01	9.66E-01	1.47E 00	1.52E 00
U236	1.13E 01	1.14E 01	1.16E 01	1.24E 01	1.42E 01	1.83E 01	2.22E 01	2.17E 01
U238	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01	1.69E 01
NP237	2.29E 01	3.22E 01	4.92E 01	7.94E 01	9.35E 01	9.41E 01	9.16E 01	6.84E 01
NP239	2.60E 03	2.57E 03	2.52E 03	2.37E 03	1.98E 03	1.05E 03	3.03E-01	1.28E-04
PU238	1.80E 05	8.37E 04	1.83E 04	1.27E 02	6.00E-03	8.20E-17		
PU239	2.03E 04	2.02E 04	2.01E 04	1.98E 04	1.88E 04	1.57E 04	1.25E 03	1.28E-04
PU240	3.80E 04	3.84E 04	3.76E 04	3.50E 04	2.85E 04	1.39E 04	1.37E 00	1.83E-06
PU241	5.92E 06	5.14E 04	1.40E 02	1.28E 02	1.08E 02	6.02E 01	3.17E-02	
PU242	2.05E 02	2.05E 02	2.05E 02	2.05E 02	2.04E 02	2.01E 02	1.71E 02	3.30E 01
AM241	1.52E 05	3.04E 05	2.22E 05	7.25E 04	3.06E 03	6.03E 01	3.17E-02	
AM242M	2.64E 03	1.67E 03	6.72E 02	2.76E 01	3.02E-03	4.13E-17		
AM242	2.64E 03	1.67E 03	6.72E 02	2.76E 01	3.02E-03	4.13E-17		
AM243	2.59E 03	2.57E 03	2.52E 03	2.37E 03	1.98E 03	1.05E 03	3.03E-01	1.28E-04
CM242	2.22E 03	1.37E 03	5.51E 02	2.26E 01	2.48E-03	3.40E-17		
CM243	2.43E 02	2.79E 01	3.66E-01	9.51E-08	1.46E-26			
CM244	3.01E 05	6.53E 03	3.08E 00	1.15E-10	1.19E-10	1.55E-10	5.80E-10	2.38E-09
CM245	1.39E 02	1.38E 02	1.36E 02	1.28E 02	1.08E 02	6.01E 01	3.14E-02	
CM246	2.64E 01	2.60E 01	2.53E 01	2.28E 01	1.70E 01	6.07E 00	1.08E-05	2.39E-28
TOTAL	6.62E 06	5.15E 05	3.06E 05	1.33E 05	5.52E 04	3.26E 04	2.68E 03	1.20E 03

Table 4.28. Watts of accumulated heavy isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	1.63E-06	8.50E-06	1.87E-05	5.59E-05	1.58E-04	5.17E-04	3.63E-03	4.57E-03
TL209	2.10E-09	3.41E-08	2.50E-07	3.58E-06	4.26E-05	4.66E-04	1.06E-02	2.62E-02
PB209	6.73E-09	1.09E-07	8.00E-07	1.15E-05	1.36E-04	1.49E-03	3.38E-02	8.37E-02
PB210	1.51E-10	3.85E-08	4.97E-07	7.31E-06	5.50E-05	3.19E-04	2.57E-03	1.09E-03
PB211	1.80E-06	9.43E-06	2.08E-05	6.21E-05	1.75E-04	5.73E-04	4.03E-03	5.07E-03
PB214	5.35E-08	3.84E-06	3.60E-05	4.29E-04	3.23E-03	1.88E-02	1.51E-01	6.38E-02
BI210	9.62E-09	2.44E-06	3.16E-05	4.64E-04	3.49E-03	2.03E-02	1.63E-01	6.89E-02
BI211	2.10E-05	1.10E-04	2.42E-04	7.23E-04	2.04E-03	6.68E-03	4.69E-02	5.90E-02
BI213	3.59E-08	5.83E-07	4.28E-06	6.12E-05	7.27E-04	7.97E-03	1.81E-01	4.47E-01
BI214	3.06E-07	2.19E-05	2.06E-04	2.45E-03	1.84E-02	1.07E-01	8.61E-01	3.65E-01
PO210	1.04E-07	2.92E-05	3.77E-04	5.55E-03	4.17E-02	2.42E-01	1.95E 00	8.24E-01
PO213	2.84E-07	4.60E-06	3.38E-05	4.84E-04	5.75E-03	6.30E-02	1.43E 00	3.53E 00
PO214	1.00E-06	7.18E-05	6.73E-04	8.03E-03	6.04E-02	3.51E-01	2.82E 00	1.19E 00
PO215	2.36E-05	1.24E-04	2.72E-04	8.13E-04	2.30E-03	7.51E-03	5.27E-02	6.64E-02
PO218	7.96E-07	5.71E-05	5.35E-04	6.38E-03	4.80E-02	2.79E-01	2.24E 00	9.49E-01
AT217	2.45E-07	3.97E-06	2.92E-05	4.17E-04	4.96E-03	5.43E-02	1.23E 00	3.05E 00
RN219	2.19E-05	1.14E-04	2.52E-04	7.51E-04	2.12E-03	6.94E-03	4.87E-02	6.13E-02
RN222	7.16E-07	5.13E-05	4.81E-04	5.74E-03	4.32E-02	2.51E-01	2.02E 00	8.53E-01
FR221	2.18E-07	3.53E-06	2.59E-05	3.71E-04	4.40E-03	4.82E-02	1.09E 00	2.71E 00
RA223	1.88E-05	9.80E-05	2.16E-04	6.45E-04	1.82E-03	5.96E-03	4.18E-02	5.26E-02
RA225	3.84E-09	6.24E-08	4.58E-07	6.55E-06	7.78E-05	8.53E-04	1.94E-02	4.79E-02
PA226	6.22E-07	4.46E-05	4.18E-04	4.99E-03	3.75E-02	2.18E-01	1.75E 00	7.41E-01
AC225	2.01E-07	3.25E-06	2.39E-05	3.42E-04	4.06E-03	4.45E-02	1.01E 00	2.50E 00
AC227	2.70E-07	1.42E-06	3.13E-06	9.35E-06	2.64E-05	8.64E-05	6.07E-04	7.63E-04
TH227	1.83E-05	9.57E-05	2.11E-04	6.30E-04	1.78E-03	5.82E-03	4.08E-02	5.14E-02
TH229	1.76E-07	2.87E-06	2.10E-05	3.01E-04	3.58E-03	3.92E-02	8.89E-01	2.20E 00
TH230	1.82E-04	2.02E-03	7.17E-03	2.76E-02	8.58E-02	2.80E-01	1.74E 00	7.40E-01
TH231	6.24E-04	6.25E-04	6.29E-04	6.39E-04	6.69E-04	7.62E-04	1.16E-03	1.19E-03
TH234	6.05E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03	6.00E-03
PA231	5.14E-05	1.03E-04	2.06E-04	5.66E-04	1.60E-03	5.23E-03	3.67E-02	4.62E-02
PA233	3.12E-02	4.35E-02	6.65E-02	1.07E-01	1.26E-01	1.27E-01	1.24E-01	9.25E-02
PA234M	8.75E-02	8.67E-02	8.67E-02	8.67E-02	8.67E-02	8.67E-02	8.67E-02	8.68E-02
U233	1.14E-04	4.54E-04	1.48E-03	7.31E-03	2.95E-02	1.09E-01	9.38E-01	2.11E 00
U234	1.59E 00	2.60E 00	3.29E 00	3.49E 00	3.47E 00	3.41E 00	2.76E 00	6.67E-01
U235	2.20E-02	2.20E-02	2.21E-02	2.25E-02	2.35E-02	2.68E-02	4.09E-02	4.20E-02
U236	3.07E-01	3.10E-01	3.16E-01	3.36E-01	3.85E-01	4.97E-01	6.03E-01	5.87E-01
U238	4.26E-01	4.26E-01	4.26E-01	4.26E-01	4.26E-01	4.26E-01	4.27E-01	4.27E-01
NP237	6.72E-01	9.47E-01	1.44E 00	2.33E 00	2.75E 00	2.76E 00	2.69E 00	2.01E 00
NP239	3.51E 00	3.47E 00	3.41E 00	3.20E 00	2.67E 00	1.42E 00	4.10E-04	1.73E-07
PU238	5.97E 03	2.77E 03	6.05E 02	4.21E 00	1.99E-04	2.72E-18		
PU239	6.31E 02	6.29E 02	6.26E 02	6.15E 02	5.85E 02	4.88E 02	3.90E 01	3.98E-06
PU240	1.18E 03	1.20E 03	1.17E 03	1.09E 03	8.89E 02	4.34E 02	4.26E-02	5.71E-08
PU241	2.45E 02	2.13E 00	5.80E-03	5.31E-03	4.49E-03	2.50E-03	1.32E-06	
PU242	6.04E 00	6.04E 00	6.04E 00	6.04E 00	6.02E 00	5.95E 00	5.05E 00	9.73E-01
AM241	5.08E 03	1.01E 04	7.41E 03	2.42E 03	1.02E 02	2.01E 00	1.06E-03	
AM242M	7.51E-01	4.76E-01	1.91E-01	7.85E-03	8.59E-07	1.18E-20		
AM242	3.52E 00	2.23E 00	8.96E-01	3.68E-02	4.03E-06	5.51E-20		
AM243	9.46E 01	9.38E 01	9.21E 01	8.64E 01	7.21E 01	3.82E 01	1.11E-02	4.68E-06
CM242	8.18E 01	5.05E 01	2.03E 01	8.34E-01	9.15E-05	1.25E-18		
CM243	8.93E 00	1.02E 00	1.35E-02	3.50E-09	5.36E-28			
CM244	1.05E 04	2.28E 02	1.08E-01	4.04E-12	4.16E-12	5.43E-12	2.03E-11	8.34E-11
CM245	4.36E 00	4.33E 00	4.26E 00	4.01E 00	3.39E 00	1.89E 00	9.87E-04	
CM246	8.67E-01	8.54E-01	8.29E-01	7.48E-01	5.57E-01	1.99E-01	3.53E-07	7.83E-30
TOTAL	2.38E 04	1.51E 04	9.95E 03	4.24E 03	1.67E 03	9.81E 02	7.16E 01	2.78E 01

Table 4.29. Ingestion toxicity (m^3 water) of accumulated heavy isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	6.73E-02	3.51E-01	7.75E-01	2.31E 00	6.54E 00	2.14E 01	1.50E 02	1.89E 02
TL209	1.29E-05	2.09E-04	1.53E-03	2.19E-02	2.60E-01	2.85E 00	6.47E 01	1.60E 02
PB209	1.95E-03	3.16E-02	2.32E-01	3.32E 00	3.94E 01	4.32E 02	9.81E 03	2.43E 04
PB210	3.65E 01	9.27E 03	1.20E 05	1.76E 06	1.32E 07	7.70E 07	6.19E 08	2.62E 08
PB211	1.35E 00	7.05E 00	1.55E 01	4.64E 01	1.31E 02	4.29E 02	3.01E 03	3.79E 03
PB214	4.40E-02	3.15E 00	2.96E 01	3.52E 02	2.65E 03	1.54E 04	1.24E 05	5.24E 04
BI210	9.13E-02	2.32E 01	3.00E 02	4.41E 03	3.31E 04	1.92E 05	1.55E 06	6.55E 05
BI211	7.71E-02	4.03E-01	8.98E-01	2.65E 00	7.49E 00	2.45E 01	1.72E 02	2.16E 02
BI213	1.17E-02	1.90E-01	1.39E 00	1.99E 01	2.37E 02	2.59E 03	5.88E 04	1.46E 05
BI214	3.66E-02	2.63E 00	2.46E 01	2.94E 02	2.21E 03	1.28E 04	1.03E 05	4.36E 04
PO210	4.72E 00	1.32E 03	1.71E 04	2.52E 05	1.89E 06	1.10E 07	8.84E 07	3.74E 07
PO213	5.72E-06	9.27E-05	6.80E-04	9.74E-03	1.16E-01	1.27E 00	2.88E 01	7.12E 01
PO214	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
PO215	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
PO218	5.49E-03	3.94E-01	3.69E 00	4.41E 01	3.31E 02	1.92E 03	1.55E 04	6.55E 03
AT217	9.75E-06	1.58E-04	1.16E-03	1.66E-02	1.97E-01	2.16E 00	4.90E 01	1.21E 02
RN219	5.40E-04	2.82E-03	6.22E-03	1.86E-02	5.25E-02	1.71E-01	1.20E 00	1.52E 00
RN222	2.20E-05	1.58E-03	1.48E-02	1.76E-01	1.32E 00	7.70E 00	6.19E 01	2.62E 01
FR221	7.31E-03	1.19E-01	8.70E-01	1.25E 01	1.48E 02	1.62E 03	3.68E 04	9.10E 04
PA223	7.71E 02	4.03E 03	8.88E 03	2.65E 04	7.49E 04	2.45E 05	1.72E 06	2.16E 06
RA225	1.17E 01	1.90E 02	1.39E 03	1.99E 04	2.37E 05	2.59E 06	5.88E 07	1.46E 08
RA226	7.32E 02	5.25E 04	4.93E 05	5.87E 06	4.42E 07	2.57E 08	2.06E 09	8.73E 08
AC225	1.17E 00	1.90E 01	1.39E 02	1.99E 03	2.37E 04	2.59E 05	5.88E 06	1.46E 07
AC227	2.68E 02	1.41E 03	3.11E 03	9.28E 03	2.62E 04	8.57E 04	6.02E 05	7.58E 05
TH227	2.66E 01	1.39E 02	3.06E 02	9.15E 02	2.59E 03	8.45E 03	5.94E 04	7.47E 04
TH229	1.45E 01	2.37E 02	1.74E 03	2.49E 04	2.96E 05	3.24E 06	7.35E 07	1.82E 08
TH230	3.22E 03	3.57E 04	1.27E 05	4.89E 05	1.52E 06	4.95E 06	3.08E 07	1.31E 07
TH231	3.96E 03	3.97E 03	3.99E 03	4.05E 03	4.24E 03	4.83E 03	7.37E 03	7.58E 03
TH234	8.50E 05	8.43E 05	8.43E 05	8.43E 05	8.43E 05	8.43E 05	8.43E 05	8.43E 05
PA231	1.87E 03	3.74E 03	7.49E 03	2.06E 04	5.83E 04	1.91E 05	1.34E 06	1.68E 06
PA233	2.31E 05	3.22E 05	4.92E 05	7.94E 05	9.35E 05	9.41E 05	9.16E 05	6.84E 05
PA234M	8.50E 02	8.43E 02	8.43E 02	8.43E 02	8.43E 02	8.43E 02	8.43E 02	8.43E 02
U233	1.31E 02	5.20E 02	1.69E 03	8.37E 03	3.38E 04	1.25E 05	1.07E 06	2.42E 06
U234	1.84E 06	3.01E 06	3.82E 06	4.04E 06	4.02E 06	3.95E 06	3.20E 06	7.73E 05
U235	2.64E 04	2.64E 04	2.66E 04	2.70E 04	2.83E 04	3.22E 04	4.91E 04	5.05E 04
U236	3.77E 05	3.81E 05	3.88E 05	4.13E 05	4.74E 05	6.12E 05	7.41E 05	7.22E 05
U238	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.22E 05
NP237	7.63E 06	1.07E 07	1.64E 07	2.65E 07	3.12E 07	3.14E 07	3.05E 07	2.28E 07
NP239	2.60E 07	2.57E 07	2.52E 07	2.37E 07	1.98E 07	1.05E 07	3.03E 03	1.28E 00
PU238	3.61E 10	1.67E 10	3.65E 09	2.54E 07	1.20E 03	1.64E-11		
PU239	4.06E 09	4.05E 09	4.03E 09	3.96E 09	3.76E 09	3.14E 09	2.51E 08	2.56E 01
PU240	7.60E 09	7.68E 09	7.53E 09	7.01E 09	5.71E 09	2.78E 09	2.73E 05	3.67E-01
PU241	2.96E 10	2.57E 08	6.98E 05	6.40E 05	5.42E 05	3.01E 05	1.59E 02	
PU242	4.09E 07	4.09E 07	4.09E 07	4.09E 07	4.08E 07	4.03E 07	3.42E 07	6.59E 06
AM241	3.81E 10	7.60E 10	5.55E 10	1.81E 10	7.64E 08	1.51E 07	7.93E 03	
AM242M	6.60E 08	4.18E 08	1.68E 08	6.90E 06	7.55E 02	1.03E-11		
AM242	2.64E 07	1.67E 07	6.72E 06	2.76E 05	3.02E 01	4.13E-13		
AM243	6.48E 08	6.42E 08	6.31E 08	5.92E 08	4.94E 08	2.62E 08	7.58E 04	3.20E 01
CM242	1.11E 08	6.86E 07	2.75E 07	1.13E 06	1.24E 02	1.70E-12		
CM243	4.86E 07	5.57E 06	7.32E 04	1.90E-02	2.91E-21			
CM244	4.30E 10	9.33E 08	4.40E 05	1.65E-05	1.70E-05	2.22E-05	8.28E-05	3.41E-04
CM245	3.48E 07	3.45E 07	3.39E 07	3.20E 07	2.70E 07	1.50E 07	7.86E 03	
CM246	6.60E 06	6.51E 06	6.32E 06	5.70E 06	4.25E 06	1.52E 06	2.69E 00	5.96E-23
TOTAL	1.60E 11	1.07E 11	7.17E 10	2.99E 10	1.09E 10	6.66E 09	3.27E 09	1.57E 09

Table 4.30. Grams of accumulated fission product elements in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
GE	2.12E 01	2.12E 01	2.12E 01	2.12E 01	2.12E 01	2.12E 01	2.12E 01	2.12E 01
AS	6.40E 00	6.40E 00	6.40E 00	6.40E 00	6.40E 00	6.40E 00	6.40E 00	6.40E 00
SE	2.78E 03	2.78E 03	2.78E 03	2.78E 03	2.77E 03	2.75E 03	2.60E 03	2.50E 03
BR	1.11E 03	1.11E 03	1.11E 03	1.11E 03	1.12E 03	1.14E 03	1.29E 03	1.39E 03
RB	1.61E 04	1.61E 04	1.61E 04	1.61E 04	1.61E 04	1.61E 04	1.61E 04	1.61E 04
SR	3.56E 04	1.80E 04	1.64E 04	1.64E 04	1.64E 04	1.64E 04	1.64E 04	1.64E 04
Y	2.17E 04	2.17E 04	2.17E 04	2.17E 04	2.17E 04	2.17E 04	2.17E 04	2.17E 04
ZR	1.80E 05	1.98E 05	2.00E 05	2.00E 05	2.00E 05	2.00E 05	1.98E 05	1.87E 05
NB	2.39E-01	1.86E 00	5.09E 00	1.64E 01	4.87E 01	1.62E 02	1.58E 03	1.29E 04
MO	1.73E 05	1.73E 05	1.73E 05	1.73E 05	1.73E 05	1.73E 05	1.73E 05	1.73E 05
TC	4.27E 04	4.27E 04	4.26E 04	4.25E 04	4.23E 04	4.13E 04	3.08E 04	1.62E 03
RU	1.14E 05	1.14E 05	1.14E 05	1.14E 05	1.14E 05	1.15E 05	1.26E 05	1.55E 05
RH	2.43E 04	2.43E 04	2.43E 04	2.43E 04	2.43E 04	2.43E 04	2.43E 04	2.43E 04
PD	8.31E 04	8.31E 04	8.31E 04	8.31E 04	8.31E 04	8.31E 04	8.30E 04	8.19E 04
AG	3.61E 03	3.61E 03	3.61E 03	3.61E 03	3.61E 03	3.62E 03	3.74E 03	4.83E 03
CD	5.17E 03	5.16E 03	5.16E 03	5.16E 03	5.16E 03	5.16E 03	5.16E 03	5.16E 03
IN	7.14E 01	7.65E 01	7.65E 01	7.65E 01	7.65E 01	7.65E 01	7.65E 01	7.65E 01
SN	2.73E 03	2.73E 03	2.73E 03	2.72E 03	2.71E 03	2.65E 03	2.16E 03	1.59E 03
SB	5.19E 02	4.76E 02	4.76E 02	4.76E 02	4.76E 02	4.76E 02	4.76E 02	4.76E 02
TE	2.52E 04	2.53E 04	2.53E 04	2.53E 04	2.53E 04	2.54E 04	2.59E 04	2.64E 04
I	1.30E 04	1.30E 04	1.30E 04	1.30E 04	1.30E 04	1.30E 04	1.29E 04	1.26E 04
XE	6.39E-03	4.86E-02	1.33E-01	4.28E-01	1.27E 00	4.22E 00	4.21E 01	4.13E 02
CS	1.22E 05	7.82E 04	7.34E 04	7.33E 04	7.33E 04	7.33E 04	7.29E 04	6.93E 04
BA	9.60E 04	1.40E 05	1.45E 05	1.45E 05	1.45E 05	1.45E 05	1.46E 05	1.49E 05
LA	6.20E 04	6.20E 04	6.20E 04	6.20E 04	6.20E 04	6.20E 04	6.20E 04	6.20E 04
CE	1.21E 05	1.21E 05	1.21E 05	1.21E 05	1.21E 05	1.21E 05	1.21E 05	1.21E 05
PR	5.77E 04	5.77E 04	5.77E 04	5.77E 04	5.77E 04	5.77E 04	5.77E 04	5.77E 04
ND	2.03E 05	2.03E 05	2.03E 05	2.03E 05	2.03E 05	2.03E 05	2.03E 05	2.03E 05
PM	4.42E 02	1.43E-09						
SM	4.48E 04	4.40E 04	4.32E 04	4.30E 04	4.30E 04	4.30E 04	4.30E 04	4.30E 04
EU	8.29E 03	8.02E 03	8.78E 03	8.98E 03	8.98E 03	8.98E 03	8.98E 03	8.98E 03
GD	6.45E 03	7.91E 03	7.93E 03	7.93E 03	7.93E 03	7.93E 03	7.93E 03	7.93E 03
TB	1.08E 02	1.08E 02	1.08E 02	1.08E 02	1.08E 02	1.08E 02	1.08E 02	1.08E 02
DY	7.72E 01	7.72E 01	7.72E 01	7.72E 01	7.72E 01	7.72E 01	7.72E 01	7.72E 01
HO	7.24E 00	7.24E 00	7.24E 00	7.23E 00	7.22E 00	7.21E 00	7.21E 00	7.21E 00
ER	1.91E 00	1.91E 00	1.92E 00	1.92E 00	1.93E 00	1.94E 00	1.94E 00	1.94E 00
TOTALS	1.47E 06	1.47E 06	1.47E 06	1.47E 06	1.47E 06	1.47E 06	1.47E 06	1.47E 06

Table 4.31. Curies of accumulated fission product isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	1.95E 01	1.94E 01	1.94E 01	1.93E 01	1.88E 01	1.75E 01	6.70E 00	4.55E-04
SR 90	2.72E 06	2.31E 05	1.67E 03	5.28E-05	1.98E-26			
Y 90	2.73E 06	2.31E 05	1.67E 03	5.28E-05	1.98E-26			
ZR 93	8.97E 01	8.97E 01	8.97E 01	8.97E 01	8.96E 01	8.93E 01	8.57E 01	5.65E 01
NB 93M	4.59E 01	8.94E 01	8.97E 01	8.97E 01	8.96E 01	8.93E 01	8.57E 01	5.65E 01
TC 99	7.27E 02	7.27E 02	7.27E 02	7.25E 02	7.20E 02	7.04E 02	5.24E 02	2.77E 01
RU106	9.45E 04							
RH106	9.45E 04							
PD107	6.19E 00	6.19E 00	6.19E 00	6.19E 00	6.19E 00	6.18E 00	6.13E 00	5.61E 00
SB125	4.56E 04	3.23E-07						
TE125M	1.89E 04	1.34E-07						
SN126	3.24E 01	3.24E 01	3.24E 01	3.22E 01	3.18E 01	3.03E 01	1.62E 01	3.17E-02
SB126M	3.24E 01	3.24E 01	3.24E 01	3.22E 01	3.18E 01	3.03E 01	1.62E 01	3.17E-02
SB126	3.23E 01	3.21E 01	3.21E 01	3.19E 01	3.15E 01	3.00E 01	1.61E 01	3.14E-02
I129	1.69E 00	1.69E 00	1.69E 00	1.69E 00	1.69E 00	1.69E 00	1.68E 00	1.62E 00
CS134	5.27E 05	1.09E-09						
CS135	1.75E 01	1.75E 01	1.75E 01	1.75E 01	1.75E 01	1.74E 01	1.71E 01	1.39E 01
CS137	4.23E 06	4.20E 05	4.13E 03	3.91E-04	3.33E-24			
BA137M	3.96E 06	3.93E 05	3.87E 03	3.66E-04	3.12E-24			
CE144	4.19E 04							
PR144	4.19E 04							
PM147	4.10E 05	1.33E-06						
SM151	5.90E 04	2.66E 04	5.40E 03	2.04E 01	2.45E-06			
EU152	4.02E 02	1.25E 00	1.20E-05	3.30E-23				
EU154	2.13E 05	2.80E 03	4.83E-01	3.26E-14				
EU155	1.34E 04	3.12E-13						
HO166M	5.17E-02	4.88E-02	4.35E-02	2.90E-02	9.14E-03	1.60E-04	4.24E-27	
TOTAL	1.52E 07	1.31E 06	1.78E 04	1.07E 03	1.04E 03	1.02E 03	7.76E 02	1.62E 02

Table 4.32. Watts of accumulated fission product isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	7.38E-03	7.38E-03	7.36E-03	7.30E-03	7.15E-03	6.64E-03	2.54E-03	1.73E-07
SR 90	3.57E 03	3.03E 02	2.18E 00	6.91E-08	2.59E-29			
Y 90	1.61E 04	1.36E 03	9.80E 00	3.11E-07	1.16E-28			
ZR 93	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.02E-02	6.70E-03
NB 93M	8.17E-03	1.59E-02	1.60E-02	1.59E-02	1.59E-02	1.59E-02	1.52E-02	1.01E-02
TC 99	4.91E-01	4.91E-01	4.91E-01	4.90E-01	4.87E-01	4.76E-01	3.54E-01	1.87E-02
RU106	5.60E 00							
RH106	9.93E 02							
PD107	5.14E-04	5.14E-04	5.14E-04	5.14E-04	5.13E-04	5.13E-04	5.09E-04	4.65E-04
SB125	1.85E 02	1.31E-09						
TE125M	3.25E 01	2.30E-10						
SN126	3.50E-02	3.50E-02	3.49E-02	3.48E-02	3.43E-02	3.27E-02	1.75E-02	3.42E-05
SB126M	2.19E-01	2.19E-01	2.19E-01	2.18E-01	2.15E-01	2.05E-01	1.10E-01	2.14E-04
SB126	4.20E-01	4.18E-01	4.17E-01	4.15E-01	4.09E-01	3.90E-01	2.09E-01	4.08E-04
I129	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.11E-03	1.07E-03
CS134	5.58E 03	1.15E-11						
CS135	8.49E-03	8.49E-03	8.49E-03	8.49E-03	8.49E-03	8.47E-03	8.30E-03	6.74E-03
CS137	6.93E 03	6.87E 02	6.76E 00	6.40E-07	5.46E-27			
BA137M	1.56E 04	1.54E 03	1.52E 01	1.44E-06	1.23E-26			
CE144	3.43E 01							
PR144	3.25E 02							
PM147	2.12E 02	6.85E-10						
SM151	1.03E 02	4.63E 01	9.41E 00	3.56E-02	4.27E-09			
EU152	7.21E 00	2.24E-02	2.15E-07	5.92E-25				
EU154	1.75E 03	2.30E 01	3.96E-03	2.68E-16				
EU155	1.12E 01	2.63E-16						
HO166M	5.56E-04	5.25E-04	4.68E-04	3.12E-04	9.83E-05	1.72E-06	4.56E-29	
TOTAL	5.13E 04	3.96E 03	4.46E 01	1.24E 00	1.19E 00	1.15E 00	7.28E-01	4.44E-02

Table 4.33. Ingestion toxicity (m^3 water) of accumulated fission product isotopes in the cladding wastes at a federal repository in the year 2005 as a function of age

	Year 2005	Years following close of the repository						
		100	300	1000	3000	10,000	100,000	1,000,000
SE 79	1.95E 01	1.94E 01	1.94E 01	1.93E 01	1.88E 01	1.75E 01	6.70E 00	4.55E-04
SR 90	9.08E 12	7.70E 11	5.55E 09	1.76E 02	6.59E-20			
Y 90	1.36E 11	1.16E 10	8.33E 07	2.64E 00	9.89E-22			
ZR 93	1.12E 05	1.12E 05	1.12E 05	1.12E 05	1.12E 05	1.12E 05	1.07E 05	7.06E 04
NB 93M	1.15E 05	2.24E 05	2.24E 05	2.24E 05	2.24E 05	2.23E 05	2.14E 05	1.41E 05
TC 99	3.64E 06	3.64E 06	3.63E 06	3.62E 06	3.60E 06	3.52E 06	2.62E 06	1.38E 05
RU106	9.45E 09							
RH106	9.45E 04							
PD107	6.19E 03	6.19E 03	6.19E 03	6.19E 03	6.19E 03	6.18E 03	6.13E 03	5.61E 03
SB125	4.56E 08	3.23E-03						
TE125M	1.89E 08	1.34E-03						
SN126	3.24E 01	3.24E 01	3.24E 01	3.22E 01	3.18E 01	3.03E 01	1.62E 01	3.17E-02
SB126M	3.24E 01	3.24E 01	3.24E 01	3.22E 01	3.18E 01	3.03E 01	1.62E 01	3.17E-02
SB126	3.23E 01	3.21E 01	3.21E 01	3.19E 01	3.15E 01	3.00E 01	1.61E 01	3.14E-02
I129	2.81E 07	2.81E 07	2.81E 07	2.81E 07	2.81E 07	2.81E 07	2.80E 07	2.70E 07
CS134	5.86E 10	1.21E-04						
CS135	1.75E 05	1.75E 05	1.75E 05	1.75E 05	1.75E 05	1.74E 05	1.71E 05	1.39E 05
CS137	2.12E 11	2.10E 10	2.07E 08	1.95E 01	1.67E-19			
BA137M	3.96E 06	3.93E 05	3.87E 03	3.66E-04	3.12E-24			
CE144	4.19E 09							
PR144	4.19E 04							
PM147	2.05E 09	6.64E-03						
SM151	1.47E 08	6.65E 07	1.35E 07	5.10E 04	6.13E-03			
EU152	5.03E 06	1.56E 04	1.50E-01	4.13E-19				
EU154	1.06E 10	1.40E 08	2.41E 04	1.63E-09				
EU155	6.68E 07	1.56E-09						
HO166M	5.17E-02	4.88E-02	4.35E-02	2.90E-02	9.14E-03	1.60E-04	4.24E-27	
TOTAL	9.51E 12	8.03E 11	5.89E 09	3.23E 07	3.22E 07	3.21E 07	3.11E 07	2.75E 07

the upper range of alpha-emitting isotopes in naturally occurring deposits. It is reasonable that wastes containing less alpha activity than 10 nCi/g be regarded as disposable in carefully selected burial grounds, whereas alpha wastes must be stored in special repositories that offer maximal assurance of permanent containment. These wastes arise at fuel reprocessing plants and consist of an assortment of materials similar to the low-level TRU wastes discussed below. About 10,000 ft^3 of intermediate-level TRU wastes is generated per ton of plutonium or ^{233}U processed. These wastes contain an average of 0.025 g of plutonium or uranium per cubic foot,[26] plus an assumed 0.025% of the fission products in the spent fuel.

Shipments and accumulations of intermediate-level TRU solid wastes at one or more federal repositories are presented in Table 4.34. The wastes are compacted on the same schedule as is assumed for the low-level TRU wastes below. They are packaged in steel canisters 2 ft in diam by 10 ft long and transported by motor freight five years following the date of waste generation. Each shipment consists of three such canisters (containing a total of 75 ft^3 of waste) in a lightly shielded cask.

The accumulated mass, radioactivity, thermal power, and ingestion toxicity of the intermediate-level TRU wastes as a function of time following the year 2005 are presented in Tables 4.35 through 4.38 for actinides, and in Tables 4.39 through 4.42 for fission products.

4.4 Low-Level Transuranic Wastes

Low-level TRU wastes are defined as those solid materials that contain plutonium or other long-lived alpha emitters in concentrations greater than 10 nCi/g and yet have sufficiently low external radiation levels that they can be handled directly without supplementary shielding (surface dose rates less than 10 mrem/hr).

Low-level TRU wastes arise principally at fuel preparation and fabrication plants, and to a lesser extent at fuel reprocessing plants.[26,27] They consist of a wide assortment of solid materials, including items

Table 4.34. Projected annual accumulation of intermediate-level transuranium waste at a federal repository

Year	* * * * Annual Addition * * * * * Volume (Thousands of m^3)	Actinide Mass (kg)	Radio-activity (MCi)	Thermal Power (kW)	Annual Number of Shipments	* * * * * Accumulation Through End of Year * * * * * Volume (Thousands of m^3)	Actinide Mass (kg)	Radio-activity (MCi)	Thermal Power (kW)	Hazard, Cubic Meters at RCG Air	Water
1984	0.0	0.0	0.0	0.0	0	0.0	0	0.00	0.0	1.2E 13	4.1E 07
1985	0.0	0.0	0.0	0.0	2	0.0	0	0.00	0.0	3.3E 13	1.2E 08
1986	0.3	0.8	0.0	0.2	150	0.3	1	0.05	0.2	5.9E 15	2.1E 10
1987	0.7	2.6	0.1	0.5	340	1.0	3	0.18	0.6	2.4E 16	8.4E 10
1988	0.8	2.8	0.2	0.5	372	1.8	6	0.32	1.0	4.3E 16	1.5E 11
1989	0.7	3.0	0.2	0.6	324	2.5	9	0.46	1.5	6.4E 16	2.2E 11
1990	1.0	4.3	0.2	0.8	454	3.5	13	0.67	2.1	9.4E 16	3.3E 11
1991	1.0	6.7	0.4	1.2	477	4.5	20	0.97	3.1	1.4E 17	4.8E 11
1992	1.1	7.0	0.3	1.2	501	5.6	27	1.25	4.0	1.8E 17	6.2E 11
1993	1.0	8.9	0.4	1.3	475	6.6	36	1.58	5.0	2.3E 17	7.9E 11
1994	1.3	11.0	0.5	1.7	589	7.8	47	1.99	6.3	2.9E 17	1.0E 12
1995	1.4	12.1	0.6	1.9	645	9.2	59	2.44	7.7	3.6E 17	1.2E 12
1996	1.7	14.8	0.7	2.3	790	10.9	74	2.99	9.4	4.5E 17	1.5E 12
1997	1.8	15.8	0.8	2.5	840	12.7	90	3.58	11.3	5.4E 17	1.8E 12
1998	2.1	18.7	0.9	3.0	995	14.8	108	4.27	13.4	6.5E 17	2.2E 12
1999	2.4	21.4	1.0	3.2	1143	17.2	130	4.99	15.6	7.6E 17	2.6E 12
2000	2.9	25.3	1.1	3.7	1349	20.1	155	5.81	18.2	8.9E 17	3.0E 12
2001	3.1	27.2	1.1	3.9	1449	23.1	182	6.66	20.8	1.0E 18	3.4E 12
2002	3.5	30.6	1.3	4.4	1632	26.6	213	7.64	23.9	1.2E 18	4.0E 12
2003	3.7	32.9	1.5	4.9	1755	30.3	246	8.71	27.2	1.4E 18	4.5E 12
2004	3.7	32.6	1.3	4.5	1740	34.0	279	9.62	30.0	1.5E 18	5.0E 12
2005	3.9	34.2	1.3	4.2	1825	37.9	313	10.40	32.4	1.7E 18	5.5E 12
TIME AFTER SHUTDOWN, YEARS											
100						37.9	313	0.86	6.5	9.8E 17	4.9E 11
300						37.9	313	0.11	3.2	7.5E 17	2.7E 10
1000						37.9	313	0.05	1.5	4.6E 17	1.0E 10
3000						37.9	313	0.02	0.6	3.0E 17	3.9E 09
10000						37.9	313	0.01	0.4	1.9E 17	2.4E 09
30000						37.9	313	0.01	0.1	7.5E 16	1.3E 09
100000						37.9	313	0.00	0.0	1.1E 16	9.5E 08
300000						37.9	313	0.00	0.0	2.5E 15	1.1E 09
1000000						37.9	313	0.00	0.0	2.1E 15	6.5E 08

Table 4.35. Grams of accumulated heavy elements in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
HE	1.17E 01	1.18E 02	2.94E 02	6.53E 02	1.07E 03	1.86E 03	4.08E 03	6.74E 03
TL	8.39E-10	3.94E-10	7.48E-11	5.64E-11	1.61E-10	5.39E-10	3.92E-09	5.66E-09
PB	2.29E-03	2.34E-02	3.50E-02	4.61E-02	2.15E-01	3.67E 00	3.99E 02	6.30E 03
BI	5.98E-08	1.07E-06	1.78E-05	6.57E-04	2.09E-02	7.87E-01	2.43E 02	1.09E 04
PO	3.72E-10	8.84E-08	9.31E-07	1.13E-05	7.91E-05	4.49E-04	3.66E-03	2.33E-03
AT	2.03E-18	3.65E-17	2.54E-16	3.12E-15	3.30E-14	3.44E-13	7.64E-12	1.89E-11
RN	8.12E-10	4.62E-09	3.31E-08	3.30E-07	2.31E-06	1.31E-05	1.07E-04	6.82E-05
FR	1.20E-13	8.98E-13	3.61E-12	3.25E-11	3.14E-10	3.19E-09	7.02E-08	1.73E-07
RA	1.54E-05	6.68E-04	5.14E-03	5.14E-02	3.61E-01	2.05E 00	1.67E 01	1.06E 01
AC	3.80E-06	2.12E-05	4.82E-05	1.46E-04	4.14E-04	1.34E-03	8.69E-03	1.10E-02
TH	2.10E-01	1.78E 00	5.12E 00	1.72E 01	5.20E 01	1.74E 02	1.37E 03	5.40E 03
PA	1.93E-02	4.00E-02	8.13E-02	2.25E-01	6.34E-01	2.03E 00	1.30E 01	1.60E 01
U	2.56E 07	2.56E 07	2.56E 07	2.56E 07	2.57E 07	2.57E 07	2.58E 07	2.58E 07
NP	2.27E 04	2.72E 04	3.52E 04	4.96E 04	5.62E 04	5.63E 04	5.47E 04	4.09E 04
PU	2.33E 05	2.13E 05	2.10E 05	2.04E 05	1.86E 05	1.41E 05	1.84E 04	1.92E 03
AM	1.72E 04	3.21E 04	2.40E 04	9.27E 03	2.13E 03	9.77E 02	2.81E-01	4.79E-06
CM	4.39E 02	1.71E 01	7.42E 00	6.95E 00	5.81E 00	3.13E 00	1.30E-02	1.05E-02
BK	1.30E-08	1.05E-19	1.04E-19	1.01E-19	9.35E-20	7.07E-20	1.96E-21	5.27E-37
CF	1.15E-05	8.83E-06	6.08E-06	1.73E-06	1.01E-07	3.39E-10	6.98E-17	1.88E-32
ES	6.03E-40							
TOTALS	2.59E 07	2.59E 07	2.59E 07	2.59E 07	2.59E 07	2.59E 07	2.59E 07	2.59E 07

Table 4.36. Curies of accumulated heavy isotopes in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	2.78E-04	1.54E-03	3.50E-03	1.06E-02	3.00E-02	9.65E-02	6.16E-01	7.61E-01
TL209	7.26E-08	1.30E-06	9.09E-06	1.12E-04	1.18E-03	1.23E-02	2.73E-01	6.75E-01
PB209	3.30E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
PB210	1.84E-06	3.99E-04	4.19E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
PB211	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
PB214	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
BI210	1.84E-06	3.99E-04	4.19E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
BI211	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
BI213	3.30E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
BI214	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
PO210	1.67E-06	3.99E-04	4.19E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
PO213	3.23E-06	5.79E-05	4.04E-04	4.96E-03	5.25E-02	5.46E-01	1.21E 01	3.00E 01
PO214	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
PO215	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
PO218	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
AT217	3.30E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
RN219	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
RN222	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
FR221	3.30E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
RA223	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
RA225	3.29E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
RA226	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
AC225	3.30E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
AC227	2.77E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
TH227	2.75E-04	1.52E-03	3.46E-03	1.05E-02	2.97E-02	9.54E-02	6.09E-01	7.53E-01
TH229	3.28E-06	5.92E-05	4.13E-04	5.07E-03	5.37E-02	5.59E-01	1.24E 01	3.07E 01
TH230	3.23E-03	2.76E-02	8.02E-02	2.70E-01	8.08E-01	2.60E 00	1.64E 01	1.05E 01
TH231	4.60E-01	4.61E-01	4.62E-01	4.68E-01	4.84E-01	5.34E-01	7.46E-01	7.63E-01
TH234	8.50E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00
PA231	8.81E-04	1.86E-03	3.82E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
PA233	1.62E 01	1.92E 01	2.48E 01	3.49E 01	3.96E 01	3.97E 01	3.86E 01	2.88E 01
PA234M	8.50E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00
U233	2.29E-03	9.77E-03	2.87E-02	1.21E-01	4.47E-01	1.61E 00	1.36E 01	3.06E 01
U234	2.65E 01	2.93E 01	3.11E 01	3.16E 01	3.15E 01	3.10E 01	2.60E 01	9.84E 00
U235	4.60E-01	4.61E-01	4.62E-01	4.68E-01	4.84E-01	5.34E-01	7.46E-01	7.63E-01
U236	6.99E 00	7.02E 00	7.10E 00	7.35E 00	7.96E 00	9.35E 00	1.07E 01	1.04E 01
U238	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00	8.43E 00
NP237	1.60E 01	1.92E 01	2.48E 01	3.49E 01	3.96E 01	3.97E 01	3.86E 01	2.88E 01
NP239	4.65E 02	4.61E 02	4.52E 02	4.25E 02	3.54E 02	1.88E 02	5.41E-02	9.22E-07
PU238	1.40E 04	6.48E 03	1.41E 03	9.47E 00	4.20E-04	5.74E-18		
PU239	8.70E 03	8.68E 03	8.63E 03	8.47E 03	8.02E 03	6.62E 03	5.20E 02	9.26E-07
PU240	1.30E 04	1.29E 04	1.27E 04	1.18E 04	9.61E 03	4.69E 03	4.60E-01	1.06E-08
PU241	1.98E 06	1.72E 04	2.47E 00	1.10E 00	9.33E-01	5.19E-01	2.74E-04	
PU242	4.66E 01	4.66E 01	4.66E 01	4.65E 01	4.64E 01	4.58E 01	3.88E 01	7.49E 00
AM241	5.08E 04	1.02E 05	7.42E 04	2.42E 04	9.86E 02	5.32E-01	2.74E-04	
AM242M	1.85E 02	1.17E 02	4.70E 01	1.93E 00	2.11E-04	2.89E-18		
AM242	1.85E 02	1.17E 02	4.70E 01	1.93E 00	2.11E-04	2.89E-18		
AM243	4.65E 02	4.61E 02	4.52E 02	4.25E 02	3.54E 02	1.88E 02	5.41E-02	9.22E-07
CM242	1.61E 02	9.60E 01	3.86E 01	1.58E 00	1.74E-04	2.38E-18		
CM243	6.18E 01	7.08E 00	9.31E-02	2.42E-08	3.71E-27			
CM244	3.48E 04	7.57E 02	3.57E-01	8.45E-13	9.52E-14	3.14E-13	2.88E-12	1.39E-11
TOTAL	2.11E 06	1.49E 05	9.82E 04	4.55E 04	1.95E 04	1.19E 04	9.84E 02	5.00E 02

Table 4.37. Watts of accumulated heavy isotopes in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	8.42E-07	4.65E-06	1.06E-05	3.21E-05	9.08E-05	2.92E-04	1.86E-03	2.30E-03
TL209	1.19E-09	2.13E-09	1.49E-07	1.82E-06	1.93E-05	2.01E-04	4.46E-03	1.10E-02
PB209	3.80E-09	6.81E-08	4.75E-07	5.83E-06	6.18E-05	6.43E-04	1.43E-02	3.53E-02
PB210	7.65E-11	1.65E-08	1.74E-07	2.11E-06	1.48E-05	8.40E-05	6.84E-04	4.36E-04
PB211	9.34E-07	5.16E-06	1.17E-05	3.56E-05	1.01E-04	3.24E-04	2.07E-03	2.55E-03
PB214	2.70E-08	1.60E-06	1.24E-05	1.24E-04	8.69E-04	4.93E-03	4.01E-02	2.56E-02
BI210	4.85E-09	1.05E-06	1.10E-05	1.34E-04	9.39E-04	5.33E-03	4.34E-02	2.76E-02
BI211	1.09E-05	6.01E-05	1.37E-04	4.15E-04	1.17E-03	3.77E-03	2.41E-02	2.97E-02
BI213	2.03E-08	3.64E-07	2.54E-06	3.12E-05	3.30E-04	3.43E-03	7.63E-02	1.88E-01
BI214	1.54E-07	9.17E-06	7.08E-05	7.08E-04	4.97E-03	2.82E-02	2.29E-01	1.46E-01
PO210	5.25E-08	1.25E-05	1.32E-04	1.60E-03	1.12E-02	6.37E-02	5.19E-01	3.31E-01
PO213	1.60E-07	2.88E-06	2.01E-05	2.46E-04	2.61E-03	2.71E-02	6.03E-01	1.49E 00
PO214	5.05E-07	3.00E-05	2.32E-04	2.32E-03	1.62E-02	9.23E-02	7.51E-01	4.79E-01
PO215	1.22E-05	6.76E-05	1.54E-04	4.67E-04	1.32E-03	4.24E-03	2.71E-02	3.34E-02
PO218	4.02E-07	2.39E-05	1.84E-04	1.84E-03	1.29E-02	7.34E-02	5.97E-01	3.80E-01
AT217	1.38E-07	2.48E-06	1.73E-05	2.12E-04	2.25E-03	2.34E-02	5.20E-01	1.28E 00
RN219	1.13E-05	6.25E-05	1.42E-04	4.31E-04	1.22E-03	3.92E-03	2.50E-02	3.09E-02
RN222	3.61E-07	2.15E-05	1.66E-04	1.66E-03	1.16E-02	6.60E-02	5.37E-01	3.42E-01
FR221	1.23E-07	2.20E-06	1.54E-05	1.89E-04	2.00E-03	2.08E-02	4.62E-01	1.14E 00
RA223	9.70E-06	5.36E-05	1.22E-04	3.70E-04	1.05E-03	3.36E-03	2.15E-02	2.65E-02
RA225	2.17E-09	3.90E-09	2.72E-07	3.34E-06	3.53E-05	3.68E-04	8.17E-03	2.02E-02
RA226	3.14E-07	1.86E-05	1.44E-04	1.44E-03	1.01E-02	5.73E-02	4.66E-01	2.97E-01
AC225	1.13E-07	2.03E-06	1.42E-05	1.74E-04	1.84E-03	1.92E-02	4.26E-01	1.05E 00
AC227	1.40E-07	7.78E-07	1.77E-06	5.37E-06	1.52E-05	4.88E-05	3.11E-04	3.85E-04
TH227	9.46E-06	5.24E-05	1.19E-04	3.62E-04	1.02E-03	3.28E-03	2.10E-02	2.59E-02
TH229	9.93E-08	1.79E-05	1.25E-05	1.53E-04	1.62E-03	1.69E-02	3.75E-01	9.27E-01
TH230	9.13E-05	7.79E-04	2.27E-03	7.64E-03	2.28E-02	7.35E-02	4.63E-01	2.97E-01
TH231	3.63E-04	3.63E-04	3.65E-04	3.69E-04	3.82E-04	4.21E-04	5.88E-04	6.02E-04
TH234	3.02E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03
PA231	2.69E-05	5.68E-05	1.16E-04	3.25E-04	9.19E-04	2.95E-03	1.89E-02	2.33E-02
PA233	2.19E-02	2.59E-02	3.36E-02	4.72E-02	5.35E-02	5.37E-02	5.22E-02	3.90E-02
PA234M	4.37E-02	4.34E-02	4.34E-02	4.34E-02	4.34E-02	4.34E-02	4.34E-02	4.34E-02
U233	6.66E-05	2.84E-04	8.36E-04	3.52E-03	1.30E-02	4.68E-02	3.96E-01	8.90E-01
U234	7.64E-01	8.43E-01	8.96E-01	9.10E-01	9.06E-01	8.93E-01	7.48E-01	2.83E-01
U235	1.28E-02	1.28E-02	1.28E-02	1.30E-02	1.34E-02	1.48E-02	2.07E-02	2.12E-02
U236	1.89E-01	1.90E-01	1.92E-01	1.99E-01	2.16E-01	2.54E-01	2.89E-01	2.81E-01
U238	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01
NP237	4.71E-01	5.63E-01	7.29E-01	1.03E 00	1.16E 00	1.17E 00	1.13E 00	8.47E-01
NP239	6.29E-01	6.23E-01	6.12E-01	5.74E-01	4.79E-01	2.54E-01	7.32E-05	1.25E-09
PU238	4.63E 02	2.15E 02	4.67E 01	3.14E-01	1.39E-05	1.90E-19		
PU239	2.70E 02	2.70E 02	2.68E 02	2.63E 02	2.49E 02	2.06E 02	1.62E 01	2.88E-08
PU240	4.04E 02	4.03E 02	3.95E 02	3.67E 02	2.99E 02	1.46E 02	1.43E-02	3.30E-10
PU241	8.24E 01	7.14E-01	1.02E-04	4.58E-05	3.87E-05	2.15E-05	1.14E-08	
PU242	1.38E 00	1.38E 00	1.38E 00	1.37E 00	1.37E 00	1.35E 00	1.15E 00	2.21E-01
AM241	1.69E 03	3.39E 03	2.48E 03	8.08E 02	3.29E 01	1.78E-02	9.15E-06	
AM242M	5.26E-02	3.33E-02	1.34E-02	5.50E-04	6.01E-08	8.23E-22		
AM242	2.46E-01	1.56E-01	6.27E-02	2.58E-03	2.82E-07	3.86E-21		
AM243	1.70E 01	1.68E 01	1.65E 01	1.55E 01	1.29E 01	6.86E 00	1.98E-03	3.36E-08
CM242	5.93E 00	3.54E 00	1.42E 00	5.84E-02	6.41E-06	8.77E-20		
CM243	2.27E 00	2.60E-01	3.42E-03	8.89E-10	1.36E-28			
CM244	1.22E 03	2.65E 01	1.25E-02	2.96E-14	3.33E-15	1.10E-14	1.01E-13	4.82E-13
TOTAL	4.16E 03	4.33E 03	3.21E 03	1.46E 03	5.99E 02	3.64E 02	2.65E 01	1.15E 01

Table 4.38. Ingestion toxicity (m^3 water) of accumulated heavy isotopes in intermediate-ratiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	3.48E-02	1.92E-01	4.38E-01	1.33E 00	3.75E 00	1.21E 01	7.70E 01	9.51E 01
TL209	7.26E-06	1.30E-04	9.09E-04	1.12E-02	1.18E-01	1.23E 00	2.73E 01	6.75E 01
PB209	1.10E-03	1.97E-02	1.38E-01	1.69E 00	1.79E 01	1.86E 02	4.14E 03	1.02E 04
PB210	1.84E 01	3.99E 03	4.19E 04	5.09E 05	3.57E 06	2.03E 07	1.65E 08	1.05E 08
PB211	6.98E-01	3.86E 00	8.78E 00	2.67E 01	7.53E 01	2.42E 02	1.55E 03	1.91E 03
PB214	2.22E-02	1.32E 00	1.02E 01	1.02E 02	7.13E 02	4.05E 03	3.30E 04	2.10E 04
BI210	4.61E-02	9.96E 00	1.05E 02	1.27E 03	8.91E 03	5.06E 04	4.12E 05	2.63E 05
BI211	3.99E-02	2.20E-01	5.02E-01	1.52E 00	4.30E 00	1.38E 01	8.83E 01	1.09E 02
BI213	6.60E-03	1.18E-01	8.26E-01	1.01E 01	1.07E 02	1.12E 03	2.48E 04	6.13E 04
BI214	1.85E-02	1.10E 00	8.48E 00	8.48E 01	5.94E 02	3.38E 03	2.75E 04	1.75E 04
PO210	2.38E 00	5.69E 02	5.99E 03	7.26E 04	5.09E 05	2.89E 06	2.35E 07	1.50E 07
PO213	3.23E-06	5.79E-05	4.04E-04	4.96E-03	5.25E-02	5.46E-01	1.21E 01	3.00E 01
PO214	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
PO215	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
PO218	2.77E-03	1.65E-01	1.27E 00	1.27E 01	8.91E 01	5.06E 02	4.12E 03	2.63E 03
AT217	5.50E-06	9.87E-05	6.89E-04	8.45E-03	8.95E-02	9.31E-01	2.07E 01	5.11E 01
RN219	2.79E-04	1.54E-03	3.51E-03	1.07E-02	3.01E-02	9.68E-02	6.18E-01	7.63E-01
RN222	1.11E-05	6.59E-04	5.09E-03	5.09E-02	3.57E-01	2.03E 00	1.65E 01	1.05E 01
FR221	4.13E-03	7.41E-02	5.16E-01	6.34E 00	6.71E 01	6.98E 02	1.55E 04	3.83E 04
RA223	3.99E 02	2.20E 03	5.02E 03	1.52E 04	4.30E 04	1.38E 05	8.83E 05	1.09E 06
RA225	6.59E 00	1.18E 02	8.26E 02	1.01E 04	1.07E 05	1.12E 06	2.48E 07	6.13E 07
RA226	3.69E 02	2.20E 04	1.70E 05	1.70E 06	1.19E 07	6.75E 07	5.49E 08	3.50E 09
AC225	6.60E-01	1.18E 01	8.26E 01	1.01E 03	1.07E 04	1.12E 05	2.48E 06	6.13E 06
AC227	1.39E 02	7.72E 02	1.76E 03	5.33E 03	1.51E 04	4.84E 04	3.09E 05	3.82E 05
TH227	1.37E 01	7.61E 01	1.73E 02	5.26E 02	1.48E 03	4.77E 03	3.05E 04	3.76E 04
TH229	8.21E 00	1.48E 02	1.03E 03	1.27E 04	1.34E 05	1.40E 06	3.10E 07	7.66E 07
TH230	1.61E 03	1.38E 04	4.01E 04	1.35E 05	4.04E 05	1.30E 06	8.20E 06	5.25E 06
TH231	2.30E 03	2.30E 03	2.31E 03	2.34E 03	2.42E 03	2.67E 03	3.73E 03	3.82E 03
TH234	4.25E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.21E 05	4.22E 05
PA231	9.79E 02	2.07E 03	4.24E 03	1.18E 04	3.35E 04	1.08E 05	6.87E 05	8.48E 05
PA233	1.62E 05	1.92E 05	2.48E 05	3.49E 05	3.96E 05	3.97E 05	3.86E 05	2.89E 05
PA234M	4.25E 02	4.21E 02	4.21E 02	4.21E 02	4.21E 02	4.21E 02	4.21E 02	4.22E 02
U233	7.62E 01	3.26E 02	9.57E 02	4.03E 03	1.49E 04	5.36E 04	4.53E 05	1.02E 06
U234	8.85E 05	9.76E 05	1.04E 06	1.05E 06	1.05E 06	1.03E 06	8.66E 05	3.28E 05
U235	1.53E 04	1.54E 04	1.54E 04	1.56E 04	1.61E 04	1.78E 04	2.49E 04	2.54E 04
U236	2.33E 05	2.34E 05	2.37E 05	2.45E 05	2.65E 05	3.12E 05	3.55E 05	3.46E 05
U238	2.11E 05	2.11E 05	2.11E 05	2.11E 05	2.11E 05	2.11E 05	2.11E 05	2.11E 05
NP237	5.35E 06	6.39E 06	8.28E 06	1.16E 07	1.32E 07	1.32E 07	1.29E 07	9.61E 06
NP239	4.65E 06	4.61E 06	4.52E 06	4.25E 06	3.54E 06	1.88E 06	5.41E 02	9.22E-03
PU238	2.80E 09	1.30E 09	2.82E 08	1.89E 06	8.41E 01	1.15E-12		
PU239	1.74E 09	1.74E 09	1.73E 09	1.69E 09	1.60E 09	1.32E 09	1.04E 08	1.85E-01
PU240	2.59E 09	2.59E 09	2.53E 09	2.36E 09	1.92E 09	9.37E 08	9.20E 04	2.12E-03
PU241	9.92E 09	8.61E 07	1.23E 04	5.52E 03	4.67E 03	2.59E 03	1.37E 00	
PU242	9.32E 06	9.32E 06	9.32E 06	9.31E 06	9.28E 06	9.16E 06	7.77E 06	1.50E 06
AM241	1.27E 10	2.54E 10	1.86E 10	6.05E 09	2.47E 08	1.33E 05	6.85E 01	
AM242M	4.62E 07	2.93E 07	1.18E 07	4.83E 05	5.28E 01	7.24E-13		
AM242	1.85E 06	1.17E 06	4.70E 05	1.93E 04	2.11E 00	2.89E-14		
AM243	1.16E 08	1.15E 08	1.13E 08	1.06E 08	8.86E 07	4.70E 07	1.35E 04	2.30E-01
CM242	8.05E 06	4.80E 06	1.93E 06	7.92E 04	8.69E 00	1.19E-13		
CM243	1.24E 07	1.42E 06	1.86E 04	4.84E-03	7.41E-22			
CM244	4.98E 09	1.08E 08	5.10E 04	1.21E-07	1.36E-08	4.49E-08	4.11E-07	1.37E-06
TOTAL	3.49E 10	3.14E 10	2.33E 10	1.02E 10	3.91E 09	2.43E 09	9.34E 08	6.36E 08

Table 4.39. Grams of accumulated fission product elements in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year 2005	Years following close of the repository						
		100	300	1000	3000	10,000	100,000	1,000,000
GE	1.14E 01	1.14E 01	1.14E 01	1.14E 01	1.14E 01	1.14E 01	1.14E 01	1.14E 01
AS	3.38E 00	3.38E 00	3.38E 00	3.38E 00	3.38E 00	3.38E 00	3.38E 00	3.38E 00
SE	1.51E 03	1.51E 03	1.51E 03	1.51E 03	1.51E 03	1.50E 03	1.41E 03	1.36E 03
BR	5.97E 02	5.98E 02	5.98E 02	5.99E 02	6.02E 02	6.13E 02	6.95E 02	7.47E 02
RB	9.12E 03	9.12E 03	9.12E 03	9.12E 03	9.12E 03	9.12E 03	9.12E 03	9.12E 03
SR	2.03E 04	1.02E 04	9.29E 03	9.28E 03	9.28E 03	9.28E 03	9.28E 03	9.28E 03
Y	1.23E 04	1.23E 04	1.23E 04	1.23E 04	1.23E 04	1.23E 04	1.23E 04	1.23E 04
ZR	9.95E 04	1.10E 05	1.11E 05	1.11E 05	1.10E 05	1.10E 05	1.10E 05	1.03E 05
NB	1.30E-01	1.02E 00	2.80E 00	9.03E 00	2.68E 01	8.90E 01	8.70E 02	7.13E 03
MO	9.25E 04	9.25E 04	9.25E 04	9.25E 04	9.25E 04	9.25E 04	9.25E 04	9.25E 04
TC	2.26E 04	2.26E 04	2.26E 04	2.26E 04	2.24E 04	2.19E 04	1.63E 04	8.61E 02
RU	5.88E 04	5.88E 04	5.88E 04	5.88E 04	5.90E 04	5.95E 04	6.51E 04	8.05E 04
RH	1.19E 04	1.19E 04	1.19E 04	1.19E 04	1.19E 04	1.19E 04	1.19E 04	1.19E 04
PD	3.99E 04	3.99E 04	3.99E 04	3.99E 04	3.99E 04	3.99E 04	3.99E 04	3.94E 04
AG	1.64E 03	1.64E 03	1.64E 03	1.64E 03	1.64E 03	1.64E 03	1.70E 03	2.20E 03
CD	2.42E 03	2.42E 03	2.42E 03	2.42E 03	2.42E 03	2.42E 03	2.42E 03	2.42E 03
IN	3.25E 01	3.49E 01	3.49E 01	3.49E 01	3.49E 01	3.49E 01	3.49E 01	3.49E 01
SN	1.34E 03	1.34E 03	1.34E 03	1.33E 03	1.33E 03	1.30E 03	1.06E 03	7.80E 02
SB	2.54E 02	2.33E 02	2.33E 02	2.33E 02	2.33E 02	2.33E 02	2.33E 02	2.33E 02
TE	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.29E 04	1.32E 04	1.34E 04
I	6.50E 03	6.50E 03	6.50E 03	6.50E 03	6.50E 03	6.50E 03	6.48E 03	6.29E 03
XE	2.59E-03	2.38E-02	6.63E-02	2.15E-01	6.40E-01	2.13E 00	2.12E 01	2.08E 02
CS	6.30E 04	3.94E 04	3.69E 04	3.69E 04	3.69E 04	3.69E 04	3.67E 04	3.51E 04
BA	5.17E 04	7.52E 04	7.77E 04	7.78E 04	7.78E 04	7.78E 04	7.80E 04	7.96E 04
LA	3.33E 04	3.33E 04	3.33E 04	3.33E 04	3.33E 04	3.33E 04	3.33E 04	3.33E 04
CE	6.54E 04	6.54E 04	6.54E 04	6.54E 04	6.54E 04	6.54E 04	6.54E 04	6.54E 04
PR	3.09E 04	3.09E 04	3.09E 04	3.09E 04	3.09E 04	3.09E 04	3.09E 04	3.09E 04
ND	1.10E 05	1.10E 05	1.10E 05	1.10E 05	1.10E 05	1.10E 05	1.10E 05	1.10E 05
PM	2.24E 02	7.25E-10						
SM	2.34E 04	2.30E 04	2.26E 04	2.25E 04	2.25E 04	2.25E 04	2.25E 04	2.25E 04
EU	4.27E 03	4.10E 03	4.48E 03	4.58E 03	4.58E 03	4.58E 03	4.58E 03	4.58E 03
GD	3.38E 03	4.14E 03	4.15E 03	4.15E 03	4.15E 03	4.15E 03	4.15E 03	4.15E 03
TB	4.93E 01	4.93E 01	4.93E 01	4.93E 01	4.93E 01	4.93E 01	4.93E 01	4.93E 01
DY	3.52E 01	3.52E 01	3.52E 01	3.52E 01	3.52E 01	3.52E 01	3.52E 01	3.52E 01
HO	3.63E 00	3.63E 00	3.63E 00	3.63E 00	3.62E 00	3.62E 00	3.62E 00	3.62E 00
ER	9.84E-01	9.85E-01	9.87E-01	9.91E-01	9.96E-01	9.99E-01	9.99E-01	9.99E-01
TOTALS	7.80E 05	7.80E 05	7.80E 05	7.80E 05	7.80E 05	7.80E 05	7.80E 05	7.80E 05

Table 4.40. Curies of accumulated fission product isotopes in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	1.04E 01	1.04E 01	1.04E 01	1.03E 01	1.01E 01	9.35E 00	3.58E 00	2.43E-04
SR 90	1.56E 06	1.32E 05	9.52E 02	3.02E-05	1.13E-26			
Y 90	1.56E 06	1.32E 05	9.52E 02	3.02E-05	1.13E-26			
ZR 93	4.94E 01	4.94E 01	4.94E 01	4.94E 01	4.93E 01	4.92E 01	4.72E 01	3.11E 01
NB 93M	2.51E 01	4.92E 01	4.94E 01	4.94E 01	4.93E 01	4.92E 01	4.72E 01	3.11E 01
TC 99	3.86E 02	3.86E 02	3.85E 02	3.84E 02	3.82E 02	3.73E 02	2.78E 02	1.47E 01
RU106	4.57E 04							
RH106	4.57E 04							
PD107	2.86E 00	2.86E 00	2.86E 00	2.86E 00	2.86E 00	2.85E 00	2.83E 00	2.59E 00
SB125	2.23E 04	1.58E-07						
TE125M	9.23E 03	6.54E-08						
SN126	1.59E 01	1.59E 01	1.58E 01	1.58E 01	1.55E 01	1.48E 01	7.93E 00	1.55E-02
SB126M	1.59E 01	1.59E 01	1.58E 01	1.58E 01	1.55E 01	1.48E 01	7.93E 00	1.55E-02
SB126	1.58E 01	1.57E 01	1.57E 01	1.56E 01	1.54E 01	1.47E 01	7.85E 00	1.53E-02
I129	8.50E-01	8.50E-01	8.50E-01	8.50E-01	8.50E-01	8.50E-01	8.47E-01	8.16E-01
CS134	3.00E 05	6.20E-10						
CS135	7.75E 00	7.75E 00	7.75E 00	7.75E 00	7.74E 00	7.73E 00	7.57E 00	6.15E 00
CS137	2.25E 06	2.23E 05	2.19E 03	2.08E-04	1.77E-24			
BA137M	2.10E 06	2.09E 05	2.05E 03	1.94E-04	1.66E-24			
CE144	2.39E 04							
PR144	2.39E 04							
PM147	2.08E 05	6.73E-07						
SM151	2.93E 04	1.32E 04	2.68E 03	1.01E 01	1.22E-06			
EU154	1.11E 05	1.46E 03	2.51E-01	1.70E-14				
EU155	6.29E 03	1.47E-13						
HO166M	2.68E-02	2.53E-02	2.25E-02	1.50E-02	4.74E-03	8.31E-05	2.20E-27	
TOTAL	8.29E 06	7.11E 05	9.39E 03	5.62E 02	5.49E 02	5.37E 02	4.11E 02	8.65E 01

Table 4.41. Watts of accumulated fission product isotopes in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	3.94E-03	3.94E-03	3.93E-03	3.90E-03	3.82E-03	3.55E-03	1.36E-03	9.22E-08
SR 90	2.04E 03	1.73E 02	1.25E 00	3.95E-08	1.48E-29			
Y 90	9.17E 03	7.78E 02	5.61E 00	1.78E-07	6.66E-29			
ZR 93	5.86E-03	5.86E-03	5.86E-03	5.85E-03	5.85E-03	5.83E-03	5.59E-03	3.69E-03
NB 93M	4.46E-03	8.76E-03	8.78E-03	8.78E-03	8.77E-03	8.74E-03	8.39E-03	5.53E-03
TC 99	2.61E-01	2.61E-01	2.60E-01	2.60E-01	2.58E-01	2.52E-01	1.88E-01	9.91E-03
RU106	2.71E 00							
RH106	4.81E 02							
PD107	2.37E-04	2.37E-04	2.37E-04	2.37E-04	2.37E-04	2.37E-04	2.35E-04	2.15E-04
SB125	9.04E 01	6.40E-10						
TE125M	1.59E 01	1.13E-10						
SN126	1.71E-02	1.71E-02	1.71E-02	1.70E-02	1.68E-02	1.60E-02	8.56E-03	1.67E-05
SB126M	1.07E-01	1.07E-01	1.07E-01	1.06E-01	1.05E-01	1.00E-01	5.36E-02	1.05E-04
SB126	2.05E-01	2.04E-01	2.04E-01	2.03E-01	2.00E-01	1.91E-01	1.02E-01	2.00E-04
I129	5.59E-04	5.59E-04	5.59E-04	5.59E-04	5.59E-04	5.59E-04	5.57E-04	5.37E-04
CS134	3.18E 03	6.57E-12						
CS135	3.77E-03	3.77E-03	3.77E-03	3.77E-03	3.76E-03	3.76E-03	3.68E-03	2.99E-03
CS137	3.68E 03	3.65E 02	3.59E 00	3.40E-07	2.90E-27			
BA137M	8.27E 03	8.20E 02	8.07E 00	7.63E-07	6.51E-27			
CE144	1.96E 01							
PR144	1.85E 02							
PM147	1.07E 02	3.47E-10						
SM151	5.10E 01	2.30E 01	4.67E 00	1.77E-02	2.12E-09			
EU154	9.09E 02	1.19E 01	2.06E-03	1.39E-16				
EU155	5.29E 00	1.24E-16						
HO166M	2.88E-04	2.72E-04	2.42E-04	1.62E-04	5.09E-05	8.93E-07	2.36E-29	
TOTAL	2.82E 04	2.17E 03	2.38E 01	6.27E-01	6.03E-01	5.82E-01	3.72E-01	2.32E-02

Table 4.42. Ingestion toxicity (m^3 water) of accumulated fission product isotopes in intermediate-radiation-level TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
SE 79	1.04E 01	1.04E 01	1.04E 01	1.03E 01	1.01E 01	9.35E 00	3.58E 00	2.43E-04
SR 90	5.19E 12	4.40E 11	3.17E 09	1.01E 02	3.77E-20			
Y 90	7.79E 10	6.60E 09	4.76E 07	1.51E 00	5.66E-22			
ZR 93	6.17E 04	6.17E 04	6.17E 04	6.17E 04	6.17E 04	6.15E 04	5.90E 04	3.89E 04
NB 93M	6.27E 04	1.23E 05	1.23E 05	1.23E 05	1.23E 05	1.23E 05	1.18E 05	7.78E 04
TC 99	1.93E 06	1.93E 06	1.93E 06	1.92E 06	1.91E 06	1.87E 06	1.39E 06	7.33E 04
RU106	4.57E 09							
RH106	4.57E 04							
PD107	2.86E 03	2.86E 03	2.86E 03	2.86E 03	2.86E 03	2.85E 03	2.83E 03	2.59E 03
SB125	2.23E 08	1.58E-03						
TE125M	9.23E 07	6.54E-04						
SN126	1.59E 01	1.59E 01	1.58E 01	1.58E 01	1.55E 01	1.48E 01	7.93E 00	1.55E-02
SB126M	1.59E 01	1.59E 01	1.58E 01	1.58E 01	1.55E 01	1.48E 01	7.93E 00	1.55E-02
SB126	1.58E 01	1.57E 01	1.57E 01	1.56E 01	1.54E 01	1.47E 01	7.85E 00	1.53E-02
I129	1.42E 07	1.42E 07	1.42E 07	1.42E 07	1.42E 07	1.42E 07	1.41E 07	1.36E 07
CS134	3.33E 10	6.89E-05						
CS135	7.75E 04	7.75E 04	7.75E 04	7.75E 04	7.74E 04	7.73E 04	7.57E 04	6.15E 04
CS137	1.12E 11	1.12E 10	1.10E 08	1.04E 01	8.85E-20			
BA137M	2.10E 06	2.09E 05	2.05E 03	1.94E-04	1.66E-24			
CE144	2.39E 09							
PR144	2.39E 04							
PM147	1.04E 09	3.37E-03						
SM151	7.32E 07	3.30E 07	6.70E 06	2.54E 04	3.05E-03			
EU154	5.54E 09	7.28E 07	1.26E 04	8.48E-10				
EU155	3.14E 07	7.34E-10						
HO166M	2.68E-02	2.53E-02	2.25E-02	1.50E-02	4.74E-03	8.31E-05	2.20E-27	
TOTAL	5.43E 12	4.58E 11	3.35E 09	1.64E 07	1.63E 07	1.63E 07	1.58E 07	1.39E 07

made of paper, cloth, wood, plastic, rubber, glass, ceramic, and metal, as well as immobilized salts and sludges that arise in the treatment of liquid waste streams and filters from cleanup of off-gas. The trans-uranium-element content of these wastes ranges from trace amounts to several grams per cubic foot, and averages about 0.25 g/ft^3. The densities of the uncompacted wastes vary from about 2 lb/ft^3 to as much as 200 lb/ft^3. About one-half to two-thirds of these wastes (by volume) are combustible and can be reduced via incineration by factors of about 50 and 20 in volume and weight, respectively. About one-half to three-fourths of the wastes (by volume) can be reduced in volume by factors of 2 to 10 through compaction.

A survey of operations at ERDA laboratories and production facilities indicated that future large plants will generate about 10,000, 20,000, and 4000 ft^3 of uncompacted low-level TRU waste per ton of plutonium or ^{233}U processed in fuel preparation, fabrication, and reprocessing, respectively.[26] Thus, an average plutonium or ^{233}U concentration in the waste of 0.25 g/ft^3 represents fuel losses of 0.25% in preparation, 0.5% in fabrication, and 0.1% in reprocessing.

Table 4.43 presents projections of low-level plutonium TRU wastes, assuming they are shipped and accumulated at a repository five years following their generation. The isotopic composition of the plutonium is taken as 1% ^{238}Pu, 59% ^{239}Pu, 24% ^{240}Pu, 12% ^{241}Pu, and 4% ^{242}Pu.[1] It is assumed that the wastes are compacted or otherwise reduced in volume by factors of 3 to 10 according to the following schedule:

Calendar year	Compaction factor
1976-1981	3
1982-1983	4
1984-1985	5
1986-1987	7.5
1988-2000	10

Low-level TRU wastes are packaged in Type 17C, 55-gal steel drums and shipped in ATMX-600 railcars.[28] Each shipment contains 1000 ft^3 of waste.

Table 4.43. Projected annual accumulation of low-level plutonium transuranic waste at a federal repository

Year	* * * * Annual Addition * * * * * Volume (Thousands of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (kW)	Annual Number of Shipments	* * * * * Accumulation Through End of Year * * * * * Volume (Millions of m^3)	Actinide Mass (MT)	Radio-activity (MCi)	Thermal Power (kW)	Hazard, Cubic Meters at RCG Air	Water
1986	0.1	0.003	0.0	0.0	4	0.000	0.00	0.0	0.0	2.4E 16	4.0E 08
1987	1.0	0.035	0.3	0.4	35	0.001	0.04	0.4	0.4	2.8E 17	4.6E 09
1988	2.0	0.069	0.7	0.8	69	0.003	0.11	1.0	1.3	7.9E 17	1.3E 10
1989	3.4	0.149	1.4	1.7	119	0.006	0.26	2.4	3.1	1.9E 18	3.1E 10
1990	3.7	0.162	1.6	1.9	129	0.010	0.42	3.9	5.0	3.1E 18	5.1E 10
1991	2.6	0.171	1.7	2.0	91	0.013	0.59	5.4	7.2	4.3E 18	7.2E 10
1992	3.2	0.210	2.0	2.5	112	0.016	0.80	7.2	9.9	5.8E 18	9.8E 10
1993	2.1	0.190	1.8	2.2	76	0.018	0.99	8.8	12.4	7.1E 18	1.2E 11
1994	2.9	0.259	2.5	3.0	104	0.021	1.25	10.9	15.8	9.0E 18	1.5E 11
1995	4.5	0.396	3.9	4.6	158	0.025	1.64	14.3	20.9	1.2E 19	2.0E 11
1996	5.9	0.523	5.1	6.1	209	0.031	2.17	18.8	27.6	1.6E 19	2.7E 11
1997	6.6	0.585	5.7	6.8	234	0.038	2.75	23.7	35.2	2.0E 19	3.4E 11
1998	6.7	0.590	5.8	6.9	236	0.045	3.34	28.4	43.1	2.4E 19	4.1E 11
1999	6.1	0.535	5.2	6.2	214	0.051	3.88	32.4	50.6	2.8E 19	4.8E 11
2000	7.2	0.633	6.2	7.4	253	0.058	4.51	37.2	59.3	3.2E 19	5.6E 11
2001	8.8	0.780	7.6	9.1	312	0.067	5.29	43.2	70.0	3.7E 19	6.6E 11
2002	9.9	0.877	8.5	10.2	351	0.077	6.17	49.9	82.0	4.3E 19	7.7E 11
2003	10.9	0.962	9.4	11.2	385	0.088	7.13	57.1	95.3	5.0E 19	8.9E 11
2004	11.6	1.021	9.9	11.9	408	0.099	8.15	64.6	109.6	5.7E 19	1.0E 12
2005	11.7	1.032	10.0	12.0	413	0.111	9.18	71.9	124.3	6.4E 19	1.2E 12
TIME AFTER SHUTDOWN, YEARS											
100						0.111	9.18	5.3	155.5	3.9E 19	1.1E 12
300						0.111	9.18	3.3	108.8	2.7E 19	7.8E 11
1000						0.111	9.18	1.5	49.6	1.7E 19	3.5E 11
3000						0.111	9.18	0.7	21.7	1.1E 19	1.4E 11
10000						0.111	9.18	0.4	13.3	7.1E 18	8.7E 10
30000						0.111	9.18	0.2	5.2	2.8E 18	3.9E 10
100000						0.111	9.18	0.0	0.8	3.7E 17	1.8E 10
300000						0.111	9.18	0.0	0.2	5.3E 16	1.6E 10
1000000						0.111	9.18	0.0	0.2	4.0E 16	5.3E 09

Shipment and accumulations of low-level ^{233}U wastes from the HTGR fuel cycle are projected in Table 4.44 using the same assumptions as were adopted for the low-level plutonium TRU wastes. The isotopic composition of the HTGR uranium is taken as 0.041% ^{232}U, 59.7% ^{233}U, 26.2% ^{234}U, 7.9% ^{235}U, and 6.1% ^{236}U.[1]

The accumulated mass, radioactivity, thermal power, and ingestion toxicity of the low-level plutonium and ^{233}U wastes as a function of time following the year 2005 are presented in Tables 4.45 through 4.48 and 4.49 through 4.52, respectively.

4.5 Noble Gases

The noble-gas fission products consist principally of stable and short-lived isotopes of krypton and xenon. Typically, from 5 to 6 kg are present in each ton of spent fuel from LWRs and LMFBRs and, while xenon comprises about 95% of the weight of the mixture, the only radioisotope remaining after 150 days decay is 10.8-y ^{85}Kr. These gases are currently discharged to the atmosphere following interim holdup for decay. Over 99% of them are released at reprocessing plants, and the remainder are discharged at power stations as a consequence of their leakage through defective fuel cladding. Although off-site radiation exposures have been small compared with current guidelines for population exposures, the noble gases will probably be recovered in future reprocessing plants.

Several processes are under development for recovery of these gases from plant off-gas streams.[29] Initially, it is likely that the mixed gases will be collected under high pressure in gas cylinders and then shipped to a large remote site and stored under conditions that will promote long-term integrity of the cylinders.

The projected accumulation of noble-gas fission products is presented in Table 4.53. It is assumed that the mixed krypton and xenon isotopes are packaged in standard 50-liter gas cylinders at a pressure of 2200 psig, stored for 1 year at the reprocessing plant,

Table 4.44. Projected annual accumulations of low-level U-233 wastes at a federal repository

Year	Annual Addition: Volume (Thousands of m^3)	Annual Addition: Actinide Mass (kg)	Annual Addition: Radioactivity (Curies)	Annual Addition: Thermal Power (Watts)	Annual Number of Shipments	Accumulation Through End of Year: Volume (Thousands of m^3)	Accumulation Through End of Year: Actinide Mass (kg)	Accumulation Through End of Year: Radioactivity (Curies)	Accumulation Through End of Year: Thermal Power (Watts)	Hazard, Cubic Meters at RCG: Air	Hazard, Cubic Meters at RCG: Water
1985	0.002	0.0	2.8	0	0	0.00	0	3	0	1.2E 12	2.4E 05
1986	0.015	0.4	26.9	1	1	0.02	0	30	1	1.2E 13	2.5E 06
1987	0.021	0.7	49.2	1	1	0.04	1	80	2	3.3E 13	6.7E 06
1988	0.020	0.7	48.5	1	1	0.06	2	130	4	5.4E 13	1.1E 07
1989	0.016	0.7	47.7	1	1	0.07	3	180	5	7.5E 13	1.5E 07
1990	0.017	0.7	49.5	1	1	0.09	3	232	7	9.6E 13	2.0E 07
1991	0.011	0.8	50.5	2	0	0.10	4	285	8	1.2E 14	2.4E 07
1992	0.011	0.8	51.1	2	0	0.11	5	338	10	1.4E 14	2.9E 07
1993	0.009	0.8	51.0	2	0	0.12	6	391	12	1.6E 14	3.3E 07
1994	0.009	0.8	50.8	2	0	0.13	6	444	13	1.9E 14	3.8E 07
1995	0.009	0.8	51.1	2	0	0.14	7	497	15	2.1E 14	4.2E 07
1996	0.009	0.8	51.2	2	0	0.15	8	550	16	2.3E 14	4.7E 07
1997	0.009	0.8	51.2	2	0	0.16	9	602	18	2.5E 14	5.1E 07
1998	0.009	0.8	50.5	2	0	0.17	9	653	19	2.7E 14	5.6E 07
1999	0.008	0.7	49.2	1	0	0.17	10	703	21	2.9E 14	6.0E 07
2000	0.008	0.7	47.8	1	0	0.18	11	751	22	3.1E 14	6.4E 07
2001	0.008	0.7	46.5	1	0	0.19	12	796	24	3.3E 14	6.8E 07
2002	0.008	0.7	45.1	1	0	0.20	12	840	25	3.5E 14	7.2E 07
2003	0.009	0.8	52.3	2	0	0.21	13	891	27	3.7E 14	7.6E 07
2004	0.022	2.0	132.0	4	1	0.23	15	1021	30	4.3E 14	8.7E 07
2005	0.048	4.2	283.5	8	2	0.28	19	1304	39	5.4E 14	1.1E 08
TIME AFTER SHUTDOWN, YEARS											
100						0.28	19	613	18	2.8E 14	5.3E 07
300						0.28	19	233	7	2.0E 14	2.6E 07
1000						0.28	19	219	6	5.1E 14	5.4E 07
3000						0.28	19	356	9	1.4E 15	1.5E 08
10000						0.28	19	674	17	3.3E 15	4.0E 08
30000						0.28	19	939	24	4.8E 15	7.5E 08
100000						0.28	19	841	21	3.9E 15	1.1E 09
300000						0.28	19	460	11	1.8E 15	9.0E 08
1000000						0.28	19	44	1	1.2E 14	1.3E 08

Table 4.45. Grams of accumulated heavy elements in low-level plutonium TRU wastes at a federal repository in the year 2005 as a function of age

	Year 2005	Years following close of the repository						
		100	300	1000	3000	10,000	100,000	1,000,000
HE	2.71E 02	4.04E 03	1.01E 04	2.23E 04	3.69E 04	6.61E 04	1.45E 05	1.93E 05
TL	3.46E-16	1.36E-13	1.53E-12	2.12E-11	2.03E-10	2.10E-09	5.48E-08	9.16E-08
PB	8.48E-09	3.55E-05	1.65E-03	9.78E-02	2.57E 00	5.94E 01	6.74E 03	7.69E 04
BI	4.62E-11	6.83E-07	5.56E-05	5.95E-03	3.05E-01	1.40E 01	4.63E 03	2.09E 05
PO	1.19E-10	3.49E-07	8.26E-06	1.62E-04	1.31E-03	7.79E-03	6.16E-02	1.11E-02
AT	1.81E-20	4.07E-17	1.12E-15	3.39E-14	5.25E-13	6.28E-12	1.46E-10	3.62E-10
RN	3.40E-11	1.95E-08	3.07E-07	4.75E-06	3.84E-05	2.28E-04	1.80E-03	3.24E-04
FR	1.90E-16	3.82E-13	1.03E-11	3.12E-10	4.82E-09	5.77E-08	1.34E-06	3.32E-06
RA	5.29E-06	3.04E-03	4.79E-02	7.39E-01	5.98E 00	3.55E 01	2.81E 02	5.04E 01
AC	8.96E-10	3.46E-07	3.77E-06	4.86E-05	4.24E-04	4.21E-03	1.14E-01	1.67E-01
TH	1.29E-01	9.16E 00	4.85E 01	2.22E 02	7.36E 02	2.61E 03	2.09E 04	6.57E 04
PA	1.68E-04	5.88E-03	2.08E-02	1.03E-01	6.63E-01	6.21E 00	1.68E 02	2.40E 02
U	1.14E 04	9.35E 04	1.97E 05	4.55E 05	1.10E 06	2.81E 06	7.33E 06	7.80E 06
NP	4.57E 03	1.45E 05	4.02E 05	8.61E 05	1.07E 06	1.08E 06	1.05E 06	7.84E 05
PU	8.74E 06	7.99E 06	7.88E 06	7.62E 06	6.96E 06	5.23E 06	6.22E 05	5.90E 04
AM	4.26E 05	9.49E 05	6.93E 05	2.26E 05	9.20E 03	1.25E-01		
TOTALS	9.18E 06	9.18E 06	9.18E 06	9.18E 06	9.18E 06	9.18E 06	9.18E 06	9.19E 06

Table 4.46. Curies of accumulated heavy isotopes in low-level plutonium TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	6.53E-08	2.51E-05	2.72E-04	3.47E-03	2.98E-02	2.93E-01	7.98E 00	1.14E 01
TL209	6.48E-10	1.45E-06	4.00E-05	1.21E-03	1.88E-02	2.25E-01	5.22E 00	1.29E 01
PB209	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
PB210	6.19E-07	1.57E-03	3.72E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
PB211	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
PB214	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
BI210	6.19E-07	1.57E-03	3.72E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
BI211	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
BI213	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
BI214	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
PO210	5.38E-07	1.57E-03	3.72E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
PO213	2.88E-08	6.46E-05	1.78E-03	5.38E-02	8.34E-01	9.99E 00	2.32E 02	5.75E 02
PO214	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
PO215	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
PO218	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
AT217	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
RN219	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
RN222	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
FR221	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
RA223	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
RA225	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
RA226	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
AC225	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
AC227	6.53E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
TH227	6.46E-08	2.48E-05	2.69E-04	3.43E-03	2.94E-02	2.90E-01	7.89E 00	1.13E 01
TH229	2.94E-08	6.61E-05	1.82E-03	5.51E-02	8.53E-01	1.02E 01	2.37E 02	5.88E 02
TH230	2.51E-03	1.77E-01	9.37E-01	4.25E 00	1.37E 01	4.52E 01	2.77E 02	4.99E 01
TH231	3.53E-03	3.59E-02	1.00E-01	3.23E-01	9.36E-01	2.83E 00	1.08E 01	1.14E 01
PA231	4.79E-07	4.25E-05	3.33E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
PA233	3.23E 00	1.02E 02	2.84E 02	6.07E 02	7.57E 02	7.62E 02	7.40E 02	5.53E 02
U233	7.54E-05	2.12E-02	1.90E-01	1.61E 00	7.71E 00	3.00E 01	2.60E 02	5.87E 02
U234	4.51E 01	3.23E 02	5.09E 02	5.57E 02	5.54E 02	5.43E 02	4.22E 02	3.38E 01
U235	3.53E-03	3.59E-02	1.00E-01	3.23E-01	9.36E-01	2.83E 00	1.08E 01	1.14E 01
U236	1.53E-01	1.55E 00	4.31E 00	1.35E 01	3.65E 01	8.82E 01	1.37E 02	1.34E 02
NP237	3.22E 00	1.02E 02	2.84E 02	6.07E 02	7.57E 02	7.62E 02	7.40E 02	5.53E 02
PU238	1.43E 06	6.54E 05	1.38E 05	5.91E 02	1.02E-04			
PU239	3.32E 05	3.31E 05	3.29E 05	3.23E 05	3.05E 05	2.50E 05	1.94E 04	1.53E-07
PU240	4.85E 05	4.80E 05	4.71E 05	4.38E 05	3.57E 05	1.74E 05	1.71E 01	
PU241	6.82E 07	5.91E 05	4.45E 01	1.64E-13				
PU242	1.43E 03	1.43E 03	1.43E 03	1.43E 03	1.42E 03	1.41E 03	1.19E 03	2.30E 02
AM241	1.46E 06	3.25E 06	2.38E 06	7.75E 05	3.15E 04	4.29E-01		
TOTAL	7.19E 07	5.31E 06	3.32E 06	1.54E 06	6.97E 05	4.28E 05	2.77E 04	7.42E 03

Table 4.47. Watts of accumulated heavy isotopes in low-level plutonium TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	1.97E-10	7.59E-08	8.22E-07	1.05E-05	9.00E-05	8.87E-04	2.41E-02	3.44E-02
TL209	1.06E-11	2.38E-08	6.53E-07	1.98E-05	3.07E-04	3.67E-03	8.54E-02	2.11E-01
PB209	3.38E-11	7.60E-08	2.09E-06	6.33E-05	9.81E-04	1.17E-02	2.73E-01	6.76E-01
PB210	2.57E-11	6.53E-08	1.54E-06	3.03E-05	2.46E-04	1.46E-03	1.15E-02	2.07E-03
PB211	2.19E-10	8.42E-08	9.12E-07	1.16E-05	9.98E-05	9.84E-04	2.67E-02	3.81E-02
PB214	1.28E-08	7.32E-06	1.15E-04	1.78E-03	1.44E-02	8.56E-02	6.77E-01	1.22E-01
BI210	1.63E-09	4.14E-06	9.80E-05	1.92E-03	1.56E-02	9.24E-02	7.31E-01	1.31E-01
BI211	2.55E-09	9.81E-07	1.06E-05	1.35E-04	1.16E-03	1.15E-02	3.12E-01	4.44E-01
BI213	1.81E-10	4.06E-07	1.12E-05	3.38E-04	5.24E-03	6.28E-02	1.46E 00	3.61E 00
BI214	7.29E-08	4.18E-05	6.59E-04	1.02E-02	8.24E-02	4.89E-01	3.87E 00	6.95E-01
PO210	1.69E-08	4.95E-05	1.17E-03	2.30E-02	1.86E-01	1.11E 00	8.75E 00	1.57E 00
PO213	1.43E-09	3.21E-06	8.82E-05	2.67E-03	4.14E-02	4.96E-01	1.15E 01	2.86E 01
PO214	2.39E-07	1.37E-04	2.16E-03	3.33E-02	2.70E-01	1.60E 00	1.27E 01	2.27E 00
PO215	2.87E-09	1.10E-06	1.20E-05	1.52E-04	1.31E-03	1.29E-02	3.50E-01	5.00E-01
PO218	1.90E-07	1.09E-04	1.71E-03	2.65E-02	2.14E-01	1.27E 00	1.01E 01	1.81E 00
AT217	1.23E-09	2.77E-06	7.61E-05	2.31E-03	3.57E-02	4.28E-01	9.95E 00	2.46E 01
RN219	2.65E-09	1.02E-06	1.10E-05	1.41E-04	1.21E-03	1.19E-02	3.24E-01	4.62E-01
RN222	1.71E-07	9.79E-05	1.54E-03	2.38E-02	1.93E-01	1.14E 00	9.05E 00	1.63E 00
FR221	1.09E-09	2.46E-06	6.75E-05	2.05E-03	3.17E-02	3.80E-01	8.83E 00	2.19E 01
RA223	2.28E-09	8.75E-07	9.48E-06	1.21E-04	1.04E-03	1.02E-02	2.78E-01	3.96E-01
RA225	1.94E-11	4.35E-08	1.19E-06	3.62E-05	5.61E-04	6.72E-03	1.56E-01	3.87E-01
RA226	1.48E-07	8.50E-05	1.34E-03	2.07E-02	1.67E-01	9.94E-01	7.87E 00	1.41E 00
AC225	1.01E-09	2.27E-06	6.23E-05	1.89E-03	2.93E-02	3.51E-01	8.15E 00	2.02E 01
AC227	3.29E-11	1.27E-08	1.37E-07	1.75E-06	1.50E-05	1.48E-04	4.03E-03	5.75E-03
TH227	2.22E-09	8.55E-07	9.26E-06	1.18E-04	1.01E-03	9.98E-03	2.71E-01	3.87E-01
TH229	8.90E-10	2.00E-06	5.49E-05	1.66E-03	2.58E-02	3.09E-01	7.18E 00	1.78E 01
TH230	7.08E-05	5.01E-03	2.65E-02	1.20E-01	3.88E-01	1.28E 00	7.81E 00	1.41E 00
TH231	2.79E-06	2.83E-05	7.92E-05	2.55E-04	7.38E-04	2.23E-03	8.48E-03	9.00E-03
PA231	1.46E-08	1.30E-06	1.02E-05	1.06E-04	9.11E-04	8.98E-03	2.44E-01	3.48E-01
PA233	4.37E-03	1.38E-01	3.83E-01	8.21E-01	1.02E 00	1.03E 00	1.00E 00	7.47E-01
U233	2.19E-06	6.17E-04	5.54E-03	4.69E-02	2.24E-01	8.73E-01	7.57E 00	1.71E 01
U234	1.30E 00	9.29E 00	1.46E 01	1.60E 01	1.60E 01	1.56E 01	1.21E 01	9.74E-01
U235	9.80E-05	9.97E-04	2.79E-03	8.97E-03	2.60E-02	7.84E-02	2.98E-01	3.17E-01
U236	4.16E-03	4.21E-02	1.17E-01	3.67E-01	9.89E-01	2.39E 00	3.72E 00	3.62E 00
NP237	9.46E-02	3.00E 00	8.33E 00	1.78E 01	2.22E 01	2.24E 01	2.17E 01	1.62E 01
PU238	4.72E 04	2.17E 04	4.56E 03	1.96E 01	3.37E-06			
PU239	1.03E 04	1.03E 04	1.02E 04	1.00E 04	9.48E 03	7.77E 03	6.03E 02	4.76E-09
PU240	1.51E 04	1.50E 04	1.47E 04	1.36E 04	1.11E 04	5.42E 03	5.32E-01	
PU241	2.83E 03	2.45E 01	1.84E-03	6.80E-18				
PU242	4.23E 01	4.23E 01	4.23E 01	4.22E 01	4.21E 01	4.15E 01	3.52E 01	6.79E 00
AM241	4.88E 04	1.09E 05	7.93E 04	2.59E 04	1.05E 03	1.43E-02		
TOTAL	1.24E 05	1.56E 05	1.09E 05	4.96E 04	2.17E 04	1.33E 04	7.96E 02	1.77E 02

Table 4.48. Ingestion toxicity (m^3 water) of accumulated heavy isotopes in low-level plutonium TRU wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL207	8.16E-06	3.14E-03	3.40E-02	4.33E-01	3.72E 00	3.67E 01	9.97E 02	1.42E 03
TL209	6.48E-08	1.45E-04	4.00E-03	1.21E-01	1.88E 00	2.25E 01	5.22E 02	1.29E 03
PB209	9.81E-06	2.20E-02	6.05E-01	1.84E 01	2.84E 02	3.40E 03	7.91E 04	1.96E 05
PB210	6.19E 00	1.57E 04	3.72E 05	7.31E 06	5.92E 07	3.51E 08	2.78E 09	4.99E 08
PB211	1.64E-04	6.30E-02	6.82E-01	8.69E 00	7.46E 01	7.36E 02	2.00E 04	2.85E 04
PB214	1.05E-02	6.01E 00	9.47E 01	1.46E 03	1.18E 04	7.02E 04	5.56E 05	9.99E 04
BI210	1.55E-02	3.93E 01	9.30E 02	1.83E 04	1.48E 05	8.78E 05	6.95E 06	1.25E 06
BI211	9.36E-06	3.60E-03	3.90E-02	4.97E-01	4.26E 00	4.20E 01	1.14E 03	1.63E 03
BI213	5.89E-05	1.32E-01	3.63E 00	1.10E 02	1.71E 03	2.04E 04	4.75E 05	1.18E 06
BI214	8.73E-03	5.01E 00	7.89E 01	1.22E 03	9.86E 03	5.85E 04	4.63E 05	8.31E 04
PO210	7.68E-01	2.25E 03	5.32E 04	1.04E 06	8.45E 06	5.02E 07	3.97E 08	7.13E 07
PO213	2.88E-08	6.46E-05	1.78E-03	5.38E-02	8.34E-01	9.99E 00	2.32E 02	5.75E 02
PO214	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
PO215	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
PO218	1.31E-03	7.51E-01	1.18E 01	1.83E 02	1.48E 03	8.78E 03	6.95E 04	1.25E 04
AT217	4.91E-08	1.10E-04	3.03E-03	9.18E-02	1.42E 00	1.70E 01	3.96E 02	9.80E 02
RN219	6.55E-08	2.52E-05	2.73E-04	3.48E-03	2.98E-02	2.94E-01	8.00E 00	1.14E 01
RN222	5.24E-06	3.00E-03	4.73E-02	7.31E-01	5.92E 00	3.51E 01	2.78E 02	4.99E 01
FR221	3.68E-05	8.26E-02	2.27E 00	6.88E 01	1.07E 03	1.28E 04	2.97E 05	7.35E 05
RA223	9.36E-02	3.60E 01	3.90E 02	4.97E 03	4.26E 04	4.20E 05	1.14E 07	1.63E 07
RA225	5.89E-02	1.32E 02	3.63E 03	1.10E 05	1.71E 06	2.04E 07	4.75E 08	1.18E 09
RA226	1.75E 02	1.00E 05	1.58E 06	2.44E 07	1.97E 08	1.17E 09	9.26E 09	1.66E 09
AC225	5.89E-03	1.32E 01	3.63E 02	1.10E 04	1.71E 05	2.04E 06	4.75E 07	1.18E 08
AC227	3.27E-02	1.26E 01	1.36E 02	1.74E 03	1.49E 04	1.47E 05	4.00E 06	5.71E 06
TH227	3.23E-03	1.24E 00	1.35E 01	1.71E 02	1.47E 03	1.45E 04	3.94E 05	5.63E 05
TH229	7.36E-02	1.65E 02	4.54E 03	1.38E 05	2.13E 06	2.55E 07	5.94E 08	1.47E 09
TH230	1.25E 03	8.87E 04	4.69E 05	2.12E 06	6.86E 06	2.26E 07	1.38E 08	2.49E 07
TH231	1.77E 01	1.80E 02	5.02E 02	1.62E 03	4.68E 03	1.41E 04	5.38E 04	5.71E 04
PA231	5.32E-01	4.73E 01	3.70E 02	3.86E 03	3.32E 04	3.27E 05	8.89E 06	1.27E 07
PA233	3.23E 04	1.02E 06	2.84E 06	6.07E 06	7.57E 06	7.62E 06	7.40E 06	5.53E 06
U233	2.51E 00	7.06E 02	6.34E 03	5.37E 04	2.57E 05	1.00E 06	8.67E 06	1.96E 07
U234	1.50E 06	1.08E 07	1.70E 07	1.86E 07	1.85E 07	1.81E 07	1.41E 07	1.13E 06
U235	1.18E 02	1.20E 03	3.35E 03	1.08E 04	3.12E 04	9.42E 04	3.58E 05	3.80E 05
U236	5.11E 03	5.18E 04	1.44E 05	4.51E 05	1.22E 06	2.94E 06	4.57E 06	4.45E 06
NP237	1.07E 06	3.40E 07	9.45E 07	2.02E 08	2.52E 08	2.54E 08	2.47E 08	1.84E 08
PU238	2.85E 11	1.31E 11	2.76E 10	1.18E 08	2.03E 01			
PU239	6.64E 10	6.63E 10	6.59E 10	6.46E 10	6.10E 10	5.00E 10	3.88E 09	3.06E-02
PU240	9.71E 10	9.61E 10	9.41E 10	8.76E 10	7.14E 10	3.48E 10	3.42E 06	
PU241	3.41E 11	2.96E 09	2.22E 05	8.20E-10				
PU242	2.86E 08	2.86E 08	2.86E 08	2.86E 08	2.85E 08	2.81E 08	2.39E 08	4.60E 07
AM241	3.65E 11	8.13E 11	5.94E 11	1.94E 11	7.88E 09	1.07E 05		
TOTAL	1.16E 12	1.11E 12	7.82E 11	3.47E 11	1.41E 11	8.70E 10	1.81E 10	5.32E 09

Table 4.49. Grams of accumulated heavy elements in low-level U-233 wastes at a federal repository in the year 2005 as a function of age

	Year 2005	Years following close of the repository						
		100	300	1000	3000	10,000	100,000	1,000,000
HE	8.95E-02	6.53E-01	1.13E 00	2.10E 00	5.72E 00	2.66E 01	4.45E 02	1.72E 03
TL	1.79E-07	7.19E-08	1.07E-08	5.46E-10	1.44E-09	3.49E-09	3.99E-09	1.02E-10
PB	6.31E-01	4.57E 00	6.65E 00	7.02E 00	7.17E 00	1.04E 01	3.75E 02	4.07E 03
BI	4.21E-04	2.64E-02	2.02E-01	2.07E 00	1.72E 01	1.54E 02	3.26E 03	1.01E 04
PO	8.13E-10	9.85E-08	1.00E-06	1.15E-05	7.87E-05	4.42E-04	3.44E-03	6.17E-04
AT	8.04E-14	7.09E-13	1.95E-12	6.10E-12	1.65E-11	3.99E-11	4.55E-11	9.68E-13
RN	1.58E-07	6.83E-08	4.48E-08	3.37E-07	2.30E-06	1.29E-05	1.01E-04	1.80E-05
FR	7.37E-10	6.50E-09	1.79E-08	5.59E-08	1.51E-07	3.66E-07	4.17E-07	8.87E-09
PA	9.21E-04	1.13E-03	5.66E-03	5.27E-02	3.60E-01	2.02E 00	1.57E 01	2.81E 00
AC	2.25E-06	1.99E-05	5.48E-05	1.72E-04	4.64E-04	1.13E-03	1.31E-03	7.20E-05
TH	9.57E-01	7.02E 00	1.92E 01	6.04E 01	1.66E 02	4.35E 02	1.14E 03	1.83E 02
PA	1.86E-05	1.65E-04	4.57E-04	1.47E-03	4.28E-03	1.32E-02	6.07E-02	6.87E-02
U	1.92E 04	1.92E 04	1.92E 04	1.91E 04	1.90E 04	1.86E 04	1.40E 04	3.14E 03
TOTALS	1.92E 04	1.92E 04	1.92E 04	1.92E 04	1.92E 04	1.92E 04	1.92E 04	1.92E 04

Table 4.50. Curies of accumulated heavy isotopes in low-level U-233 wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL208	5.23E 01	2.10E 01	3.06E 00	3.62E-03	4.00E-09	1.32E-08	1.32E-07	1.30E-06
TL209	2.88E-03	2.53E-02	6.97E-02	2.18E-01	5.89E-01	1.43E 00	1.63E 00	3.46E-02
PB209	1.31E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
PB210	1.97E-06	4.43E-04	4.53E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
PB212	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
PB214	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
BI210	1.97E-06	4.43E-04	4.53E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
BI211	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
BI212	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
BI213	1.31E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
BI214	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
PO210	1.79E-06	4.43E-04	4.53E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
PO212	9.29E 01	3.73E 01	5.44E 00	6.43E-03	7.11E-09	2.35E-08	2.35E-07	2.32E-06
PO213	1.28E-01	1.13E 00	3.10E 00	9.69E 00	2.62E 01	6.34E 01	7.23E 01	1.54E 00
PO214	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
PO215	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
PO216	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
PO218	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
AT217	1.31E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
RN219	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
RN220	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
RN222	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
FR221	1.31E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
RA223	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
RA224	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
RA225	1.30E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
RA226	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
AC225	1.31E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
TH227	1.84E-07	5.67E-06	1.93E-05	6.91E-05	2.01E-04	6.22E-04	2.85E-03	3.23E-03
TH228	1.44E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
TH229	1.30E-01	1.15E 00	3.17E 00	9.91E 00	2.68E 01	6.49E 01	7.40E 01	1.57E 00
TH230	3.41E-03	3.04E-02	8.43E-02	2.72E-01	8.00E-01	2.55E 00	1.54E 01	2.78E 00
U232	1.48E 02	5.67E 01	8.27E 00	9.64E-03	4.19E-11			
U233	1.08E 02	1.08E 02	1.08E 02	1.08E 02	1.07E 02	1.04E 02	7.06E 01	1.50E 00
U234	3.12E 01	3.12E 01	3.12E 01	3.11E 01	3.09E 01	3.03E 01	2.36E 01	1.88E 00
U236	7.47E-02	7.47E-02	7.47E-02	7.47E-02	7.47E-02	7.47E-02	7.45E-02	7.26E-02
TOTAL	1.30E 03	6.13E 02	2.33E 02	2.19E 02	3.56E 02	6.74E 02	8.41E 02	4.39E 01

Table 4.51. Watts of accumulated heavy isotopes in low-level U-233 wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL208	1.22E 00	4.88E-01	7.12E-02	8.43E-05	9.32E-11	3.08E-10	3.08E-09	3.04E-08
TL209	4.70E-05	4.14E-04	1.14E-03	3.57E-03	9.63E-03	2.33E-02	2.66E-02	5.66E-04
PB209	1.50E-04	1.32E-03	3.64E-03	1.14E-02	3.08E-02	7.46E-02	8.51E-02	1.81E-03
PB210	8.18E-11	1.84E-08	1.88E-07	2.15E-06	1.47E-05	8.27E-05	6.44E-04	1.15E-04
PB212	2.08E-01	8.36E-02	1.22E-02	1.44E-05	1.59E-11	5.28E-11	5.26E-10	5.20E-09
PB214	2.82E-08	1.78E-06	1.33E-05	1.26E-04	8.65E-04	4.85E-03	3.78E-02	6.77E-03
BI210	5.19E-09	1.17E-06	1.19E-05	1.37E-04	9.34E-04	5.24E-03	4.09E-02	7.32E-03
BI211	7.28E-09	2.24E-07	7.64E-07	2.73E-06	7.95E-06	2.46E-05	1.13E-04	1.28E-04
BI212	2.52E 00	1.01E 00	1.47E-01	1.75E-04	1.93E-10	6.39E-10	6.37E-09	6.29E-08
BI213	8.03E-04	7.08E-03	1.95E-02	6.09E-02	1.65E-01	3.99E-01	4.55E-01	9.67E-03
BI214	1.61E-07	1.02E-05	7.61E-05	7.23E-04	4.94E-03	2.77E-02	2.16E-01	3.87E-02
PO210	5.63E-08	1.40E-05	1.42E-04	1.63E-03	1.12E-02	6.27E-02	4.89E-01	8.75E-02
PO212	4.92E 00	1.98E 00	2.88E-01	3.41E-04	3.77E-10	1.25E-09	1.24E-08	1.23E-07
PO213	6.35E-03	5.60E-02	1.54E-01	4.81E-01	1.30E 00	3.15E 00	3.59E 00	7.64E-02
PO214	5.27E-07	3.34E-05	2.49E-04	2.37E-03	1.62E-02	9.08E-02	7.07E-01	1.27E-01
PO215	8.19E-09	2.52E-07	8.59E-07	3.07E-06	8.94E-06	2.76E-05	1.27E-04	1.43E-04
PO216	5.94E 00	2.38E 00	3.48E-01	4.11E-04	4.55E-10	1.51E-09	1.50E-08	1.48E-07
PO218	4.19E-07	2.65E-05	1.98E-04	1.88E-03	1.29E-02	7.22E-02	5.62E-01	1.01E-01
AT217	5.48E-03	4.83E-02	1.33E-01	4.15E-01	1.12E 00	2.72E 00	3.10E 00	6.59E-02
RN219	7.57E-09	2.33E-07	7.94E-07	2.84E-06	8.26E-06	2.55E-05	1.17E-04	1.33E-04
RN220	5.50E 00	2.21E 00	3.22E-01	3.81E-04	4.21E-10	1.39E-09	1.39E-08	1.37E-07
RN222	3.77E-07	2.39E-05	1.78E-04	1.69E-03	1.16E-02	6.49E-02	5.06E-01	9.06E-02
FR221	4.86E-03	4.29E-02	1.18E-01	3.69E-01	9.96E-01	2.41E 00	2.75E 00	5.85E-02
RA223	6.49E-09	2.00E-07	6.82E-07	2.43E-06	7.09E-06	2.19E-05	1.00E-04	1.14E-04
RA224	4.96E 00	1.99E 00	2.91E-01	3.44E-04	3.80E-10	1.26E-09	1.26E-08	1.24E-07
RA225	8.57E-05	7.58E-04	2.08E-03	6.52E-03	1.76E-02	4.27E-02	4.87E-02	1.03E-03
RA226	3.28E-07	2.07E-05	1.55E-04	1.47E-03	1.00E-02	5.64E-02	4.39E-01	7.87E-02
AC225	4.49E-03	3.96E-02	1.09E-01	3.40E-01	9.19E-01	2.23E 00	2.54E 00	5.40E-02
TH227	6.33E-09	1.95E-07	6.66E-07	2.38E-06	6.92E-06	2.14E-05	9.80E-05	1.11E-04
TH228	4.73E 00	1.91E 00	2.78E-01	3.29E-04	3.64E-10	1.20E-09	1.20E-08	1.19E-07
TH229	3.92E-03	3.48E-02	9.57E-02	3.00E-01	8.10E-01	1.96E 00	2.24E 00	4.75E-02
TH230	9.62E-05	8.59E-04	2.38E-03	7.69E-03	2.26E-02	7.22E-02	4.36E-01	7.85E-02
U232	4.77E 00	1.82E 00	2.65E-01	3.09E-04	1.34E-12			
U233	3.15E 00	3.15E 00	3.15E 00	3.14E 00	3.11E 00	3.02E 00	2.06E 00	4.37E-02
U234	8.98E-01	8.97E-01	8.97E-01	8.95E-01	8.90E-01	8.73E-01	6.78E-01	5.42E-02
U236	2.03E-03	2.03E-03	2.03E-03	2.03E-03	2.03E-03	2.03E-03	2.02E-03	1.97E-03
TOTAL	3.88E 01	1.82E 01	6.71E 00	6.05E 00	9.47E 00	1.74E 01	2.10E 01	1.03E 00

Table 4.52. Ingestion toxicity (m^3 water) of accumulated heavy isotopes in low-level U-233 wastes at a federal repository in the year 2005 as a function of age

	Year	Years following close of the repository						
	2005	100	300	1000	3000	10,000	100,000	1,000,000
TL208	1.05E 04	4.19E 03	6.12E 02	7.24E-01	8.00E-07	2.65E-06	2.64E-05	2.61E-04
TL209	2.88E-01	2.53E 00	6.97E 00	2.18E 01	5.89E 01	1.43E 02	1.63E 02	3.46E 00
PB209	4.36E 01	3.84E 02	1.06E 03	3.30E 03	8.93E 03	2.16E 04	2.47E 04	5.24E 02
PB210	1.97E 01	4.43E 03	4.53E 04	5.19E 05	3.55E 06	1.99E 07	1.55E 08	2.78E 07
PB212	7.26E 06	2.91E 06	4.25E 05	5.03E 02	5.56E-04	1.84E-03	1.83E-02	1.81E-01
PB214	2.32E-02	1.46E 00	1.09E 01	1.04E 02	7.10E 02	3.99E 03	3.10E 04	5.56E 03
BI210	4.93E-02	1.11E 01	1.13E 02	1.30E 03	8.87E 03	4.98E 04	3.88E 05	6.95E 04
BI211	2.67E-05	8.22E-04	2.80E-03	1.00E-02	2.91E-02	9.01E-02	4.13E-01	4.69E-01
BI212	3.63E 05	1.46E 05	2.12E 04	2.51E 01	2.78E-05	9.20E-05	9.17E-04	9.05E-03
BI213	2.61E 02	2.30E 03	6.33E 03	1.98E 04	5.36E 04	1.30E 05	1.48E 05	3.15E 03
BI214	1.93E-02	1.22E 00	9.11E 00	8.65E 01	5.92E 02	3.32E 03	2.59E 04	4.63E 03
PO210	2.55E 00	6.33E 02	6.46E 03	7.42E 04	5.07E 05	2.85E 06	2.22E 07	3.97E 06
PO212	9.29E 01	3.73E 01	5.44E 00	6.43E-03	7.11E-09	2.35E-08	2.35E-07	2.32E-06
PO213	1.28E-01	1.13E 00	3.10E 00	9.69E 00	2.62E 01	6.34E 01	7.23E 01	1.54E 00
PO214	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
PO215	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
PO216	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
PO218	2.89E-03	1.83E-01	1.37E 00	1.30E 01	8.87E 01	4.98E 02	3.88E 03	6.95E 02
AT217	2.18E-01	1.92E 00	5.28E 00	1.65E 01	4.46E 01	1.08E 02	1.23E 02	2.62E 00
RN219	1.87E-07	5.75E-06	1.96E-05	7.01E-05	2.04E-04	6.30E-04	2.89E-03	3.27E-03
RN220	1.45E 02	5.82E 01	8.49E 00	1.01E-02	1.11E-08	3.68E-08	3.67E-07	3.62E-06
RN222	1.16E-05	7.32E-04	5.47E-03	5.19E-02	3.55E-01	1.99E 00	1.55E 01	2.78E 00
FR221	1.63E 02	1.44E 03	3.96E 03	1.24E 04	3.35E 04	8.11E 04	9.25E 04	1.97E 03
RA223	2.67E-01	8.22E 00	2.80E 01	1.00E 02	2.91E 02	9.01E 02	4.13E 03	4.68E 03
RA224	7.26E 07	2.91E 07	4.25E 06	5.03E 03	5.56E-03	1.84E-02	1.83E-01	1.81E 00
RA225	2.60E 05	2.30E 06	6.33E 06	1.98E 07	5.36E 07	1.30E 08	1.48E 08	3.15E 06
RA226	3.86E 02	2.44E 04	1.82E 05	1.73E 06	1.18E 07	6.64E 07	5.17E 08	9.27E 07
AC225	2.61E 04	2.30E 05	6.33E 05	1.98E 06	5.36E 06	1.30E 07	1.48E 07	3.15E 05
TH227	9.20E-03	2.84E-01	9.67E-01	3.45E 00	1.01E 01	3.11E 01	1.42E 02	1.61E 02
TH228	2.06E 07	8.32E 06	1.21E 06	1.44E 03	1.59E-03	5.26E-03	5.24E-02	5.17E-01
TH229	3.24E 05	2.88E 06	7.92E 06	2.48E 07	6.69E 07	1.62E 08	1.85E 08	3.93E 06
TH230	1.70E 03	1.52E 04	4.22E 04	1.36E 05	4.00E 05	1.28E 06	7.72E 06	1.39E 06
U232	4.95E 06	1.89E 06	2.76E 05	3.21E 02	1.40E-06			
U233	3.61E 06	3.61E 06	3.61E 06	3.60E 06	3.57E 06	3.46E 06	2.35E 06	5.01E 04
U234	1.04E 06	1.04E 06	1.04E 06	1.04E 06	1.03E 06	1.01E 06	7.85E 05	6.28E 04
U236	2.49E 03	2.49E 03	2.49E 03	2.49E 03	2.49E 03	2.49E 03	2.48E 03	2.42E 03
TOTAL	1.11E 08	5.25E 07	2.60E 07	5.37E 07	1.47E 08	4.00E 08	1.05E 09	1.33E 08

Table 4.53. Projected annual accumulation of noble-gas fission products

Year	* * Annual Addition * * * Number of Cylinders	Radio-activity (MCi)	Thermal Power (kW)	Annual Number of Shipments	* Accumulation Through End of Year * Number of Cylinders	Radio-activity (MCi)	Thermal Power (kW)	Hazard (m^3 of Air at RCG)
1980	0	0.0	0.1	0	0	0	0	1.4E 11
1981	0	0.1	0.1	0	0	0	0	3.8E 11
1982	21	2.8	4.2	3	21	3	4	9.7E 12
1983	62	8.3	12.5	10	84	11	17	3.7E 13
1984	69	9.2	13.9	12	153	20	29	6.5E 13
1985	78	10.4	15.6	13	231	29	43	9.6E 13
1986	111	14.7	22.1	18	342	42	63	1.4E 14
1987	164	21.5	32.4	27	505	61	91	2.0E 14
1988	160	20.8	31.3	27	666	78	117	2.6E 14
1989	187	23.8	35.8	31	853	97	145	3.2E 14
1990	238	30.4	45.7	40	1090	121	182	4.0E 14
1991	264	33.9	51.0	44	1355	148	222	4.9E 14
1992	321	41.1	61.8	53	1675	180	270	6.0E 14
1993	352	45.5	68.3	59	2027	214	322	7.1E 14
1994	411	52.8	79.4	68	2438	253	381	8.4E 14
1995	442	56.0	84.2	74	2880	294	442	9.8E 14
1996	504	63.2	95.0	84	3384	339	509	1.1E 15
1997	532	66.5	99.9	89	3916	384	578	1.3E 15
1998	613	77.4	116.4	102	4529	438	658	1.5E 15
1999	678	86.7	130.3	113	5207	497	748	1.7E 15
2000	621	79.0	118.9	104	5829	546	820	1.8E 15
2001	582	73.4	110.6	97	6410	585	880	2.0E 15
TIME AFTER SHUTDOWN, YEARS								
100					6410	1	1	3.3E 12
300					6410	0	0	9.1E 06
1000					6410	0	0	3.3E-13
3000					6410	0	0	0.0

and then shipped by rail to a repository for long-term storage. An individual shipment consists of six gas cylinders contained in a specially-designed water-filled cask.[30]

4.6 Iodine

Iodine is a semivolatile fission product which, because of its complex physical and chemical properties and its high biological significance, has always required special attention to ensure adequate safety in its management. About 0.01 g of iodine isotopes is formed per MWd (thermal), and the isotope of greatest concern during reactor operation and fuel reprocessing is 8.05-d ^{131}I. However, the species of consequence to longer-term waste management is 1.6×10^7-y ^{129}I, which comprises about 75% of the weight of the fission product iodine isotopes in spent fuels at the time of reprocessing.

Research and development work aimed at reducing iodine releases from fuel reprocessing plants to "near zero" levels shows promise of removing at least 99.9% of it from other fuel constituents by volatilization at the head-end of the process.[29] Once separated, it would subsequently be trapped and retained separately from the other waste streams. The final form into which the iodine may be processed for packaging, shipment, and disposal has not been defined as yet, but concentrates of ^{129}I must receive careful attention because of this isotope's very long half-life.

The accumulation of fission product iodine is given in Table 4.54. In constructing this table, it was assumed that 99.9% of the iodine was recovered in a pure form at the reprocessing plants, converted to barium iodate, concreted, and stored for 1 year before shipment to a repository or to a disposal site. The barium iodate was assumed to be concreted with a mixture of cement, water, and 0.9 wt % butyl stearate (to reduce the iodine leach rate), resulting in a product containing 10 wt % iodine.[31] On a volumetric basis, the product contains 5.29 kg of iodine per cubic foot. It is shipped by motor freight in Type 17C, 55-gal drums, 64 drums per shipment. The minimum number of annual shipments is taken to be one per reprocessing plant.

Table 4.54. Projected annual accumulation of fission product iodine

Year	Annual Addition: Volume (m^3)	Annual Addition: Iodine Mass (kg)	Annual Addition: Radioactivity (Curies)	Annual Addition: Thermal Power (Watts)	Annual Number of Shipments	Accumulation Through End of Year: Volume (m^3)	Accumulation Through End of Year: Iodine Mass (kg)	Accumulation Through End of Year: Radioactivity (Curies)	Accumulation Through End of Year: Thermal Power (Watts)	Hazard, Cubic Meters at RCG: Air	Hazard, Cubic Meters at RCG: Water
1980	0.00	1	0.1	0.000	0	0.00	1	0	0.000	4.4E 09	1.5E 06
1981	0.01	1	0.2	0.000	0	0.01	2	0	0.000	1.3E 10	4.2E 06
1982	0.44	81	11.2	0.007	1	0.45	83	11	0.007	5.7E 11	1.9E 08
1983	1.30	243	33.5	0.020	4	1.75	327	45	0.027	2.2E 12	7.5E 08
1984	1.44	270	37.1	0.022	5	3.19	597	82	0.050	4.1E 12	1.4E 09
1985	1.62	303	41.7	0.025	6	4.82	900	124	0.075	6.2E 12	2.1E 09
1986	2.30	429	59.0	0.036	8	7.11	1329	183	0.111	9.1E 12	3.0E 09
1987	3.45	644	88.5	0.053	12	10.56	1973	271	0.164	1.4E 13	4.5E 09
1988	3.44	643	88.2	0.053	12	14.00	2615	360	0.217	1.8E 13	6.0E 09
1989	4.13	772	105.6	0.064	14	18.13	3387	465	0.281	2.3E 13	7.8E 09
1990	5.20	972	133.1	0.080	18	23.33	4359	598	0.362	3.0E 13	1.0E 10
1991	5.75	1074	147.2	0.089	20	29.09	5434	746	0.451	3.7E 13	1.2E 10
1992	7.01	1309	179.3	0.108	24	36.09	6743	925	0.559	4.6E 13	1.5E 10
1993	7.60	1419	194.6	0.118	26	43.69	8162	1120	0.677	5.6E 13	1.9E 10
1994	8.92	1666	228.3	0.138	30	52.61	9828	1348	0.815	6.7E 13	2.2E 10
1995	9.83	1836	251.1	0.152	33	62.43	11663	1599	0.966	8.0E 13	2.7E 10
1996	11.34	2118	289.4	0.175	39	73.77	13781	1888	1.141	9.4E 13	3.1E 10
1997	12.03	2247	306.9	0.185	41	85.80	16029	2195	1.327	1.1E 14	3.7E 10
1998	13.72	2564	350.4	0.212	47	99.52	18592	2546	1.538	1.3E 14	4.2E 10
1999	14.94	2790	381.8	0.231	51	114.46	21383	2927	1.769	1.5E 14	4.9E 10
2000	13.92	2600	355.0	0.215	47	128.38	23983	3282	1.984	1.6E 14	5.5E 10
2001	13.35	2493	339.3	0.206	45	141.73	26477	3622	2.190	1.8E 14	6.0E 10
TIME AFTER SHUTDOWN, YEARS											
100						141.73	26477	3622	2.190	1.8E 14	6.0E 10
300						141.73	26477	3622	2.190	1.8E 14	6.0E 10
1000						141.73	26477	3622	2.190	1.8E 14	6.0E 10
3000						141.73	26477	3621	2.189	1.8E 14	6.0E 10
10000						141.73	26477	3620	2.189	1.8E 14	6.0E 10
30000						141.73	26477	3617	2.187	1.8E 14	6.0E 10
100000						141.73	26477	3606	2.180	1.8E 14	6.0E 10
300000						141.73	26477	3575	2.161	1.8E 14	6.0E 10
1000000						141.73	26477	3468	2.097	1.7E 14	5.8E 10

4.7 Carbon-14

Carbon-14 is produced in oxide-fueled reactors principally by an (n,p) reaction with ^{14}N impurity in the fuels, but also as the product of an (n,α) reaction with ^{17}O. In HTGRs, it is also produced by (n,α) reactions with the graphite fuel blocks. The chemical behavior of carbon during nitric acid dissolution of the fuel is not known. The assumption most often made is that it will be released as a gas, most probably CO_2, from the dissolver. In HTGR fuel reprocessing, the ^{14}C will be oxidized with the graphite in the fuel block burning step.

The ^{14}C activity which appears in the fuel reprocessing plant depends on the amount of nitrogen impurity in the fuel. A value of 25 ppm nitrogen has been recommended for LWR fuels, although values from 1 to 100 ppm have been observed.[32] The nitrogen content of HTGR fuel blocks is assumed to be 30 ppm, in close agreement with values used elsewhere.[33] The nitrogen content of LMFBR fuel is also assumed to be 25 ppm. The ^{14}C activities resulting in spent fuels from the reference reactors are as follows:

Reactor	^{14}C Activity (Ci/MTHM)
PWR-U	0.598
PWR-Pu	0.314
BWR-U	0.539
BWR-Pu	0.293
HTGR	16.5
LMFBR	0.454

The projected annual accumulations of ^{14}C which will be generated by LWRs and LMFBRs are given in Table 4.55.

4.8 Tritium

Tritium wastes are generated at nuclear power stations and at fuel reprocessing plants. Tritium in light water reactor wastes arises principally from neutron reactions with light elements such as lithium and boron that may be present in the primary coolants. New power

Table 4.55. Projected annual accumulation (Ci) of carbon-14 from reactor fuels

Year	* * Annual Addition * * LWR	LMFBR	Total	Accumulation Through End of Year LWR	LMFBR	Total
1981	198	0	198	198	0	198
1982	605	0	605	803	0	803
1983	668	0	668	1471	0	1471
1984	748	0	748	2219	0	2219
1985	1059	0	1059	3278	0	3278
1986	1546	1	1547	4823	1	4825
1987	1485	1	1486	6308	3	6310
1988	1681	2	1683	7988	5	7993
1989	2155	2	2158	10142	7	10149
1990	2410	2	2412	12551	9	12560
1991	2922	5	2928	15472	15	15487
1992	3244	6	3250	18714	21	18735
1993	3764	7	3771	22475	28	22503
1994	3961	8	3969	26434	36	26469
1995	4452	8	4460	30882	44	30926
1996	4670	10	4680	35548	54	35602
1997	5450	17	5466	40994	71	41064
1998	6110	30	6140	47098	101	47199
1999	5480	52	5532	52573	153	52726
2000	4961	87	5047	57527	240	57767
TIME AFTER SHUTDOWN, YEARS						
100				56836	237	57072
300				55477	231	55708
1000				50973	212	51185
3000				40019	167	40186
10000				17160	71	17231
30000				1527	6	1533
100000				0	0	0

stations may have the capability for recycling the coolant until the tritium concentration reaches about 5 μCi/ml, and then to maintain that concentration by additions of fresh water to the coolant as required. Operating experience with this technique is lacking; however, using the annual rates of tritium generation reported in ref. 34, it is estimated that about 63,380 and 10,560 gal of tritiated water will be bled annually from the primary circuits of the reference PWR and BWR, respectively. This waste could be stored in tanks at the power stations until it is shipped to disposal sites.

Between 400 and 1300 Ci of tritium per metric ton of fuel, depending on the type of reference reactor, is produced in fission and appears in wastes from fuel reprocessing. A few percent may be associated with the fuel cladding, but most is present with the core materials and is eventually released as water vapor to the atmosphere. Future plants having head-end operations like "voloxidation"[17] should be able to separate and recover the tritium in a relatively small volume, perhaps in as little as a few liters of tritiated water per day. This concentrate could then be converted into an appropriately stable, solid form [such as $Ca(OH)_2$, perhaps], packaged, and shipped to a designated storage or disposal site.

There is evidence that tritium may act differently in LMFBRs than in other reactor types.[34] As much as 95% may diffuse through the stainless steel cladding during reactor operation and appear as a sodium tritide sludge in the primary-coolant cold traps. If experience bears out this behavior, processes for recovery and packaging of the tritium from LMFBR fuels will be installed at the power stations rather than at the reprocessing plants.

The projected accumulation of tritium in the form of tritiated water from the primary coolant circuits of LWRs is presented in Table 4.56. After storage at the power stations for one year, this water is shipped to a disposal site in tank trucks of 4000-gal capacity each.

Table 4.56. Projected annual accumulation of tritiated water from reactors

Year	* * Annual Addition * * * Volume (Thousands of m^3)	Radio-activity (MCi)	Thermal Power (Watts)	Annual Number of Shipments	* * * * Accumulation Through End of Year * * * * Volume (Thousands of m^3)	Radio-activity (MCi)	Thermal Power (Watts)	Hazard, Cubic Meters at RCG Air	Water
1971	0.56	0.0026	0.09	37	0.6	0.003	0.1	1.3E 10	6.8E 05
1972	0.90	0.0042	0.15	59	1.5	0.007	0.2	3.4E 10	2.2E 06
1973	1.04	0.0049	0.17	69	2.5	0.011	0.4	5.6E 10	3.8E 06
1974	1.60	0.0076	0.27	106	4.1	0.018	0.6	9.1E 10	6.1E 06
1975	2.33	0.0110	0.39	154	6.4	0.028	1.0	1.4E 11	9.4E 06
1976	3.68	0.0174	0.62	243	10.1	0.044	1.6	2.2E 11	1.5E 07
1977	5.79	0.0274	0.97	382	15.9	0.069	2.5	3.5E 11	2.3E 07
1978	6.66	0.0315	1.12	440	22.6	0.097	3.4	4.8E 11	3.2E 07
1979	7.85	0.0371	1.32	518	30.4	0.128	4.6	6.4E 11	4.3E 07
1980	8.57	0.0405	1.44	566	39.0	0.162	5.8	8.1E 11	5.4E 07
1981	9.48	0.0448	1.59	626	48.4	0.198	7.0	9.9E 11	6.6E 07
1982	10.78	0.0509	1.81	712	59.2	0.238	8.5	1.2E 12	7.9E 07
1983	12.70	0.0600	2.14	839	71.9	0.285	10.1	1.4E 12	9.5E 07
1984	15.00	0.0709	2.52	991	86.9	0.340	12.1	1.7E 12	1.1E 08
1985	17.91	0.0846	3.01	1183	104.8	0.406	14.5	2.0E 12	1.4E 08
1986	20.22	0.0955	3.40	1335	125.1	0.479	17.1	2.4E 12	1.6E 08
1987	22.98	0.1086	3.87	1518	148.0	0.561	20.0	2.8E 12	1.9E 08
1988	25.75	0.1217	4.33	1701	173.8	0.652	23.2	3.3E 12	2.2E 08
1989	28.66	0.1354	4.82	1893	202.4	0.752	26.8	3.8E 12	2.5E 08
1990	31.71	0.1499	5.33	2095	234.2	0.860	30.6	4.3E 12	2.9E 08
1991	34.64	0.1637	5.83	2288	268.8	0.977	34.8	4.9E 12	3.3E 08
1992	37.83	0.1787	6.36	2498	306.6	1.102	39.2	5.5E 12	3.7E 08
1993	41.01	0.1938	6.90	2709	347.6	1.235	44.0	6.2E 12	4.1E 08
1994	44.34	0.2095	7.46	2928	392.0	1.377	49.0	6.9E 12	4.6E 08
1995	47.66	0.2252	8.02	3148	439.6	1.526	54.3	7.6E 12	5.1E 08
1996	50.86	0.2403	8.56	3359	490.5	1.683	59.9	8.4E 12	5.6E 08
1997	53.90	0.2547	9.07	3560	544.4	1.845	65.7	9.2E 12	6.1E 08
1998	56.72	0.2680	9.54	3747	601.1	2.011	71.6	1.0E 13	6.7E 08
1999	59.49	0.2811	10.01	3929	660.6	2.182	77.7	1.1E 13	7.3E 08
2000	62.26	0.2942	10.47	4112	722.9	2.356	83.9	1.2E 13	7.9E 08
2001	64.83	0.3063	10.91	4282	787.7	2.533	90.2	1.3E 13	8.4E 08
TIME AFTER SHUTDOWN, YEARS									
100					787.7	0.009	0.3	4.4E 10	3.0E 06
300					787.7	0.000	0.0	5.5E 05	3.6E 01
1000					787.7	0.000	0.0	3.5E-12	2.4E-16
3000					787.7	0.000	0.0	2.8E-61	1.8E-65
10000					787.7	0.0	0.0	0.0	0.0

Shipments and accumulations of fission-product tritium one year after its separation from spent fuel at reprocessing plants and LMFBR power stations are presented in Table 4.57. It is assumed that this tritium is recovered in water at a concentration of 200 Ci/liter and is then immobilized as $Ca(OH)_2$. The tritiated $Ca(OH)_2$ is packaged for shipment in Foamglas shipping containers [0.16 ft^3 of $Ca(OH)_2$ per container] and shipped by motor freight to a repository for long-term storage. Each shipment consists of 64 containers carrying a total net payload of 10.2 ft^3 of $Ca(OH)_2$.

4.9 Low-Level Non-TRU Solid Wastes

These diverse solid wastes are common to all facilities handling radioactive materials. They range from concentrates of the radionuclides generated in the decontamination of plant effluent streams to almost every conceivable type of contaminated solid refuse from plant operations. They normally require minimal shielding; and, since they contain less than 10 nCi of long-lived alpha activity per gram, they are currently disposable in surface burial grounds. Based on operating experiences at ERDA sites, we estimate that 40,000, 80,000, and 16,000 ft^3 of these wastes per ton of plutonium or ^{233}U processed will be generated at fuel preparation, fabrication, and reprocessing plants, respectively. Their average radioactivity level is taken to be 1 Ci of a 160-day-old LWR fission-product mixture per cubic foot. Additionally, we estimate that 15,000 ft^3/year will be generated at each 1000-MW(e) power station.[35] These reactor wastes are assumed to contain 0.1, 0.2, and 0.3 Ci of a 160-day-old mixture of induced (corrosion product) isotopes per cubic foot during the years 1971 to 1985, 1986 to 1990, and 1991 to 2000, respectively. The wastes are packaged in Type 17C, 55-gal steel drums and shipped by motor freight to licensed burial grounds 1 year after their generation. Individual shipments consist of 64 drums containing a total of 475 ft^3 of waste, and 1 acre of land is utilized for the burial of each 50,000 ft^3 of waste.

The projected annual and accumulated amounts of compacted, solid non-TRU wastes from reactors at one or more surface burial grounds

Table 4.57. Projected annual accumulation of fission product tritium

Year	* * Annual Addition * * * Volume (m^3)	Radio-activity (MCi)	Thermal Power (Watts)	Annual Number of Shipments	* * * * Accumulation Through End of Year * * * * Volume (m^3)	Radio-activity (MCi)	Thermal Power (Watts)	Hazard, Cubic Meters at RCG Air	Water
1980	0.0	0.00	0	0	0.0	0.00	0	4.2E 09	2.8E 05
1981	0.0	0.00	0	0	0.0	0.00	0	1.2E 10	7.8E 05
1982	3.1	0.16	6	11	3.1	0.16	6	8.2E 11	5.4E 07
1983	9.3	0.48	17	32	12.4	0.64	23	3.2E 12	2.1E 08
1984	10.3	0.54	19	36	22.8	1.14	41	5.7E 12	3.8E 08
1985	11.6	0.61	22	40	34.4	1.69	60	8.4E 12	5.6E 08
1986	16.5	0.86	31	57	50.8	2.45	87	1.2E 13	8.2E 08
1987	24.6	1.28	46	85	75.5	3.60	128	1.8E 13	1.2E 09
1988	24.4	1.27	45	85	99.9	4.68	166	2.3E 13	1.6E 09
1989	29.1	1.52	54	101	129.0	5.94	211	3.0E 13	2.0E 09
1990	36.7	1.91	68	127	165.7	7.52	268	3.8E 13	2.5E 09
1991	40.7	2.12	75	141	206.3	9.23	328	4.6E 13	3.1E 09
1992	49.5	2.58	92	171	255.9	11.31	402	5.7E 13	3.8E 09
1993	53.9	2.81	100	187	309.8	13.50	480	6.7E 13	4.5E 09
1994	63.2	3.29	117	219	373.0	16.05	571	8.0E 13	5.3E 09
1995	69.1	3.60	128	239	442.0	18.77	667	9.4E 13	6.3E 09
1996	79.4	4.14	147	275	521.4	21.88	778	1.1E 14	7.3E 09
1997	84.1	4.39	156	291	605.5	25.06	891	1.3E 14	8.4E 09
1998	96.4	5.02	179	334	701.9	28.71	1021	1.4E 14	9.6E 09
1999	105.6	5.51	196	366	807.5	32.63	1160	1.6E 14	1.1E 10
2000	98.2	5.12	182	340	905.6	35.96	1279	1.8E 14	1.2E 10
2001	94.0	4.90	174	325	999.6	38.88	1383	1.9E 14	1.3E 10
TIME AFTER SHUTDOWN, YEARS									
100					999.6	0.14	5	6.8E 11	4.5E 07
300					999.6	0.00	0	8.4E 06	5.6E 02
1000					999.6	0.00	0	5.4E-11	3.6E-15
3000					999.6	0.00	0	4.2E-60	2.8E-64
10000					999.6	0.0	0	0.0	0.0

are given in Table 4.58. Table 4.59 presents the annual and accumulated amounts of compacted, solid non-TRU wastes from all fuel cycle sources (including reactors) at surface burial grounds.

4.10 Ore Tailings

The processes used to extract uranium from ore are based on either alkaline or acid leaching followed by recovery of the uranium from the leach liquors by solvent extraction or ion exchange techniques.[36] The ore typically averages about 0.2% uranium as U_3O_8, and the mills normally recover about 95% of it. The remaining 5% is discharged in the wastes, or tailings, with the other naturally occurring radioisotopes originally present in the ore. The tailings consist of sands, slimes containing the bulk of the radioactivity, and process leach liquors. They are discharged to tailings ponds adjacent to the mills from which the liquids either evaporate or seep into the ground. The solids, which are roughly equivalent in volume to the original ore, average about 0.16 yd^3 per pound of recovered U_3O_8. Their future disposition remains in doubt; however, it is likely that they will be returned to the mines from which they came or will be covered in place with plastic or asphaltic membranes and earth to reduce dispersal by weathering.

Thorium ores are not as yet processed on a large scale in the U.S., but for this study we consider them comparable to uranium ores in milling and tailings characteristics.

The accumulations of tailings from milling uranium and thorium ores are presented in Tables 4.60 and 4.61. These projections are based on the assumption that 95% of the uranium and thorium is extracted from ores that assay 0.2% uranium or thorium. The unrecovered 5% and all radioactive daughters remain with the tailings. The volume of tailings is estimated on the basis of 0.16 yd^3 being formed per pound of recovered U_3O_8 or ThO_2.

Table 4.56. Projected annual accumulation of low-level nontransuranic waste from reactors

Year	Annual Addition: Volume (Millions of m^3)	Annual Addition: Radioactivity (MCi)	Annual Addition: Thermal Power (kW)	Annual Addition: Burial Area (Acres)	Annual Number of Shipments	Accumulation Through End of Year: Volume (Millions of m^3)	Accumulation Through End of Year: Radioactivity (MCi)	Accumulation Through End of Year: Thermal Power (kW)	Accumulation Through End of Year: Burial Area (Acres)	Hazard, Cubic Meters at RCG: Air	Hazard, Cubic Meters at RCG: Water
1971	0.002	0.00	0.01	1.5	158	0.002	0.00	0.0	1	2.1E 12	2.7E 07
1972	0.003	0.00	0.01	2.4	253	0.006	0.01	0.0	4	5.0E 12	6.4E 07
1973	0.004	0.01	0.02	3.0	316	0.010	0.01	0.0	7	8.1E 12	1.1E 08
1974	0.006	0.01	0.03	4.5	474	0.016	0.02	0.1	11	1.3E 13	1.7E 08
1975	0.010	0.01	0.04	6.9	726	0.026	0.03	0.1	18	2.0E 13	2.6E 08
1976	0.014	0.02	0.06	9.6	1014	0.040	0.04	0.1	28	2.9E 13	3.8E 08
1977	0.019	0.03	0.08	13.2	1389	0.058	0.06	0.2	41	4.1E 13	5.4E 08
1978	0.021	0.03	0.09	14.8	1563	0.079	0.07	0.2	56	5.3E 13	7.0E 08
1979	0.024	0.03	0.10	16.7	1759	0.103	0.09	0.3	73	6.5E 13	8.7E 08
1980	0.026	0.04	0.11	18.0	1898	0.128	0.11	0.3	91	7.7E 13	1.0E 09
1981	0.029	0.04	0.12	20.4	2151	0.157	0.12	0.4	111	8.9E 13	1.2E 09
1982	0.033	0.05	0.14	23.6	2485	0.191	0.14	0.4	135	1.0E 14	1.4E 09
1983	0.038	0.05	0.16	27.1	2858	0.229	0.17	0.5	162	1.2E 14	1.6E 09
1984	0.045	0.06	0.19	31.8	3344	0.274	0.19	0.6	194	1.4E 14	1.9E 09
1985	0.054	0.08	0.22	38.0	4001	0.328	0.23	0.7	232	1.6E 14	2.2E 09
1986	0.062	0.18	0.52	44.0	4636	0.390	0.35	1.0	276	2.5E 14	3.4E 09
1987	0.071	0.20	0.59	50.0	5267	0.461	0.47	1.4	326	3.4E 14	4.6E 09
1988	0.079	0.22	0.66	56.0	5899	0.541	0.59	1.7	382	4.2E 14	5.7E 09
1989	0.088	0.25	0.73	62.3	6562	0.629	0.71	2.1	444	5.1E 14	6.9E 09
1990	0.098	0.27	0.81	68.9	7257	0.726	0.83	2.4	513	5.9E 14	8.1E 09
1991	0.107	0.45	1.33	75.5	7952	0.833	1.10	3.2	589	7.9E 14	1.1E 10
1992	0.117	0.49	1.45	82.4	8678	0.950	1.35	3.9	671	9.7E 14	1.3E 10
1993	0.126	0.53	1.57	89.3	9404	1.077	1.59	4.6	760	1.1E 15	1.5E 10
1994	0.137	0.58	1.69	96.5	10162	1.213	1.82	5.3	857	1.3E 15	1.8E 10
1995	0.147	0.62	1.82	103.7	10920	1.360	2.04	5.9	961	1.5E 15	2.0E 10
1996	0.157	0.67	1.95	111.2	11709	1.518	2.26	6.6	1072	1.6E 15	2.2E 10
1997	0.168	0.71	2.08	118.7	12499	1.686	2.48	7.2	1191	1.8E 15	2.5E 10
1998	0.179	0.76	2.22	126.5	13320	1.865	2.70	7.8	1317	1.9E 15	2.7E 10
1999	0.191	0.81	2.37	134.8	14195	2.056	2.92	8.5	1452	2.1E 15	3.0E 10
2000	0.204	0.86	2.52	143.8	15142	2.260	3.15	9.1	1596	2.3E 15	3.2E 10
2001	0.217	0.92	2.68	153.0	16108	2.476	3.39	9.8	1749	2.4E 15	3.5E 10
TIME AFTER SHUTDOWN, YEARS											
100						2.476	0.11	0.0	1749	5.2E 13	3.5E 09
300						2.476	0.02	0.0	1749	1.2E 13	7.8E 08
1000						2.476	0.00	0.0	1749	1.6E 11	1.2E 07
3000						2.476	0.00	0.0	1749	9.9E 10	7.6E 06
10000						2.476	0.00	0.0	1749	9.4E 10	7.1E 06
30000						2.476	0.00	0.0	1749	8.2E 10	6.0E 06
100000						2.476	0.00	0.0	1749	5.4E 10	3.3E 06
300000						2.476	0.00	0.0	1749	2.5E 10	7.1E 05
1000000						2.476	0.00	0.0	1749	1.4E 10	1.1E 05

Table 4.59. Projected annual accumulation of low-level nontransuranic waste at surface burial grounds

Year	* * * * Annual Addition * * * * * Volume (Millions of m^3)	Radio-activity (MCi)	Thermal Power (kW)	Burial Area (Acres)	Annual Number of Shipments	* * * * * Accumulation Through End of Year * * * * * Volume (Millions of m^3)	Radio-activity (MCi)	Thermal Power (kW)	Burial Area (Acres)	Hazard, Cubic Meters at RCG Air	Water
1971	0.002	0.00	0.01	1.5	158	0.002	0.00	0.0	1	2.1E 12	2.7E 07
1972	0.003	0.00	0.01	2.4	253	0.006	0.01	0.0	4	5.0E 12	6.4E 07
1973	0.004	0.01	0.02	3.0	316	0.010	0.01	0.0	7	8.1E 12	1.1E 08
1974	0.006	0.01	0.03	4.5	474	0.016	0.02	0.1	11	1.3E 13	1.7E 08
1975	0.010	0.01	0.04	6.9	726	0.026	0.03	0.1	18	2.0E 13	2.6E 08
1976	0.014	0.02	0.06	9.6	1014	0.040	0.04	0.1	28	2.9E 13	3.8E 08
1977	0.019	0.03	0.08	13.2	1389	0.058	0.06	0.2	41	4.1E 13	5.4E 08
1978	0.021	0.03	0.09	14.8	1563	0.079	0.07	0.2	56	5.3E 13	7.0E 08
1979	0.024	0.03	0.10	16.7	1759	0.103	0.09	0.3	73	6.5E 13	8.7E 08
1980	0.026	0.04	0.11	18.0	1898	0.128	0.11	0.3	91	7.7E 13	1.0E 09
1981	0.029	0.04	0.12	20.4	2151	0.157	0.12	0.4	111	8.9E 13	1.2E 09
1982	0.034	0.05	0.14	24.0	2527	0.191	0.14	0.4	135	1.0E 14	1.4E 09
1983	0.043	0.05	0.16	30.0	3160	0.234	0.17	0.5	165	1.2E 14	1.7E 09
1984	0.053	0.06	0.19	37.4	3935	0.287	0.19	0.6	203	1.4E 14	2.0E 09
1985	0.067	0.08	0.23	47.6	5007	0.354	0.23	0.7	250	1.7E 14	2.5E 09
1986	0.077	0.18	0.52	54.4	5729	0.431	0.35	1.0	305	2.6E 14	3.8E 09
1987	0.081	0.20	0.59	57.4	6040	0.512	0.48	1.4	362	3.5E 14	5.2E 09
1988	0.092	0.22	0.66	65.0	6847	0.605	0.60	1.7	427	4.3E 14	6.5E 09
1989	0.097	0.25	0.73	68.4	7204	0.701	0.71	2.1	495	5.2E 14	7.9E 09
1990	0.109	0.28	0.81	77.3	8132	0.811	0.83	2.4	573	6.1E 14	9.3E 09
1991	0.125	0.45	1.33	88.2	9288	0.936	1.10	3.2	661	8.1E 14	1.2E 10
1992	0.140	0.50	1.46	99.2	10443	1.076	1.36	4.0	760	9.9E 14	1.5E 10
1993	0.153	0.54	1.58	108.1	11376	1.229	1.59	4.6	868	1.2E 15	1.8E 10
1994	0.163	0.58	1.71	115.5	12153	1.393	1.83	5.3	984	1.3E 15	2.1E 10
1995	0.171	0.62	1.83	120.9	12725	1.564	2.05	6.0	1105	1.5E 15	2.4E 10
1996	0.186	0.67	1.97	131.5	13845	1.750	2.27	6.6	1236	1.7E 15	2.7E 10
1997	0.203	0.71	2.10	143.7	15128	1.954	2.49	7.3	1380	1.8E 15	3.0E 10
1998	0.219	0.76	2.24	154.6	16277	2.173	2.71	7.9	1534	2.0E 15	3.3E 10
1999	0.235	0.81	2.39	165.7	17439	2.407	2.94	8.5	1700	2.2E 15	3.6E 10
2000	0.250	0.87	2.55	176.6	18588	2.657	3.17	9.2	1877	2.4E 15	3.9E 10
2001	0.264	0.92	2.71	186.2	19597	2.921	3.41	9.9	2063	2.5E 15	4.3E 10
TIME AFTER SHUTDOWN, YEARS											
100						2.921	0.11	0.0	2063	5.9E 13	4.1E 09
300						2.921	0.02	0.0	2063	1.2E 13	7.8E 08
1000						2.921	0.00	0.0	2063	1.6E 11	1.2E 07
3000						2.921	0.00	0.0	2063	9.9E 10	7.6E 06
10000						2.921	0.00	0.0	2063	9.4E 10	7.1E 06
30000						2.921	0.00	0.0	2063	8.2E 10	6.0E 06
100000						2.921	0.00	0.0	2063	5.4E 10	3.3E 06
300000						2.921	0.00	0.0	2063	2.6E 10	7.3E 05
1000000						2.921	0.00	0.0	2063	1.4E 10	1.2E 05

Table 4.60. Projected annual accumulation of uranium ore tailings

Year	* * * * Annual Addition * * * * * Volume (Millions of m^3)	Heavy Element (MT)	Radio-activity (MCi)	Thermal Power (kW)	* * * * * Accumulation Through End of Year * * * * * Volume (Billions of m^3)	Heavy Elements (MT)	Radio-activity (MCi)	Thermal Power (kW)	Hazard, Cubic Meters at RCG Air	Water
1970	0.82	132	0.01	0.21	0.001	132	0.0	0.2	1.3E 16	4.0E 10
1971	0.77	125	0.01	0.20	0.002	257	0.0	0.4	2.5E 16	7.7E 10
1972	1.43	231	0.02	0.36	0.003	487	0.0	0.8	4.8E 16	1.5E 11
1973	2.28	369	0.03	0.58	0.005	857	0.1	1.3	8.4E 16	2.6E 11
1974	2.73	442	0.03	0.70	0.008	1298	0.1	2.0	1.3E 17	3.9E 11
1975	3.58	578	0.04	0.91	0.012	1877	0.1	2.9	1.8E 17	5.6E 11
1976	2.93	474	0.03	0.75	0.015	2351	0.2	3.7	2.3E 17	7.0E 11
1977	3.26	526	0.04	0.83	0.018	2877	0.2	4.5	2.8E 17	8.6E 11
1978	3.22	521	0.04	0.82	0.021	3398	0.2	5.3	3.3E 17	1.0E 12
1979	4.16	673	0.05	1.06	0.025	4071	0.3	6.3	4.0E 17	1.2E 12
1980	4.99	807	0.06	1.27	0.030	4878	0.3	7.6	4.8E 17	1.5E 12
1981	5.48	886	0.06	1.40	0.036	5764	0.4	9.0	5.7E 17	1.7E 12
1982	6.57	1062	0.08	1.67	0.042	6826	0.5	10.6	6.7E 17	2.0E 12
1983	8.02	1296	0.09	2.04	0.050	8122	0.6	12.6	8.0E 17	2.4E 12
1984	8.71	1407	0.10	2.22	0.059	9529	0.7	14.8	9.4E 17	2.9E 12
1985	9.47	1530	0.11	2.41	0.068	11059	0.8	17.2	1.1E 18	3.3E 12
1986	10.16	1643	0.12	2.59	0.079	12701	0.9	19.7	1.2E 18	3.8E 12
1987	11.24	1816	0.13	2.86	0.090	14517	1.0	22.5	1.4E 18	4.4E 12
1988	12.14	1963	0.14	3.09	0.102	16480	1.2	25.6	1.6E 18	4.9E 12
1989	12.35	1996	0.14	3.15	0.114	18476	1.3	28.7	1.8E 18	5.5E 12
1990	12.96	2095	0.15	3.30	0.127	20571	1.4	31.9	2.0E 18	6.2E 12
1991	13.53	2187	0.16	3.45	0.141	22758	1.6	35.3	2.2E 18	6.8E 12
1992	14.58	2357	0.17	3.72	0.155	25115	1.8	39.0	2.5E 18	7.5E 12
1993	15.81	2555	0.18	4.03	0.171	27669	1.9	43.0	2.7E 18	8.3E 12
1994	16.54	2674	0.19	4.22	0.188	30343	2.1	47.1	3.0E 18	9.1E 12
1995	16.85	2724	0.20	4.29	0.205	33067	2.3	51.3	3.3E 18	9.9E 12
1996	17.23	2785	0.20	4.39	0.222	35852	2.5	55.6	3.5E 18	1.1E 13
1997	18.00	2909	0.21	4.59	0.240	38761	2.7	60.1	3.8E 18	1.2E 13
1998	18.90	3054	0.22	4.82	0.259	41816	2.9	64.9	4.1E 18	1.3E 13
1999	19.78	3197	0.23	5.04	0.279	45012	3.2	69.8	4.4E 18	1.3E 13
2000	20.26	3274	0.24	5.16	0.299	48287	3.4	74.9	4.7E 18	1.4E 13
TIME AFTER SHUTDOWN, YEARS										
100					0.299	48287	3.4	74.9	4.7E 18	1.4E 13
300					0.299	48287	3.4	74.9	4.7E 18	1.4E 13
1000					0.299	48287	3.4	74.7	4.7E 18	1.4E 13
3000					0.299	48287	3.3	73.9	4.6E 18	1.4E 13
10000					0.299	48287	3.2	69.9	4.3E 18	1.4E 13
30000					0.299	48287	2.7	59.1	3.6E 18	1.2E 13
100000					0.299	48287	1.5	33.8	2.0E 18	6.6E 12
300000					0.299	48287	0.5	9.8	5.4E 17	1.8E 12
1000000					0.299	48287	0.2	4.7	2.4E 17	7.3E 11

Table 4.61. Projected annual accumulation of thorium ore tailings

Year	* * * * Annual Addition * * * * * Volume (Millions of m^3)	Heavy Element (MT)	Radio-activity (Curies)	Thermal Power (Watts)	* * * * * Accumulation Through End of Year * * * * * Volume (Millions of m^3)	Heavy Elements (MT)	Radio-activity (Curies)	Thermal Power (Watts)	Hazard, Meters Air	Cubic at RCG Water
1976	0.003	0.5	4	0	0.00	1	4	0	1.4E 12	3.8E 07
1977	0.001	0.1	1	0	0.00	1	6	0	2.5E 12	4.1E 07
1978	0.001	0.1	1	0	0.00	1	8	0	3.3E 12	4.4E 07
1979	0.001	0.1	1	0	0.01	1	10	0	4.0E 12	4.8E 07
1980	0.001	0.1	1	0	0.01	1	11	0	4.6E 12	5.1E 07
1981	0.001	0.1	1	0	0.01	1	12	0	5.1E 12	5.4E 07
1982	0.001	0.1	1	0	0.01	1	13	0	5.6E 12	5.7E 07
1983	0.001	0.1	1	0	0.01	1	14	0	6.0E 12	5.9E 07
1984	0.001	0.1	1	0	0.01	1	15	0	6.3E 12	6.1E 07
1985	0.001	0.1	1	0	0.01	1	16	0	6.7E 12	6.3E 07
1986	0.001	0.1	1	0	0.01	2	16	0	7.0E 12	6.5E 07
1987	0.001	0.1	1	0	0.01	2	17	0	7.2E 12	6.7E 07
1988	0.001	0.1	1	0	0.01	2	17	0	7.5E 12	6.8E 07
1989	0.001	0.1	1	0	0.01	2	18	0	7.7E 12	7.0E 07
1990	0.001	0.1	1	0	0.01	2	18	0	7.9E 12	7.1E 07
1991	0.001	0.1	1	0	0.01	2	19	0	8.1E 12	7.2E 07
1992	0.001	0.1	1	0	0.01	2	19	0	8.3E 12	7.3E 07
1993	0.001	0.1	1	0	0.01	2	19	0	8.4E 12	7.4E 07
1994	0.011	1.7	13	0	0.03	4	32	1	1.3E 13	1.9E 08
1995	0.012	2.0	15	0	0.04	6	51	1	2.0E 13	3.1E 08
1996	0.021	3.5	26	0	0.06	9	84	2	3.3E 13	5.2E 08
1997	0.028	4.5	34	0	0.09	14	130	3	5.2E 13	7.9E 08
1998	0.032	5.1	38	1	0.12	19	186	4	7.5E 13	1.1E 09
1999	0.035	5.7	43	1	0.15	25	251	5	1.0E 14	1.4E 09
2000	0.039	6.4	48	1	0.19	31	323	7	1.3E 14	1.7E 09
TIME AFTER SHUTDOWN, YEARS										
100					0.19	31	34	1	1.7E 13	1.2E 08
300					0.19	31	34	1	1.6E 13	1.2E 08
1000					0.19	31	34	1	1.6E 13	1.2E 08
3000					0.19	31	34	1	1.6E 13	1.2E 08
10000					0.19	31	34	1	1.6E 13	1.2E 08
30000					0.19	31	34	1	1.6E 13	1.2E 08
100000					0.19	31	34	1	1.6E 13	1.2E 08
300000					0.19	31	34	1	1.6E 13	1.2E 08
1000000					0.19	31	34	1	1.6E 13	1.2E 08

5. REFERENCES

1. J. O. Blomeke, C. W. Kee, and J. P. Nichols, Projections of Radioactive Wastes to be Generated by the U.S. Nuclear Power Industry, ORNL/TM-3965 (1974).

2. E. J. Hanrahan, U.S. Energy Research and Development Administration, personal communication to F. P. Baranowski, ERDA, August 19, 1976.

3. Westinghouse Nuclear Energy Systems, RESAR-3, Reference Safety Analysis Report, DOCKET STN 50-480 (1972).

4. General Electric Standard Safety Analysis Report, BWR/6, DOCKET STN 50-447 (1973).

5. Pacific Northwest Laboratories, Theoretical Analysis of Plutonium Buildup and Uranium Depletion in Pressurized Water and Boiling Water Power Reactors, Report Y49024 to IAEA Division of Nuclear Power Reactors (July 1968).

6. L. J. Colby, R. C. Dahlberg, and S. Jaye, HTGR Fuel and Fuel Cycle Summary Description, GA-10233 (May 1971).

7. Keith E. Asmussen, Gulf General Atomic Company, unpublished mass flow data for reference 1160-MW(e) HTGR (August 1973).

8. T. D. Wolsko, Argonne National Laboratory, unpublished normalized mass flow data for the A. I. and G. E. Follow-On LMFBR designs (November 1969).

9. Oak Ridge National Laboratory, KWIKPLAN - A Code for Calculating Nuclear Fuel Cycle Mass Balances (unpublished).

10. Reactor Fuel Cycle Costs for Nuclear Power Evaluation, WASH-1099 (December 1971).

11. Energy Research and Development Administration, LWR Spent Fuel Disposition Capabilities, 1976-1985, ERDA-76-25 (May 1976).

12. M. J. Bell, ORIGEN - The ORNL Isotope Generation and Depletion Code, ORNL-4628 (May 1973).

13. "Siting of Fuel Reprocessing Plants and Related Waste Management Facilities," Federal Register 35, No. 222, 17530 (Nov. 14, 1970).

14. Staffs of the Oak Ridge National Laboratory and Gulf General Atomic, National HTGR Fuel Recycle Development Program Plan, ORNL-4702 (August 1971).

15. L. Küchler, L. Schäffer, and B. Wottech, "The Thorex Two-Stage Process for Reprocessing Thorium Reactor Fuel with High Burnup," Kerntechnik 13 Jahrgang, No. 7/8 (1971).

16. J. W. Codding, W. O. Haas, and F. H. Heumann, Equilibrium Data for Purex Systems, KAPL-602 (November 1951).

17. Voloxidation--Removal of Volatile Fission Products from Spent LMFBR Fuels, J. H. Goode (compiler and editor), ORNL/TM-3723 (January 1973).

18. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle, Volume 2, Chapter 6.0, ERDA-76-43 (May 1976).

19. Code of Federal Regulations, Title 10, Part 20, Appendix B, Table II.

20. J. J. Perona and J. O. Blomeke, A Parametric Study of Shipping Casks for Solid Radioactive Wastes, ORNL/TM-3651 (February 1972).

21. J. J. Perona, R. S. Dillon, and J. O. Blomeke, Design and Safety Considerations of Shipping Solidified High-Level Radioactive Wastes, ORNL/TM-2971 (December 1970).

22. G. R. Kilp, Westinghouse Electric Corp., Nuclear Fuel Division, Pittsburgh, Pa., personal communication (December 19, 1975).

23. Alternatives for Managing Wastes from Reactors and Post-Fission Operation in the LWR Fuel Cycle, Volume 2, Chapter 7.0, ERDA-76-43 (May 1976).

24. M. O. Marlowe, General Electric Company, San Jose, California, personal communication (February 18, 1976).

25. J. O. Blomeke and J. J. Perona, Storage, Shipment, and Disposal of Spent Fuel Cladding, ORNL/TM-3650 (January 1972).

26. H. W. Godbee and J. P. Nichols, Sources of Transuranium Solid Wastes and Their Influence on the Proposed National Radioactive Waste Repository, ORNL/TM-3277 (January 1971).

27. H. H. Van Tuyl et al., A Survey of Alpha Waste Generation and Disposal as Solids in the U.S. Nuclear Fuel Industry, BNWL-B-34 (December 1970).

28. E. P. McDonald, An Analysis of Waste Transportation Methods: The Shipment of Radioactive Waste Materials, Internal Report, Monsanto Research Corporation, Mound Laboratory (Facilities Engineering), Miamisburg, Ohio (April 10, 1970).

29. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle, Volume 2, Chapter 13.0, ERDA-76-43 (May 1976).

30. J. O. Blomeke and J. J. Perona, Management of Noble-Gas Fission-Product Wastes from Reprocessing Spent Fuels, ORNL/TM-2677 (Nov. 21, 1969).

31. W. E. Clark, C. T. Thompson, and W. B. Howerton, Fixation of Radioiodine with Portland Cement. I. Preliminary Scoping Studies, ORNL/TM-5064 (1975).

32. W. T. Crow, U.S. Nuclear Regulatory Commission, personal communication to L. C. Rouse, U.S. Nuclear Regulatory Commission (October 1974).

33. L. H. Brooks, C. A. Heath, B. Kirstein, and D. G. Roberts, Carbon-14 in the HTGR Fuel Cycle, GA-A13174 (November 1974).

34. L. E. Trevorrow, B. J. Kullen, R. L. Jarry, and M. J. Steindler, Tritium and Noble-Gas Fission Products in the Nuclear Fuel Cycle. I. Reactors, ANL-8102 (1974).

35. A. H. Kibbey and H. W. Godbee, A Critical Review of Solid Radioactive Waste Practices at Nuclear Power Plants, ORNL-4924 (March 1974).

36. E. C. Tsivoglou and R. L. O'Connell, "Nature, Volume, and Activity of Uranium Mill Wastes," pp. 101-122 in Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vol. II, IAEA, Vienna, 1964.

APPENDIX A

Radioactivity and Thermal Power of High-Level Waste from One Metric Ton of Heavy Metal as a Function of Time for Six Reactor Types

Table A.1. Curies of heavy isotopes in the high-level waste from one metric ton of uranium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
PB212	0.0	3.14E-03	1.12E-03	2.13E-04	6.50E-05	1.15E-08	1.07E-09
BI212	0.0	3.14E-03	1.12E-03	2.13E-04	6.50E-05	1.15E-08	1.07E-09
PO216	0.0	3.14E-03	1.12E-03	2.13E-04	6.50E-05	1.15E-08	1.07E-09
RN220	0.0	3.14E-03	1.12E-03	2.13E-04	6.50E-05	1.15E-08	1.07E-09
RA224	0.0	3.14E-03	1.12E-03	2.13E-04	6.50E-05	1.15E-08	1.07E-09
TH228	0.0	3.12E-03	1.11E-03	2.12E-04	6.50E-05	1.15E-08	1.07E-09
TH234	0.0	3.14E-01	1.57E-03	1.57E-03	1.57E-03	1.57E-03	1.57E-03
PA233	0.0	5.92E-01	5.93E-01	5.94E-01	6.01E-01	6.35E-01	6.44E-01
PA234M	0.0	3.14E-01	1.57E-03	1.57E-03	1.57E-03	1.57E-03	1.57E-03
U234	1.79E 00	4.86E-03	5.33E-03	6.67E-03	1.91E-02	3.40E-02	3.33E-02
U236	0.0	1.30E-03	1.30E-03	1.30E-03	1.32E-03	1.51E-03	2.70E-03
U237	0.0	1.53E-02	1.29E-02	9.24E-03	1.30E-04	9.89E-07	4.65E-07
U238	3.22E-01	1.57E-03	1.57E-03	1.57E-03	1.57E-03	1.57E-03	1.57E-03
NP237	0.0	5.93E-01	5.93E-01	5.94E-01	6.01E-01	6.35E-01	6.44E-01
NP239	0.0	1.73E 01	1.73E 01	1.73E 01	1.72E 01	1.58E 01	7.01E 00
PU236	0.0	2.71E-03	1.31E-03	2.38E-04	7.40E-14	0.0	0.0
PU238	0.0	2.50E 00	6.93E 01	6.65E 01	3.53E 01	1.74E-01	2.25E-19
PU239	0.0	1.62E 00	1.62E 00	1.63E 00	1.67E 00	2.04E 00	3.99E 00
PU240	0.0	2.41E 00	2.98E 00	4.09E 00	7.51E 00	6.96E 00	2.76E 00
PU241	0.0	6.18E 02	5.36E 02	3.85E 02	5.41E 00	4.12E-02	1.94E-02
PU242	0.0	8.69E-03	8.70E-03	8.71E-03	8.88E-03	9.21E-03	9.13E-03
AM241	0.0	2.38E 02	2.40E 02	2.42E 02	2.21E 02	5.25E 01	1.94E-02
AM242M	0.0	7.25E 00	7.15E 00	6.92E 00	4.59E 00	7.58E-02	1.13E-19
AM242	0.0	7.25E 00	7.15E 00	6.92E 00	4.59E 00	7.58E-02	1.13E-19
AM243	0.0	1.73E 01	1.73E 01	1.73E 01	1.72E 01	1.58E 01	7.01E 00
CM242	0.0	1.37E 04	1.35E 02	5.68E 00	3.77E 00	6.21E-02	9.31E-20
CM243	0.0	2.93E 00	2.74E 00	2.36E 00	3.35E-01	1.14E-09	0.0
CM244	0.0	1.97E 03	1.76E 03	1.35E 03	4.28E 01	4.71E-14	1.17E-14
CM245	0.0	4.47E-02	4.47E-02	4.47E-02	4.43E-02	4.11E-02	1.93E-02
CM246	0.0	9.33E-03	9.33E-03	9.32E-03	9.20E-03	8.06E-03	2.14E-03
SUBTOT	2.12E 00	1.66E 04	2.80E 03	2.10E 03	3.63E 02	9.50E 01	2.22E 01
TOTALS	2.19E 00	1.66E 04	2.80E 03	2.10E 03	3.63E 02	9.50E 01	2.23E 01

Table A.2. Curies of fission product isotopes in the high-level waste from one metric ton of uranium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	3.88E-01	3.88E-01	3.88E-01	3.87E-01	3.84E-01	3.49E-01
SR 89	0.0	8.37E 04	3.79E-02	5.99E-17	0.0	0.0	0.0
SR 90	0.0	7.62E 04	7.07E 04	5.95E 04	6.46E 03	1.47E-06	0.0
Y 90	0.0	7.62E 04	7.08E 04	5.95E 04	6.46E 03	1.47E-06	0.0
Y 91	0.0	1.42E 05	3.33E-01	2.44E-14	0.0	0.0	0.0
ZR 93	0.0	2.91E 00	2.91E 00	2.91E 00	2.91E 00	2.91E 00	2.89E 00
ZR 95	0.0	2.53E 05	2.33E 00	4.12E-12	0.0	0.0	0.0
NB 93M	0.0	3.06E-01	6.97E-01	1.38E 00	2.76E 00	2.76E 00	2.74E 00
NB 95	0.0	4.79E 05	5.02E 00	8.89E-12	0.0	0.0	0.0
NB 95M	0.0	3.22E 03	2.96E-02	5.23E-14	0.0	0.0	0.0
TC 99	0.0	1.44E 01	1.44E 01	1.44E 01	1.44E 01	1.43E 01	1.39E 01
RU106	0.0	3.93E 05	5.02E 04	4.11E 02	6.22E-25	0.0	0.0
RH106	0.0	3.93E 05	5.02E 04	4.11E 02	6.22E-25	0.0	0.0
PD107	0.0	1.15E-01	1.15E-01	1.15E-01	1.15E-01	1.15E-01	1.15E-01
AG110	0.0	6.55E 04	3.22E 03	2.83E 00	0.0	0.0	0.0
CD113M	0.0	3.36E 01	2.91E 01	2.09E 01	2.90E-01	7.78E-20	0.0
SN119M	0.0	5.48E 01	2.47E 00	1.79E-03	0.0	0.0	0.0
SN121M	0.0	1.77E-01	1.70E-01	1.54E-01	4.42E-02	1.67E-07	0.0
SN123	0.0	1.81E 03	5.04E 00	5.47E-06	0.0	0.0	0.0
SN126	0.0	5.91E-01	5.91E-01	5.91E-01	5.91E-01	5.87E-01	5.52E-01
SB125	0.0	9.05E 03	4.22E 03	7.14E 02	8.48E-08	0.0	0.0
SB126	0.0	1.65E-01	8.28E-02	8.28E-02	8.27E-02	8.22E-02	7.72E-02
SB126M	0.0	5.91E-01	5.91E-01	5.91E-01	5.91E-01	5.87E-01	5.52E-01
TE125M	0.0	2.16E 03	1.03E 03	1.74E 02	2.07E-08	0.0	0.0
TE127	0.0	5.06E 03	4.76E 00	4.13E-07	0.0	0.0	0.0
TE127M	0.0	5.16E 03	4.86E 00	4.22E-07	0.0	0.0	0.0
CS134	0.0	2.30E 05	8.39E 04	7.95E 03	5.62E-10	0.0	0.0
CS135	0.0	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.76E-01
CS137	0.0	1.08E 05	1.01E 05	8.57E 04	1.08E 04	1.08E-05	0.0
BA137M	0.0	1.02E 05	9.52E 04	8.11E 04	1.02E 04	1.02E-05	0.0
CE144	0.0	7.31E 05	5.05E 04	9.93E 01	0.0	0.0	0.0
PR144	0.0	7.31E 05	5.05E 04	9.93E 01	0.0	0.0	0.0
PR144M	0.0	8.77E 03	6.07E 02	1.19E 00	0.0	0.0	0.0
PM147	0.0	9.08E 04	4.11E 04	6.46E 03	3.02E-07	0.0	0.0
SM151	0.0	1.12E 03	1.09E 03	1.04E 03	5.30E 02	6.42E-01	0.0
EU152	0.0	9.72E 00	8.28E 00	5.70E 00	4.68E-02	6.54E-23	0.0
EU154	0.0	1.23E 04	9.66E 03	5.49E 03	3.88E 00	0.0	0.0
EU155	0.0	2.55E 03	1.65E 03	6.00E 02	1.35E-03	0.0	0.0
GD153	0.0	2.13E 01	9.08E-01	5.76E-04	0.0	0.0	0.0
TB160	0.0	3.01E 02	8.24E-03	1.86E-13	0.0	0.0	0.0
HO166M	0.0	1.01E-03	1.00E-03	1.00E-03	9.49E-04	5.64E-04	3.10E-06
SUBTOT	0.0	4.00E 06	6.85E 05	3.09E 05	3.45E 04	2.28E 01	2.16E 01
TOTALS	0.0	4.24E 06	6.85E 05	3.09E 05	3.45E 04	2.28E 01	2.16E 01

Table A.3. Curies of heavy isotopes in the high-level waste from one metric ton of plutonium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
TH234	0.0	3.08E-01	1.54E-03	1.54E-03	1.54E-03	1.54E-03	1.54E-03
PA233	0.0	1.16E-01	1.18E-01	1.23E-01	1.79E-01	4.59E-01	5.74E-01
PA234M	0.0	3.08E-01	1.54E-03	1.54E-03	1.54E-03	1.54E-03	1.54E-03
U234	1.64E 00	5.31E-03	1.16E-02	2.95E-02	2.10E-01	5.24E-01	5.15E-01
U237	0.0	7.19E-02	6.23E-02	4.48E-02	9.91E-04	3.46E-04	1.62E-04
U238	3.16E-01	1.54E-03	1.54E-03	1.54E-03	1.54E-03	1.54E-03	1.54E-03
NP237	0.0	1.16E-01	1.18E-01	1.23E-01	1.79E-01	4.59E-01	5.74E-01
NP239	0.0	2.73E 02	2.73E 02	2.72E 02	2.70E 02	2.49E 02	1.10E 02
PU238	1.71E 04	8.91E 01	9.19E 02	8.94E 02	5.60E 02	7.71E 00	1.14E-17
PU239	1.37E 03	3.37E 00	3.39E 00	3.45E 00	4.16E 00	1.06E 01	4.60E 01
PU240	2.55E 03	1.00E 01	2.58E 01	5.63E 01	1.51E 02	1.41E 02	5.59E 01
PU241	6.76E 05	2.98E 03	2.59E 03	1.86E 03	4.13E 01	1.44E 01	6.77E 00
PU242	1.48E 01	9.29E-02	9.33E-02	9.42E-02	1.03E-01	1.24E-01	1.46E-01
AM241	0.0	2.01E 03	2.01E 03	2.01E 03	1.80E 03	4.37E 02	6.77E 00
AM242M	0.0	3.69E 02	3.64E 02	3.52E 02	2.34E 02	3.85E 00	5.75E-18
AM242	0.0	3.69E 02	3.64E 02	3.52E 02	2.34E 02	3.85E 00	5.76E-18
AM243	0.0	2.73E 02	2.73E 02	2.72E 02	2.70E 02	2.49E 02	1.10E 02
CM242	0.0	1.70E 05	1.90E 03	2.89E 02	1.92E 02	3.16E 00	4.73E-18
CM243	0.0	2.71E 01	2.54E 01	2.18E 01	3.10E 00	1.06E-08	0.0
CM244	0.0	5.43E 04	4.84E 04	3.70E 04	1.18E 03	1.93E-12	6.57E-12
CM245	0.0	1.56E 01	1.56E 01	1.56E 01	1.55E 01	1.44E 01	6.76E 00
CM246	0.0	3.01E 00	3.01E 00	3.00E 00	2.96E 00	2.60E 00	6.90E-01
BK249	0.0	2.81E-01	2.50E-02	8.86E-05	0.0	0.0	0.0
CF249	0.0	4.72E-04	1.09E-03	1.14E-03	9.53E-04	1.62E-04	3.25E-12
CF250	0.0	3.25E-03	2.77E-03	1.91E-03	1.62E-05	4.62E-12	3.23E-12
CF252	0.0	3.82E-03	1.74E-03	2.78E-04	1.60E-14	0.0	0.0
SUBTOT	6.97E 05	2.30E 05	5.72E 04	4.35E 04	4.96E 03	1.14E 03	3.45E 02
TOTALS	6.97E 05	2.30E 05	5.72E 04	4.35E 04	4.96E 03	1.14E 03	3.46E 02

Table A.4. Curies of fission product isotopes in the high-level waste from one metric ton of plutonium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	3.75E-01	3.75E-01	3.75E-01	3.74E-01	3.71E-01	3.37E-01
SR 89	0.0	5.90E 04	2.68E-02	4.23E-17	0.0	0.0	0.0
SR 90	0.0	4.41E 04	4.09E 04	3.45E 04	3.74E 03	8.54E-07	0.0
Y 90	0.0	4.41E 04	4.10E 04	3.45E 04	3.74E 03	8.54E-07	0.0
Y 91	0.0	1.06E 05	2.50E-01	1.83E-14	0.0	0.0	0.0
ZR 93	0.0	2.26E 00	2.26E 00	2.26E 00	2.26E 00	2.26E 00	2.25E 00
ZR 95	0.0	2.32E 05	2.13E 00	3.77E-12	0.0	0.0	0.0
NB 93M	0.0	2.36E-01	5.41E-01	1.08E 00	2.14E 00	2.15E 00	2.14E 00
NB 95	0.0	4.38E 05	4.60E 00	8.14E-12	0.0	0.0	0.0
NB 95M	0.0	2.95E 03	2.71E-02	4.79E-14	0.0	0.0	0.0
TC 99	0.0	1.45E 01	1.45E 01	1.45E 01	1.45E 01	1.45E 01	1.41E 01
RU106	0.0	6.32E 05	8.07E 04	6.62E 02	1.00E-24	0.0	0.0
RH106	0.0	6.32E 05	8.07E 04	6.62E 02	1.00E-24	0.0	0.0
PD107	0.0	2.29E-01	2.29E-01	2.29E-01	2.29E-01	2.29E-01	2.29E-01
AG110	0.0	1.33E 05	6.53E 03	5.76E 00	0.0	0.0	0.0
CD113M	0.0	5.90E 01	5.12E 01	3.67E 01	5.10E-01	1.37E-19	0.0
SN119M	0.0	7.27E 01	3.27E 00	2.37E-03	0.0	0.0	0.0
SN121M	0.0	3.13E-01	3.00E-01	2.73E-01	7.82E-02	2.96E-07	0.0
SN123	0.0	2.21E 03	6.15E 00	6.67E-06	0.0	0.0	0.0
SN126	0.0	9.29E-01	9.29E-01	9.29E-01	9.29E-01	9.23E-01	8.67E-01
SB125	0.0	1.41E 04	6.57E 03	1.11E 03	1.32E-07	0.0	0.0
SB126	0.0	2.29E-01	1.30E-01	1.30E-01	1.30E-01	1.29E-01	1.21E-01
SB126M	0.0	9.29E-01	9.29E-01	9.29E-01	9.29E-01	9.23E-01	8.67E-01
TE125M	0.0	3.37E 03	1.61E 03	2.71E 02	3.22E-08	0.0	0.0
TE127	0.0	6.48E 03	6.10E 00	5.29E-07	0.0	0.0	0.0
TE127M	0.0	6.62E 03	6.23E 00	5.40E-07	0.0	0.0	0.0
CS134	0.0	2.13E 05	7.76E 04	7.36E 03	5.13E-10	0.0	0.0
CS135	0.0	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.87E-01	6.85E-01
CS137	0.0	1.11E 05	1.03E 05	8.78E 04	1.11E 04	1.10E-05	0.0
BA137M	0.0	1.05E 05	9.76E 04	8.31E 04	1.05E 04	1.04E-05	0.0
CE144	0.0	6.33E 05	4.38E 04	8.61E 01	0.0	0.0	0.0
PR144	0.0	6.33E 05	4.38E 04	8.61E 01	0.0	0.0	0.0
PR144M	0.0	7.60E 03	5.26E 02	1.03E 00	0.0	0.0	0.0
PM147	0.0	9.65E 04	4.37E 04	6.87E 03	3.22E-07	0.0	0.0
SM151	0.0	1.43E 03	1.40E 03	1.33E 03	6.81E 02	8.29E-01	0.0
EU152	0.0	2.66E 01	2.26E 01	1.56E 01	1.28E-01	1.79E-22	0.0
EU154	0.0	1.69E 04	1.33E 04	7.54E 03	5.30E 00	0.0	0.0
EU155	0.0	3.69E 03	2.39E 03	8.69E 02	1.96E-03	0.0	0.0
GD153	0.0	1.29E 01	5.52E-01	3.50E-04	0.0	0.0	0.0
TB160	0.0	5.34E 02	1.46E-02	3.30E-13	0.0	0.0	0.0
HO166M	0.0	1.71E-03	1.70E-03	1.70E-03	1.61E-03	9.58E-04	5.27E-06
SUBTOT	0.0	4.18E 06	6.85E 05	2.67E 05	2.97E 04	2.30E 01	2.16E 01
TOTALS	0.0	4.44E 06	6.85E 05	2.67E 05	2.97E 04	2.30E 01	2.16E 01

Table A.5. Curies of heavy isotopes in the high-level waste from one metric ton of uranium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
TH234	0.0	3.17E-01	1.59E-03	1.59E-03	1.59E-03	1.59E-03	1.59E-03
PA233	0.0	2.55E-01	2.56E-01	2.56E-01	2.64E-01	3.01E-01	3.13E-01
PA234M	0.0	3.17E-01	1.59E-03	1.59E-03	1.59E-03	1.59E-03	1.59E-03
U234	1.42E 00	3.88E-03	4.30E-03	5.45E-03	1.64E-02	3.16E-02	3.10E-02
U236	0.0	1.00E-03	1.00E-03	1.00E-03	1.02E-03	1.17E-03	2.15E-03
U237	0.0	1.32E-02	1.12E-02	8.04E-03	1.35E-04	2.19E-05	1.03E-05
U238	3.25E-01	1.59E-03	1.59E-03	1.59E-03	1.59E-03	1.59E-03	1.59E-03
NP237	0.0	2.56E-01	2.56E-01	2.56E-01	2.64E-01	3.01E-01	3.13E-01
NP239	0.0	1.36E 01	1.36E 01	1.36E 01	1.35E 01	1.24E 01	5.51E 00
PU238	0.0	1.00E 01	5.95E 01	5.73E 01	3.22E 01	2.62E-01	3.69E-19
PU239	0.0	1.52E 00	1.52E 00	1.53E 00	1.56E 00	1.85E 00	3.32E 00
PU240	0.0	2.33E 00	2.77E 00	3.61E 00	6.23E 00	5.76E 00	2.29E 00
PU241	0.0	5.38E 02	4.66E 02	3.35E 02	5.63E 00	9.12E-01	4.29E-01
PU242	0.0	7.10E-03	7.12E-03	7.15E-03	7.45E-03	8.28E-03	9.69E-03
AM241	0.0	2.61E 02	2.62E 02	2.64E 02	2.38E 02	5.71E 01	4.29E-01
AM242M	0.0	1.19E 01	1.17E 01	1.14E 01	7.54E 00	1.24E-01	1.86E-19
AM242	0.0	1.19E 01	1.17E 01	1.14E 01	7.54E 00	1.24E-01	1.86E-19
AM243	0.0	1.36E 01	1.36E 01	1.36E 01	1.35E 01	1.24E 01	5.51E 00
CM242	0.0	1.02E 04	1.06E 02	9.33E 00	6.18E 00	1.02E-01	1.53E-19
CM243	0.0	2.04E 00	1.91E 00	1.64E 00	2.34E-01	7.98E-10	0.0
CM244	0.0	1.51E 03	1.34E 03	1.03E 03	3.27E 01	5.73E-14	2.20E-13
CM245	0.0	9.90E-01	9.89E-01	9.89E-01	9.81E-01	9.10E-01	4.28E-01
CM246	0.0	1.98E-01	1.98E-01	1.97E-01	1.95E-01	1.71E-01	4.54E-02
SUBTOT	1.75E 00	1.25E 04	2.30E 03	1.75E 03	3.67E 02	9.29E 01	1.86E 01
TOTALS	1.80E 00	1.25E 04	2.30E 03	1.75E 03	3.67E 02	9.29E 01	1.87E 01

Table A.6. Curies of fission product isotopes in the high-level waste from one metric ton of uranium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	3.22E-01	3.22E-01	3.22E-01	3.21E-01	3.18E-01	2.89E-01
SR 89	0.0	5.62E 04	2.55E-02	4.02E-17	0.0	0.0	0.0
SR 90	0.0	6.19E 04	5.74E 04	4.83E 04	5.25E 03	1.20E-06	0.0
Y 90	0.0	6.19E 04	5.75E 04	4.83E 04	5.25E 03	1.20E-06	0.0
Y 91	0.0	9.56E 04	2.25E-01	1.64E-14	0.0	0.0	0.0
ZR 93	0.0	2.41E 00	2.41E 00	2.41E 00	2.41E 00	2.40E 00	2.39E 00
ZR 95	0.0	1.73E 05	1.59E 00	2.82E-12	0.0	0.0	0.0
NB 93M	0.0	2.90E-01	6.08E-01	1.17E 00	2.28E 00	2.28E 00	2.27E 00
NB 95	0.0	3.28E 05	3.44E 00	6.09E-12	0.0	0.0	0.0
NB 95M	0.0	2.20E 03	2.02E-02	3.59E-14	0.0	0.0	0.0
TC 99	0.0	1.21E 01	1.21E 01	1.21E 01	1.21E 01	1.20E 01	1.17E 01
RU106	0.0	3.02E 05	3.85E 04	3.16E 02	4.77E-25	0.0	0.0
RH106	0.0	3.02E 05	3.85E 04	3.16E 02	4.77E-25	0.0	0.0
PD107	0.0	9.95E-02	9.95E-02	9.95E-02	9.95E-02	9.95E-02	9.94E-02
AG110	0.0	4.65E 04	2.28E 03	2.01E 00	0.0	0.0	0.0
CD113M	0.0	2.75E 01	2.38E 01	1.71E 01	2.37E-01	6.36E-20	0.0
SN119M	0.0	4.01E 01	1.81E 00	1.31E-03	0.0	0.0	0.0
SN121M	0.0	1.51E-01	1.44E-01	1.31E-01	3.76E-02	1.42E-07	0.0
SN123	0.0	1.29E 03	3.58E 00	3.88E-06	0.0	0.0	0.0
SN126	0.0	5.03E-01	5.03E-01	5.03E-01	5.03E-01	5.00E-01	4.69E-01
SB125	0.0	7.25E 03	3.38E 03	5.72E 02	6.79E-08	0.0	0.0
SB126	0.0	1.29E-01	7.04E-02	7.04E-02	7.04E-02	7.00E-02	6.57E-02
SB126M	0.0	5.03E-01	5.03E-01	5.03E-01	5.03E-01	5.00E-01	4.69E-01
TE125M	0.0	1.73E 03	8.26E 02	1.40E 02	1.66E-08	0.0	0.0
TE127	0.0	3.59E 03	3.38E 00	2.94E-07	0.0	0.0	0.0
TE127M	0.0	3.67E 03	3.45E 00	3.00E-07	0.0	0.0	0.0
CS134	0.0	1.65E 05	6.01E 04	5.70E 03	4.05E-10	0.0	0.0
CS135	0.0	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.80E-01
CS137	0.0	8.94E 04	8.34E 04	7.10E 04	8.93E 03	8.90E-06	0.0
BA137M	0.0	8.45E 04	7.89E 04	6.71E 04	8.45E 03	8.42E-06	0.0
CE144	0.0	5.14E 05	3.56E 04	6.98E 01	0.0	0.0	0.0
PR144	0.0	5.14E 05	3.56E 04	6.98E 01	0.0	0.0	0.0
PR144M	0.0	6.17E 03	4.27E 02	8.38E-01	0.0	0.0	0.0
PM147	0.0	7.95E 04	3.60E 04	5.66E 03	2.65E-07	0.0	0.0
SM151	0.0	9.73E 02	9.51E 02	9.03E 02	4.61E 02	5.61E-01	0.0
EU152	0.0	1.15E 01	9.83E 00	6.76E 00	5.56E-02	7.76E-23	0.0
EU154	0.0	9.50E 03	7.46E 03	4.24E 03	3.00E 00	0.0	0.0
EU155	0.0	2.02E 03	1.31E 03	4.76E 02	1.07E-03	0.0	0.0
GD153	0.0	1.75E 01	7.47E-01	4.74E-04	0.0	0.0	0.0
TB160	0.0	1.95E 02	5.34E-03	1.21E-13	0.0	0.0	0.0
SUBTOT	0.0	2.91E 06	5.38E 05	2.53E 05	2.84E 04	1.91E 01	1.81E 01
TOTALS	0.0	3.07E 06	5.38E 05	2.53E 05	2.84E 04	1.91E 01	1.81E 01

Table A.7. Curies of heavy isotopes in the high-level waste from one metric ton of plutonium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
TH234	0.0	3.12E-01	1.56E-03	1.56E-03	1.56E-03	1.56E-03	1.56E-03
PA233	0.0	1.05E-01	1.07E-01	1.12E-01	1.74E-01	4.84E-01	6.12E-01
PA234M	0.0	3.12E-01	1.56E-03	1.56E-03	1.56E-03	1.56E-03	1.56E-03
U234	1.65E 00	6.23E-03	1.08E-02	2.37E-02	1.51E-01	3.63E-01	3.56E-01
U237	0.0	5.99E-02	5.19E-02	3.74E-02	9.46E-04	4.00E-04	1.88E-04
U238	3.18E-01	1.56E-03	1.56E-03	1.56E-03	1.56E-03	1.56E-03	1.56E-03
NP237	0.0	1.05E-01	1.07E-01	1.12E-01	1.74E-01	4.84E-01	6.12E-01
NP239	0.0	2.17E 02	2.17E 02	2.17E 02	2.15E 02	1.98E 02	8.77E 01
PU238	1.75E 04	9.47E 01	6.61E 02	6.41E 02	3.91E 02	4.87E 00	7.16E-18
PU239	1.17E 03	2.92E 00	2.94E 00	2.99E 00	3.55E 00	8.68E 00	3.68E 01
PU240	2.37E 03	9.44E 00	2.08E 01	4.29E 01	1.11E 02	1.04E 02	4.12E 01
PU241	5.30E 05	2.49E 03	2.16E 03	1.55E 03	3.94E 01	1.67E 01	7.84E 00
PU242	1.23E 01	7.49E-02	7.52E-02	7.57E-02	8.16E-02	9.69E-02	1.21E-01
AM241	0.0	2.25E 03	2.25E 03	2.24E 03	1.99E 03	4.84E 02	7.84E 00
AM242M	0.0	2.31E 02	2.28E 02	2.21E 02	1.46E 02	2.42E 00	3.61E-18
AM242	0.0	2.31E 02	2.28E 02	2.21E 02	1.46E 02	2.42E 00	3.61E-18
AM243	0.0	2.17E 02	2.17E 02	2.17E 02	2.15E 02	1.98E 02	8.77E 01
CM242	0.0	1.16E 05	1.28E 03	1.81E 02	1.20E 02	1.98E 00	2.97E-18
CM243	0.0	1.74E 01	1.63E 01	1.40E 01	2.00E 00	6.82E-09	0.0
CM244	0.0	3.93E 04	3.50E 04	2.68E 04	8.53E 02	1.57E-12	6.53E-12
CM245	0.0	1.81E 01	1.81E 01	1.81E 01	1.80E 01	1.66E 01	7.83E 00
CM246	0.0	3.32E 00	3.32E 00	3.31E 00	3.27E 00	2.86E 00	7.62E-01
BK249	0.0	2.55E-01	2.27E-02	8.03E-05	0.0	0.0	0.0
CF249	0.0	4.70E-04	1.03E-03	1.07E-03	8.99E-04	1.53E-04	3.06E-12
CF250	0.0	2.89E-03	2.46E-03	1.70E-03	1.44E-05	3.30E-12	2.31E-12
CF252	0.0	3.06E-03	1.39E-03	2.23E-04	1.28E-14	0.0	0.0
SUBTOT	5.51E 05	1.61E 05	4.23E 04	3.23E 04	4.25E 03	1.04E 03	2.79E 02
TOTALS	5.51E 05	1.61E 05	4.23E 04	3.23E 04	4.25E 03	1.04E 03	2.80E 02

Table A.8. Curies of fission product isotopes in the high-level waste from one metric ton of plutonium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.08E-01	2.79E-01
SR 89	0.0	4.15E 04	1.88E-02	2.97E-17	0.0	0.0	0.0
SR 90	0.0	3.73E 04	3.47E 04	2.92E 04	3.17E 03	7.22E-07	0.0
Y 90	0.0	3.73E 04	3.47E 04	2.92E 04	3.17E 03	7.22E-07	0.0
Y 91	0.0	7.45E 04	1.75E-01	1.28E-14	0.0	0.0	0.0
ZR 93	0.0	1.90E 00	1.90E 00	1.90E 00	1.90E 00	1.90E 00	1.89E 00
ZR 95	0.0	1.60E 05	1.47E 00	2.61E-12	0.0	0.0	0.0
NB 93M	0.0	2.26E-01	4.78E-01	9.21E-01	1.80E 00	1.81E 00	1.80E 00
NB 95	0.0	3.03E 05	3.17E 00	5.62E-12	0.0	0.0	0.0
NB 95M	0.0	2.03E 03	1.87E-02	3.31E-14	0.0	0.0	0.0
TC 99	0.0	1.21E 01	1.21E 01	1.21E 01	1.21E 01	1.21E 01	1.17E 01
RU106	0.0	4.51E 05	5.75E 04	4.72E 02	7.13E-25	0.0	0.0
RH106	0.0	4.51E 05	5.75E 04	4.72E 02	7.13E-25	0.0	0.0
PD107	0.0	1.88E-01	1.88E-01	1.88E-01	1.88E-01	1.88E-01	1.87E-01
AG110	0.0	9.13E 04	4.48E 03	3.95E 00	0.0	0.0	0.0
CD113M	0.0	4.66E 01	4.04E 01	2.89E 01	4.02E-01	1.08E-19	0.0
SN119M	0.0	5.07E 01	2.29E 00	1.65E-03	0.0	0.0	0.0
SN121M	0.0	2.54E-01	2.44E-01	2.21E-01	6.35E-02	2.40E-07	0.0
SN123	0.0	1.51E 03	4.21E 00	4.56E-06	0.0	0.0	0.0
SN126	0.0	7.62E-01	7.62E-01	7.61E-01	7.61E-01	7.56E-01	7.10E-01
SB125	0.0	1.07E 04	5.02E 03	8.48E 02	1.01E-07	0.0	0.0
SB126	0.0	1.74E-01	1.07E-01	1.07E-01	1.07E-01	1.06E-01	9.95E-02
SB126M	0.0	7.62E-01	7.62E-01	7.61E-01	7.61E-01	7.56E-01	7.10E-01
TE125M	0.0	2.58E 03	1.23E 03	2.07E 02	2.46E-08	0.0	0.0
TE127	0.0	4.39E 03	4.13E 00	3.59E-07	0.0	0.0	0.0
TE127M	0.0	4.48E 03	4.22E 00	3.66E-07	0.0	0.0	0.0
CS134	0.0	1.58E 05	5.76E 04	5.46E 03	3.86E-10	0.0	0.0
CS135	0.0	6.54E-01	6.54E-01	6.54E-01	6.54E-01	6.54E-01	6.52E-01
CS137	0.0	9.13E 04	8.52E 04	7.25E 04	9.12E 03	9.09E-06	0.0
BA137M	0.0	8.63E 04	8.06E 04	6.86E 04	8.63E 03	8.60E-06	0.0
CE144	0.0	4.53E 05	3.13E 04	6.16E 01	0.0	0.0	0.0
PR144	0.0	4.53E 05	3.13E 04	6.16E 01	0.0	0.0	0.0
PR144M	0.0	5.44E 03	3.76E 02	7.39E-01	0.0	0.0	0.0
PM147	0.0	8.11E 04	3.67E 04	5.77E 03	2.70E-07	0.0	0.0
SM151	0.0	1.21E 03	1.19E 03	1.13E 03	5.76E 02	7.00E-01	0.0
EU152	0.0	2.84E 01	2.42E 01	1.67E 01	1.37E-01	1.91E-22	0.0
EU154	0.0	1.30E 04	1.02E 04	5.80E 03	4.11E 00	0.0	0.0
EU155	0.0	2.90E 03	1.88E 03	6.84E 02	1.54E-03	0.0	0.0
GD153	0.0	1.10E 01	4.67E-01	2.96E-04	0.0	0.0	0.0
TB160	0.0	3.44E 02	9.41E-03	2.13E-13	0.0	0.0	0.0
HO166M	0.0	1.20E-03	1.20E-03	1.19E-03	1.13E-03	6.73E-04	3.70E-06
SUBTOT	0.0	3.02E 06	5.32E 05	2.20E 05	2.47E 04	1.93E 01	1.81E 01
TOTALS	0.0	3.19E 06	5.32E 05	2.20E 05	2.47E 04	1.93E 01	1.81E 01

Table A.9. Curies of heavy isotopes in the high-level waste from one metric ton of blended LMFBR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
TL208	0.0	7.56E-03	2.70E-03	4.42E-04	1.19E-04	2.10E-08	5.73E-10
PB212	0.0	2.10E-02	7.49E-03	1.23E-03	3.29E-04	5.83E-08	1.59E-09
BI212	0.0	2.10E-02	7.49E-03	1.23E-03	3.29E-04	5.83E-08	1.59E-09
PO212	0.0	1.34E-02	4.79E-03	7.86E-04	2.11E-04	3.73E-08	1.02E-09
PO216	0.0	2.10E-02	7.49E-03	1.23E-03	3.29E-04	5.83E-08	1.59E-09
RN220	0.0	2.10E-02	7.49E-03	1.23E-03	3.29E-04	5.83E-08	1.59E-09
RA224	0.0	2.10E-02	7.49E-03	1.23E-03	3.29E-04	5.83E-08	1.59E-09
TH228	0.0	2.12E-02	7.45E-03	1.22E-03	3.29E-04	5.83E-08	1.59E-09
TH234	0.0	2.87E-01	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03
PA233	0.0	1.44E-01	1.47E-01	1.52E-01	2.15E-01	5.25E-01	6.20E-01
PA234M	0.0	2.87E-01	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03
U234	0.0	6.29E-04	3.24E-03	1.03E-02	7.96E-02	1.90E-01	1.86E-01
U237	0.0	1.78E-01	6.17E-02	4.42E-02	6.19E-04	1.96E-06	9.23E-07
U238	3.03E-01	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03
NP237	0.0	1.45E-01	1.47E-01	1.52E-01	2.15E-01	5.25E-01	6.20E-01
NP239	0.0	5.41E 01	5.41E 01	5.41E 01	5.36E 01	4.94E 01	2.19E 01
PU236	4.88E 00	1.29E-02	6.21E-03	1.13E-03	3.52E-13	0.0	0.0
PU238	2.73E 04	9.40E 01	3.64E 02	3.52E 02	2.10E 02	2.40E 00	3.50E-18
PU239	3.21E 03	1.93E 01	1.93E 01	1.93E 01	1.94E 01	2.02E 01	2.32E 01
PU240	4.66E 03	2.62E 01	2.66E 01	2.75E 01	2.98E 01	2.72E 01	1.08E 01
PU241	1.00E 06	2.96E 03	2.57E 03	1.84E 03	2.57E 01	8.18E-02	3.85E-02
PU242	1.32E 01	7.17E-02	7.18E-02	7.21E-02	7.47E-02	7.96E-02	7.85E-02
AM241	0.0	2.26E 03	2.26E 03	2.26E 03	2.01E 03	4.76E 02	3.87E-02
AM242M	0.0	1.13E 02	1.11E 02	1.08E 02	7.16E 01	1.18E 00	1.76E-18
AM242	0.0	1.13E 02	1.11E 02	1.08E 02	7.16E 01	1.18E 00	1.76E-18
AM243	0.0	5.41E 01	5.41E 01	5.41E 01	5.36E 01	4.94E 01	2.19E 01
CM242	0.0	5.54E 04	6.15E 02	8.85E 01	5.87E 01	9.68E-01	1.45E-18
CM243	0.0	4.53E 01	4.24E 01	3.65E 01	5.19E 00	1.77E-08	0.0
CM244	0.0	1.48E 03	1.32E 03	1.01E 03	3.21E 01	1.99E-12	1.96E-12
CM245	0.0	8.88E-02	8.88E-02	8.88E-02	8.81E-02	8.17E-02	3.84E-02
CM246	0.0	4.01E-03	4.01E-03	4.01E-03	3.95E-03	3.46E-03	9.21E-04
SUBTOT	1.03E 06	6.26E 04	7.54E 03	5.95E 03	2.64E 03	6.30E 02	7.93E 01
TOTALS	1.03E 06	6.26E 04	7.54E 03	5.95E 03	2.64E 03	6.30E 02	7.96E 01

Table A.10. Curies of fission product isotopes in the high-level waste from one metric ton of blended LMFBR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	3.21E-01	3.21E-01	3.21E-01	3.21E-01	3.17E-01	2.88E-01
SR 89	0.0	2.46E 05	1.12E-01	1.76E-16	0.0	0.0	0.0
SR 90	0.0	4.72E 04	4.38E 04	3.69E 04	4.00E 03	9.12E-07	0.0
Y 90	0.0	4.72E 04	4.38E 04	3.69E 04	4.01E 03	9.13E-07	0.0
Y 91	0.0	3.82E 05	8.97E-01	6.57E-14	0.0	0.0	0.0
ZR 93	0.0	2.40E 00	2.40E 00	2.40E 00	2.40E 00	2.40E 00	2.39E 00
ZR 95	0.0	7.59E 05	6.97E 00	1.23E-11	0.0	0.0	0.0
NB 93M	0.0	1.82E-01	5.17E-01	1.11E 00	2.28E 00	2.28E 00	2.27E 00
NB 95	0.0	1.25E 06	1.50E 01	2.66E-11	0.0	0.0	0.0
NB 95M	0.0	9.63E 03	8.86E-02	1.57E-13	0.0	0.0	0.0
TC 99	0.0	1.60E 01	1.60E 01	1.60E 01	1.60E 01	1.59E 01	1.55E 01
RU103	0.0	5.70E 05	2.71E-03	9.85E-23	0.0	0.0	0.0
RU106	0.0	1.09E 06	1.39E 05	1.14E 03	1.72E-24	0.0	0.0
RH103M	0.0	5.71E 05	2.71E-03	9.86E-23	0.0	0.0	0.0
RH106	0.0	1.09E 06	1.39E 05	1.14E 03	1.72E-24	0.0	0.0
PD107	0.0	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.34E-01
AG110	0.0	2.41E 04	1.18E 03	1.04E 00	0.0	0.0	0.0
CD113M	0.0	1.81E 02	1.57E 02	1.13E 02	1.57E 00	4.20E-19	0.0
SN119M	0.0	2.92E 02	1.32E 01	9.51E-03	0.0	0.0	0.0
SN121M	0.0	1.37E 00	1.31E 00	1.19E 00	3.42E-01	1.29E-06	0.0
SN123	0.0	9.52E 03	2.65E 01	2.87E-05	0.0	0.0	0.0
SN126	0.0	1.36E 00	1.36E 00	1.36E 00	1.36E 00	1.36E 00	1.27E 00
SB124	0.0	3.77E 02	1.25E-03	2.04E-16	0.0	0.0	0.0
SB125	0.0	2.55E 04	1.19E 04	2.02E 03	2.39E-07	0.0	0.0
SB126	0.0	2.47E 01	1.91E-01	1.91E-01	1.91E-01	1.90E-01	1.78E-01
SB126M	0.0	1.36E 00	1.36E 00	1.36E 00	1.36E 00	1.36E 00	1.27E 00
TE123M	0.0	1.78E 00	3.12E-03	1.15E-09	0.0	0.0	0.0
TE125M	0.0	5.88E 03	2.91E 03	4.92E 02	5.84E-08	0.0	0.0
TE127	0.0	1.75E 04	1.65E 01	1.43E-06	0.0	0.0	0.0
TE127M	0.0	1.79E 04	1.69E 01	1.46E-06	0.0	0.0	0.0
CS134	0.0	3.11E 04	1.13E 04	1.08E 03	7.75E-11	0.0	0.0
CS135	0.0	1.81E 00	1.81E 00	1.81E 00	1.81E 00	1.81E 00	1.81E 00
CS137	0.0	1.21E 05	1.13E 05	9.62E 04	1.21E 04	1.21E-05	0.0
BA137M	0.0	1.15E 05	1.07E 05	9.10E 04	1.15E 04	1.14E-05	0.0
CE144	0.0	1.03E 06	7.13E 04	1.40E 02	0.0	0.0	0.0
PR144	0.0	1.03E 06	7.13E 04	1.40E 02	0.0	0.0	0.0
PR144M	0.0	1.24E 04	8.56E 02	1.68E 00	0.0	0.0	0.0
PM147	0.0	3.26E 05	1.47E 05	2.32E 04	1.09E-06	0.0	0.0
SM151	0.0	4.76E 03	4.66E 03	4.42E 03	2.26E 03	2.75E 00	0.0
EU152	0.0	1.41E 01	1.20E 01	8.27E 00	6.80E-02	9.49E-23	0.0
EU154	0.0	2.29E 03	1.80E 03	1.02E 03	7.21E-01	0.0	0.0
EU155	0.0	2.04E 04	1.32E 04	4.80E 03	1.08E-02	0.0	0.0
GD153	0.0	6.03E-01	2.57E-02	1.63E-05	0.0	0.0	0.0
TB160	0.0	9.68E 02	2.65E-02	5.99E-13	0.0	0.0	0.0
SUBTOT	0.0	8.85E 06	9.23E 05	3.01E 05	3.39E 04	2.86E 01	2.52E 01
TOTALS	0.0	9.29E 06	9.23E 05	3.01E 05	3.39E 04	2.86E 01	2.52E 01

Table A.11. Curies of heavy isotopes in the high-level waste from one metric ton of HTGR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
TL207	0.0	7.13E-02	1.41E-01	2.77E-01	7.85E-01	7.99E-01	6.60E-01
TL208	0.0	6.67E 01	4.68E-01	5.08E-01	2.15E-01	2.03E-04	1.66E-04
PB211	0.0	7.16E-02	1.41E-01	2.78E-01	7.87E-01	8.02E-01	6.62E-01
PB212	0.0	1.85E 02	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
BI211	0.0	7.16E-02	1.41E-01	2.78E-01	7.87E-01	8.02E-01	6.62E-01
BI212	0.0	1.85E 02	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
PO212	0.0	1.19E 02	8.31E-01	9.03E-01	3.83E-01	3.61E-04	2.94E-04
PO215	0.0	7.16E-02	1.41E-01	2.78E-01	7.87E-01	8.02E-01	6.62E-01
PO216	0.0	1.85E 02	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
RN219	0.0	7.16E-02	1.41E-01	2.78E-01	7.87E-01	8.02E-01	6.62E-01
RN220	0.0	1.85E 02	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
FR223	0.0	1.02E-03	1.97E-03	3.88E-03	1.10E-02	1.12E-02	9.27E-03
RA223	0.0	7.16E-02	1.41E-01	2.78E-01	7.87E-01	8.02E-01	6.62E-01
RA224	0.0	1.85E 02	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
RA228	0.0	3.65E-02	2.69E-02	1.33E-02	4.61E-04	4.60E-04	4.60E-04
AC227	0.0	7.25E-02	1.41E-01	2.77E-01	7.87E-01	8.02E-01	6.62E-01
AC228	0.0	3.65E-02	2.69E-02	1.33E-02	4.61E-04	4.60E-04	4.60E-04
TH227	0.0	3.49E-04	1.39E-01	2.74E-01	7.76E-01	7.90E-01	6.53E-01
TH228	0.0	9.23E-01	1.30E 00	1.41E 00	5.98E-01	5.64E-04	4.60E-04
PA231	0.0	8.18E-01	8.18E-01	8.18E-01	8.17E-01	8.01E-01	6.61E-01
PA233	0.0	8.26E 04	1.57E 00	1.57E 00	1.58E 00	1.63E 00	1.64E 00
U232	3.02E 02	1.46E 00	1.45E 00	1.38E 00	5.82E-01	1.02E-04	0.0
U233	2.21E 02	1.10E 00	1.14E 00	1.14E 00	1.14E 00	1.15E 00	1.16E 00
U234	6.37E 01	7.79E-01	9.35E-01	1.29E 00	4.43E 00	7.51E 00	7.33E 00
U236	5.15E-01	3.54E-01	3.54E-01	3.54E-01	3.54E-01	3.55E-01	3.60E-01
U237	0.0	1.27E-03	2.20E-01	1.58E-01	2.21E-03	4.52E-06	2.13E-06
NP237	0.0	1.57E 00	1.57E 00	1.57E 00	1.58E 00	1.63E 00	1.64E 00
NP239	0.0	7.28E 00	7.28E 00	7.28E 00	7.22E 00	6.65E 00	2.94E 00
PU236	0.0	1.60E 00	7.71E-01	1.41E-01	4.37E-11	0.0	0.0
PU238	0.0	1.87E 04	1.83E 04	1.73E 04	8.60E 03	7.83E 00	1.43E-20
PU239	0.0	1.50E 01	1.50E 01	1.50E 01	1.50E 01	1.48E 01	1.25E 01
PU240	0.0	3.19E 01	3.23E 01	3.32E 01	3.58E 01	3.27E 01	1.30E 01
PU241	0.0	1.06E 04	9.17E 03	6.58E 03	9.19E 01	1.88E-01	8.86E-02
PU242	0.0	4.14E-01	4.14E-01	4.14E-01	4.14E-01	4.13E-01	4.08E-01
AM241	0.0	2.25E 01	6.97E 01	1.56E 02	3.30E 02	7.91E 01	8.86E-02
AM242M	0.0	4.60E-01	4.54E-01	4.40E-01	2.92E-01	4.81E-03	7.18E-21
AM242	0.0	4.60E-01	4.54E-01	4.40E-01	2.92E-01	4.81E-03	7.18E-21
AM243	0.0	7.28E 00	7.28E 00	7.28E 00	7.22E 00	6.65E 00	2.94E 00
CM242	0.0	1.42E 03	1.38E 01	3.61E-01	2.39E-01	3.94E-03	5.91E-21
CM243	0.0	9.26E-01	8.67E-01	7.45E-01	1.06E-01	3.62E-10	0.0
CM244	0.0	1.62E 03	1.45E 03	1.11E 03	3.53E 01	7.60E-14	3.78E-13
CM245	0.0	2.05E-01	2.05E-01	2.04E-01	2.03E-01	1.88E-01	8.84E-02
CM246	0.0	1.26E-01	1.26E-01	1.26E-01	1.25E-01	1.09E-01	2.90E-02
SUBTOT	5.87E 02	1.16E 05	2.91E 04	2.53E 04	9.15E 03	1.68E 02	5.02E 01
TOTALS	5.87E 02	1.16E 05	2.91E 04	2.53E 04	9.15E 03	1.69E 02	6.07E 01

Table A.12. Curies of fission product isotopes in the high-level waste from one metric ton of HTGR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SE 79	0.0	1.79E 00	1.79E 00	1.79E 00	1.79E 00	1.77E 00	1.61E 00
SR 89	0.0	1.05E 05	4.76E-02	7.51E-17	0.0	0.0	0.0
SR 90	0.0	3.06E 05	2.84E 05	2.39E 05	2.59E 04	5.92E-06	0.0
Y 90	0.0	3.06E 05	2.84E 05	2.39E 05	2.59E 04	5.92E-06	0.0
Y 91	0.0	1.57E 05	3.68E-01	2.69E-14	0.0	0.0	0.0
ZR 93	0.0	1.03E 01	1.03E 01	1.03E 01	1.03E 01	1.03E 01	1.02E 01
ZR 95	0.0	2.32E 05	2.13E 00	3.78E-12	0.0	0.0	0.0
NB 93M	0.0	1.40E 00	2.73E 00	5.08E 00	9.77E 00	9.79E 00	9.73E 00
NB 95	0.0	4.73E 05	4.60E 00	8.15E-12	0.0	0.0	0.0
NB 95M	0.0	2.95E 03	2.71E-02	4.80E-14	0.0	0.0	0.0
TC 99	0.0	3.39E 01	3.39E 01	3.39E 01	3.38E 01	3.37E 01	3.28E 01
RU106	0.0	1.17E 05	1.50E 04	1.23E 02	1.86E-25	0.0	0.0
RH106	0.0	1.17E 05	1.50E 04	1.23E 02	1.86E-25	0.0	0.0
PD107	0.0	4.51E-02	4.51E-02	4.51E-02	4.51E-02	4.51E-02	4.51E-02
AG110	0.0	1.55E 04	7.62E 02	6.71E-01	0.0	0.0	0.0
CD113M	0.0	4.08E 01	3.54E 01	2.54E 01	3.52E-01	9.44E-20	0.0
SN119M	0.0	5.97E 01	2.69E 00	1.95E-03	0.0	0.0	0.0
SN121M	0.0	8.98E-02	8.62E-02	7.82E-02	2.24E-02	8.49E-08	0.0
SN123	0.0	2.92E 03	8.11E 00	8.80E-06	0.0	0.0	0.0
SN126	0.0	2.07E 00	2.07E 00	2.07E 00	2.07E 00	2.05E 00	1.93E 00
SB125	0.0	1.94E 04	9.06E 03	1.53E 03	1.82E-07	0.0	0.0
SB126	0.0	2.90E-01	2.89E-01	2.89E-01	2.89E-01	2.87E-01	2.70E-01
SB126M	0.0	2.07E 00	2.07E 00	2.07E 00	2.07E 00	2.05E 00	1.93E 00
TE123M	0.0	1.00E 00	1.76E-03	6.51E-10	0.0	0.0	0.0
TE125M	0.0	4.71E 03	2.21E 03	3.74E 02	4.44E-08	0.0	0.0
TE127	0.0	8.45E 03	7.95E 00	6.91E-07	0.0	0.0	0.0
TE127M	0.0	8.62E 03	8.12E 00	7.05E-07	0.0	0.0	0.0
CS134	0.0	6.35E 05	2.31E 05	2.20E 04	1.58E-09	0.0	0.0
CS135	0.0	9.00E-01	9.00E-01	9.00E-01	9.00E-01	9.00E-01	8.97E-01
CS137	0.0	3.02E 05	2.82E 05	2.40E 05	3.02E 04	3.01E-05	0.0
BA137M	0.0	2.86E 05	2.67E 05	2.27E 05	2.85E 04	2.85E-05	0.0
CE144	0.0	1.38E 06	9.54E 04	1.87E 02	0.0	0.0	0.0
PR144	0.0	1.38E 06	9.54E 04	1.87E 02	0.0	0.0	0.0
PR144M	0.0	1.66E 04	1.15E 03	2.25E 00	0.0	0.0	0.0
PM147	0.0	1.57E 05	7.10E 04	1.12E 04	5.24E-07	0.0	0.0
SM151	0.0	6.44E 02	6.30E 02	5.98E 02	3.05E 02	3.72E-01	0.0
EU152	0.0	2.62E 00	2.23E 00	1.53E 00	1.26E-02	1.76E-23	0.0
EU154	0.0	2.33E 04	1.83E 04	1.04E 04	7.35E 00	0.0	0.0
EU155	0.0	4.52E 03	2.93E 03	1.06E 03	2.40E-03	0.0	0.0
TB160	0.0	6.46E 01	1.77E-03	4.00E-14	0.0	0.0	0.0
SUBTOT	0.0	6.06E 06	1.67E 06	9.92E 05	1.11E 05	6.13E 01	5.94E 01
TOTALS	0.0	6.11E 06	1.67E 06	9.92E 05	1.11E 05	6.13E 01	5.94E 01

Table A.13. Thermal power as a function of time in high-level waste generated in reprocessing one ton of spent fuel[a]

Time since reprocessing[b] (years)	Thermal power (watts)					
	PWR-U	PWR-Pu	BWR-U	BWR-Pu	HTGR	LMFBR
			Fission products[c]			
0	1.88 + 4[d]	2.01 + 4	1.36 + 4	1.44 + 4	2.12 + 4	3.62 + 4
3	2.87 + 3	2.93 + 3	2.18 + 3	2.21 + 3	6.46 + 3	3.03 + 3
10	9.46 + 2	8.05 + 2	7.65 + 2	6.58 + 2	3.14 + 3	7.56 + 2
100	9.45 + 1	7.76 + 1	7.76 + 1	6.46 + 1	3.33 + 2	8.46 + 1
1,000	1.97 - 2	2.48 - 2	1.67 - 2	2.06 - 2	4.65 - 2	3.31 - 2
10,000	1.88 - 2	2.36 - 2	1.59 - 2	1.95 - 2	4.41 - 2	3.12 - 2
			Actinides[e]			
0	5.82 + 2	8.23 + 3	4.37 + 2	5.73 + 3	7.51 + 2	2.18 + 3
3	7.78 + 1	1.88 + 3	6.24 + 1	1.38 + 3	6.61 + 2	1.62 + 2
10	5.85 + 1	1.42 + 3	4.78 + 1	1.05 + 3	6.19 + 2	1.31 + 2
100	1.12 + 1	1.43 + 2	1.12 + 1	1.26 + 2	2.99 + 2	8.12 + 1
1,000	2.66 + 0	2.97 + 1	2.67 + 0	2.80 + 1	5.17 + 0	1.94 + 1
10,000	5.01 - 1	7.85 + 0	4.25 - 1	6.32 + 0	1.62 + 0	1.92 + 0

[a] PWR fuels are irradiated to 33,000 MWd/ton at 30 MW/ton; BWR fuels are irradiated to 27,500 MWd/ton at 20.7 MW/ton; HTGR fuels are irradiated to 94,270 MWd/ton at 64.6 MW/ton; LMFBR core and blankets are irradiated to an average of 37,120 MWd/ton at 64.6 MW/ton.

[b] Fuels are reprocessed 160, 250, and 90 days after discharge from LWRs, HTGRs, and LMFBRs, respectively.

[c] Assumes that all of the tritium and noble gases and 99.9% of the halogen fission products are separated from the waste during reprocessing.

[d] Read as 1.88×10^4.

[e] Consists of all the actinides remaining after removal of 99.5% of the uranium and plutonium during reprocessing.

APPENDIX B

Radioactivity and Thermal Power of the Cladding Waste from One Metric Ton of Heavy Metal as a Function of Time for Five Reactor Types

Table B.1. Curies of induced radioactivity in the cladding waste from one metric ton of uranium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
H 3	0.0	1.46E-02	1.23E-02	8.29E-03	5.20E-05	4.87E-27	0.0
C 14	0.0	1.81E-01	1.81E-01	1.81E-01	1.79E-01	1.60E-01	5.39E-02
MN 54	0.0	6.97E 02	5.68E 01	1.64E-01	0.0	0.0	0.0
FE 55	0.0	7.19E 03	3.23E 03	5.00E 02	1.89E-08	0.0	0.0
CO 58	0.0	1.74E 03	4.10E-02	6.57E-13	0.0	0.0	0.0
CO 60	0.0	4.90E 02	3.30E 02	1.31E 02	9.27E-04	0.0	0.0
NI 59	0.0	3.52E 00	3.52E 00	3.52E 00	3.51E 00	3.49E 00	3.22E 00
NI 63	0.0	5.49E 02	5.37E 02	5.10E 02	2.59E 02	2.94E-01	0.0
ZN 65	0.0	1.36E-01	6.11E-03	4.41E-06	0.0	0.0	0.0
ZR 93	0.0	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.02E-01
ZR 95	0.0	5.24E 03	4.41E-02	6.35E-14	0.0	0.0	0.0
NB 93M	0.0	1.04E-02	2.52E-02	5.22E-02	1.14E-01	1.14E-01	1.08E-01
NB 95	0.0	9.73E 03	9.37E-02	1.35E-13	0.0	0.0	0.0
MO 93	0.0	1.42E-02	1.42E-02	1.42E-02	1.41E-02	1.31E-02	6.56E-03
TC 99	0.0	1.05E-02	1.05E-02	1.05E-02	1.04E-02	1.04E-02	1.01E-02
SN119M	0.0	1.60E 01	7.68E-01	6.40E-04	0.0	0.0	0.0
SN121M	0.0	3.60E-01	3.51E-01	3.29E-01	1.45E-01	3.97E-05	0.0
SN123	1.98E 06	1.83E 03	4.20E 00	2.92E-06	0.0	0.0	0.0
SB124	0.0	2.97E 03	9.43E-03	1.40E-15	0.0	0.0	0.0
SB125	0.0	1.54E 04	7.12E 03	1.18E 03	1.09E-07	0.0	0.0
TE125M	0.0	6.25E 03	2.95E 03	4.89E 02	4.51E-08	0.0	0.0
SUBTOT	1.98E 06	5.21E 04	1.42E 04	2.81E 03	2.63E 02	4.18E 00	3.50E 00
TOTALS	1.98E 06	5.28E 04	1.42E 04	2.81E 03	2.63E 02	4.18E 00	3.51E 00

Table B.2. Curies of heavy isotopes in the cladding waste from one metric ton of uranium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
U237	0.0	1.53E-03	1.29E-03	9.24E-04	1.29E-05	4.94E-10	2.32E-10
NP239	0.0	8.67E-03	8.67E-03	8.66E-03	8.59E-03	7.92E-03	3.50E-03
PU238	0.0	2.50E-01	2.77E-01	2.63E-01	1.32E-01	1.90E-04	1.12E-22
PU239	0.0	1.62E-01	1.62E-01	1.62E-01	1.62E-01	1.58E-01	1.23E-01
PU240	0.0	2.41E-01	2.41E-01	2.42E-01	2.41E-01	2.20E-01	8.74E-02
PU241	0.0	6.18E 01	5.36E 01	3.85E 01	5.36E-01	2.06E-05	9.68E-06
AM241	0.0	1.19E-01	3.95E-01	8.99E-01	1.92E 00	4.59E-01	9.94E-06
AM242M	0.0	3.62E-03	3.57E-03	3.46E-03	2.30E-03	3.79E-05	5.66E-23
AM242	0.0	3.62E-03	3.57E-03	3.46E-03	2.30E-03	3.79E-05	5.66E-23
AM243	0.0	8.67E-03	8.67E-03	8.66E-03	8.59E-03	7.92E-03	3.50E-03
CM242	0.0	6.84E 00	6.77E-02	2.84E-03	1.88E-03	3.11E-05	4.65E-23
CM243	0.0	1.46E-03	1.37E-03	1.18E-03	1.68E-04	5.72E-13	0.0
CM244	0.0	9.86E-01	8.79E-01	6.73E-01	2.14E-02	2.35E-17	5.85E-18
SUBTOT	0.0	7.05E 01	5.57E 01	4.07E 01	3.04E 00	8.53E-01	2.18E-01
TOTALS	2.19E 00	7.05E 01	5.57E 01	4.07E 01	3.04E 00	8.57E-01	2.22E-01

Table B.3. Curies of fission product isotopes in the cladding waste from one metric ton of uranium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SR 90	0.0	3.81E 01	3.54E 01	2.98E 01	3.23E 00	7.37E-10	0.0
Y 90	0.0	3.81E 01	3.54E 01	2.98E 01	3.23E 00	7.38E-10	0.0
ZR 93	0.0	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.44E-03
ZR 95	0.0	1.27E 02	1.16E-03	2.06E-15	0.0	0.0	0.0
NB 95	0.0	2.39E 02	2.51E-03	4.44E-15	0.0	0.0	0.0
TC 99	0.0	7.19E-03	7.19E-03	7.19E-03	7.19E-03	7.17E-03	6.96E-03
RU106	0.0	1.97E 02	2.51E 01	2.06E-01	3.11E-28	0.0	0.0
RH106	0.0	1.97E 02	2.51E 01	2.06E-01	3.11E-28	0.0	0.0
AG110	0.0	3.28E 01	1.61E 00	1.42E-03	0.0	0.0	0.0
CD113M	0.0	1.68E-02	1.46E-02	1.04E-02	1.45E-04	3.89E-23	0.0
SN119M	0.0	2.74E-02	1.23E-03	8.91E-07	0.0	0.0	0.0
SN123	0.0	9.07E-01	2.52E-03	2.73E-09	0.0	0.0	0.0
SB125	0.0	4.52E 00	2.11E 00	3.57E-01	4.24E-11	0.0	0.0
TE125M	0.0	1.08E 00	5.16E-01	8.72E-02	1.04E-11	0.0	0.0
TE127	0.0	2.53E 00	2.38E-03	2.06E-10	0.0	0.0	0.0
TE127M	0.0	2.58E 00	2.43E-03	2.11E-10	0.0	0.0	0.0
CS134	0.0	1.15E 02	4.19E 01	3.98E 00	2.84E-13	0.0	0.0
CS137	0.0	5.39E 01	5.03E 01	4.28E 01	5.39E 00	5.37E-09	0.0
BA137M	0.0	5.10E 01	4.76E 01	4.05E 01	5.10E 00	5.08E-09	0.0
CE144	0.0	3.65E 02	2.53E 01	4.96E-02	0.0	0.0	0.0
PR144	0.0	3.65E 02	2.53E 01	4.97E-02	0.0	0.0	0.0
PR144M	0.0	4.38E 00	3.03E-01	5.96E-04	0.0	0.0	0.0
PM147	0.0	4.54E 01	2.05E 01	3.23E 00	1.52E-10	0.0	0.0
SM151	0.0	5.58E-01	5.46E-01	5.18E-01	2.65E-01	3.22E-04	0.0
EU152	0.0	4.86E-03	4.14E-03	2.85E-03	2.34E-05	3.27E-26	0.0
EU154	0.0	6.15E 00	4.83E 00	2.75E 00	1.94E-03	0.0	0.0
EU155	0.0	1.27E 00	8.25E-01	3.00E-01	6.76E-07	0.0	0.0
SUBTOT	0.0	1.89E 03	3.43E 02	1.55E 02	1.72E 01	8.94E-03	8.40E-03
TOTALS	0.0	2.12E 03	3.43E 02	1.55E 02	1.72E 01	1.14E-02	1.08E-02

Table B.4. Curies of induced radioactivity in the cladding waste from one metric ton of plutonium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
H 3	0.0	1.34E-02	1.13E-02	7.63E-03	4.78E-05	4.48E-27	0.0
C 14	0.0	9.56E-02	9.56E-02	9.55E-02	9.44E-02	8.47E-02	2.85E-02
MN 54	0.0	7.63E 02	6.22E 01	1.79E-01	0.0	0.0	0.0
FE 55	0.0	3.06E 03	1.37E 03	2.12E 02	8.02E-09	0.0	0.0
CO 58	0.0	2.38E 03	5.63E-02	9.01E-13	0.0	0.0	0.0
CO 60	0.0	3.14E 02	2.12E 02	8.42E 01	5.94E-04	0.0	0.0
NI 59	0.0	1.47E 00	1.47E 00	1.47E 00	1.47E 00	1.46E 00	1.35E 00
NI 63	0.0	2.31E 02	2.26E 02	2.15E 02	1.09E 02	1.24E-01	0.0
ZN 65	0.0	5.33E-02	2.40E-03	1.73E-06	0.0	0.0	0.0
ZR 93	0.0	6.82E-02	6.82E-02	6.82E-02	6.82E-02	6.82E-02	6.79E-02
ZR 95	0.0	3.78E 03	3.18E-02	4.58E-14	0.0	0.0	0.0
NB 93M	0.0	6.44E-03	1.59E-02	3.31E-02	7.28E-02	7.29E-02	7.02E-02
NB 95	0.0	7.02E 03	6.76E-02	9.73E-14	0.0	0.0	0.0
MO 93	0.0	5.92E-03	5.92E-03	5.91E-03	5.87E-03	5.48E-03	2.74E-03
TC 99	0.0	9.08E-03	9.08E-03	9.08E-03	9.08E-03	9.05E-03	8.78E-03
SN119M	0.0	6.95E 00	3.33E-01	2.78E-04	0.0	0.0	0.0
SN121M	0.0	2.74E-01	2.66E-01	2.50E-01	1.10E-01	3.02E-05	0.0
SN123	1.98E 06	1.83E 03	4.20E 00	2.92E-06	0.0	0.0	0.0
SB124	0.0	2.91E 03	9.23E-03	1.37E-15	0.0	0.0	0.0
SB125	0.0	1.32E 04	6.11E 03	1.01E 03	9.33E-08	0.0	0.0
TE125M	0.0	5.35E 03	2.53E 03	4.20E 02	3.86E-08	0.0	0.0
SUBTOT	1.98E 06	4.08E 04	1.05E 04	1.95E 03	1.11E 02	1.82E 00	1.53E 00
TOTALS	1.98E 06	4.12E 04	1.05E 04	1.95E 03	1.11E 02	1.82E 00	1.53E 00

Table B.5. Curies of heavy isotopes in the cladding waste from one metric ton of plutonium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
U237	0.0	7.19E-03	6.22E-03	4.46E-03	6.24E-05	1.73E-07	8.12E-08
NP239	0.0	1.36E-01	1.36E-01	1.36E-01	1.35E-01	1.25E-01	5.51E-02
PU238	1.71E 04	8.91E 00	9.12E 00	8.64E 00	4.35E 00	7.53E-03	5.71E-21
PU239	1.37E 03	3.37E-01	3.37E-01	3.37E-01	3.36E-01	3.31E-01	2.75E-01
PU240	2.55E 03	1.00E 00	1.01E 00	1.03E 00	1.06E 00	9.71E-01	3.86E-01
PU241	6.76E 05	2.98E 02	2.59E 02	1.86E 02	2.60E 00	7.20E-03	3.38E-03
PU242	1.48E 01	9.29E-03	9.29E-03	9.30E-03	9.30E-03	9.29E-03	9.15E-03
AM241	0.0	1.00E 00	2.33E 00	4.76E 00	9.64E 00	2.31E 00	3.39E-03
AM242M	0.0	1.84E-01	1.82E-01	1.76E-01	1.17E-01	1.93E-03	2.88E-21
AM242	0.0	1.84E-01	1.82E-01	1.76E-01	1.17E-01	1.93E-03	2.88E-21
AM243	0.0	1.36E-01	1.36E-01	1.36E-01	1.35E-01	1.25E-01	5.51E-02
CM242	0.0	8.48E 01	9.50E-01	1.44E-01	9.58E-02	1.58E-03	2.37E-21
CM243	0.0	1.35E-02	1.27E-02	1.09E-02	1.55E-03	5.29E-12	0.0
CM244	0.0	2.72E 01	2.42E 01	1.85E 01	5.90E-01	9.64E-16	3.28E-15
CM245	0.0	7.82E-03	7.81E-03	7.81E-03	7.75E-03	7.19E-03	3.38E-03
CM246	0.0	1.50E-03	1.50E-03	1.50E-03	1.48E-03	1.30E-03	3.45E-04
SUBTOT	6.97E 05	4.22E 02	2.98E 02	2.20E 02	1.92E 01	3.90E 00	7.91E-01
TOTALS	6.97E 05	4.22E 02	2.98E 02	2.20E 02	1.92E 01	3.91E 00	8.03E-01

Table B.6. Curies of fission product isotopes in the cladding waste from one metric ton of plutonium-enriched PWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SR 90	0.0	2.20E 01	2.05E 01	1.72E 01	1.87E 00	4.26E-10	0.0
Y 90	0.0	2.21E 01	2.05E 01	1.72E 01	1.87E 00	4.26E-10	0.0
ZR 93	0.0	1.13E-03	1.13E-03	1.13E-03	1.13E-03	1.13E-03	1.12E-03
ZR 95	0.0	1.16E 02	1.07E-03	1.89E-15	0.0	0.0	0.0
NB 95	0.0	2.19E 02	2.30E-03	4.07E-15	0.0	0.0	0.0
TC 99	0.0	7.27E-03	7.27E-03	7.27E-03	7.26E-03	7.24E-03	7.03E-03
RU106	0.0	3.16E 02	4.04E 01	3.31E-01	5.00E-28	0.0	0.0
RH106	0.0	3.16E 02	4.04E 01	3.31E-01	5.00E-28	0.0	0.0
AG110	0.0	6.66E 01	3.27E 00	2.88E-03	0.0	0.0	0.0
CD113M	0.0	2.95E-02	2.56E-02	1.83E-02	2.55E-04	6.83E-23	0.0
SN119M	0.0	3.63E-02	1.64E-03	1.18E-06	0.0	0.0	0.0
SN123	0.0	1.11E 00	3.07E-03	3.34E-09	0.0	0.0	0.0
SB125	0.0	7.04E 00	3.29E 00	5.56E-01	6.61E-11	0.0	0.0
TE125M	0.0	1.69E 00	8.03E-01	1.36E-01	1.61E-11	0.0	0.0
TE127	0.0	3.24E 00	3.05E-03	2.65E-10	0.0	0.0	0.0
TE127M	0.0	3.31E 00	3.11E-03	2.70E-10	0.0	0.0	0.0
CS134	0.0	1.06E 02	3.88E 01	3.68E 00	2.57E-13	0.0	0.0
CS137	0.0	5.53E 01	5.16E 01	4.39E 01	5.53E 00	5.51E-09	0.0
BA137M	0.0	5.23E 01	4.88E 01	4.15E 01	5.23E 00	5.21E-09	0.0
CE144	0.0	3.17E 02	2.19E 01	4.30E-02	0.0	0.0	0.0
PR144	0.0	3.17E 02	2.19E 01	4.30E-02	0.0	0.0	0.0
PR144M	0.0	3.80E 00	2.63E-01	5.16E-04	0.0	0.0	0.0
PM147	0.0	4.82E 01	2.18E 01	3.43E 00	1.61E-10	0.0	0.0
SM151	0.0	7.17E-01	7.02E-01	6.66E-01	3.40E-01	4.14E-04	0.0
EU152	0.0	1.33E-02	1.13E-02	7.79E-03	6.40E-05	8.94E-26	0.0
EU154	0.0	8.44E 00	6.63E 00	3.77E 00	2.68E-03	0.0	0.0
EU155	0.0	1.84E 00	1.19E 00	4.34E-01	9.78E-07	0.0	0.0
SUBTOT	0.0	2.00E 03	3.43E 02	1.33E 02	1.48E 01	8.79E-03	8.16E-03
TOTALS	0.0	2.22E 03	3.43E 02	1.33E 02	1.48E 01	1.15E-02	1.08E-02

Table B.7. Curies of induced radioactivity in the cladding waste from one metric ton of uranium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
MN 54	0.0	6.64E 02	5.41E 01	1.56E-01	0.0	0.0	0.0
FE 55	0.0	7.48E 03	3.36E 03	5.20E 02	1.97E-08	0.0	0.0
CO 58	0.0	8.26E 02	1.95E-02	3.12E-13	0.0	0.0	0.0
CO 60	0.0	5.65E 03	3.80E 03	1.51E 03	1.07E-02	0.0	0.0
NI 59	0.0	1.90E 00	1.90E 00	1.90E 00	1.90E 00	1.89E C0	1.74E 00
NI 63	0.0	2.97E 02	2.90E 02	2.75E 02	1.40E 02	1.59E-01	0.0
ZN 65	0.0	9.03E-02	4.06E-03	2.93E-06	0.0	0.0	0.0
ZR 93	0.0	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.24E-01	1.24E-01
ZR 95	0.0	5.07E 03	4.26E-02	6.13E-14	0.0	0.0	0.0
NB 93M	0.0	1.31E-02	2.89E-02	5.76E-C2	1.24E-01	1.24E-01	1.24E-01
NB 95	0.0	9.41E 03	9.05E-02	1.30E-13	0.0	0.0	0.0
SN119M	0.0	1.72E 01	8.26E-01	6.89E-04	C.0	0.0	0.0
SN121M	0.0	4.62E-01	4.49E-01	4.22E-01	1.86E-01	4.97E-C5	0.C
SN123	2.83E 06	7.41E 02	1.70E 00	1.18E-06	C.0	0.0	0.0
SB124	0.0	3.81E 03	1.21E-02	1.80E-15	0.0	0.0	0.0
SB125	0.0	1.70E 04	7.88E 03	1.31E 03	1.20E-07	0.0	0.0
TE125M	0.0	6.94E 03	3.26E 03	5.41E 02	4.99E-08	0.0	0.0
SUBTOT	2.83E 06	5.79E 04	1.87E 04	4.16E 03	1.42E 02	2.29E 00	1.99E 00
TOTALS	2.83E 06	5.84E 04	1.87E 04	4.16E 03	1.42E 02	2.29E 00	1.99E 00

Table B.8. Curies of heavy isotopes in the cladding waste from one metric ton of uranium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
U237	0.0	1.32E-03	1.12E-03	8.04E-04	1.12E-05	1.09E-08	5.14E-09
NP239	0.0	6.81E-03	6.81E-03	6.81E-03	6.75E-03	6.22E-03	2.75E-03
PU238	0.0	1.00E 00	1.00E 00	9.49E-01	4.73E-01	5.45E-04	1.84E-22
PU239	0.0	1.52E-01	1.52E-01	1.52E-01	1.52E-01	1.48E-01	1.16E-01
PU240	0.0	2.33E-01	2.33E-01	2.34E-01	2.33E-01	2.12E-01	8.43E-02
PU241	0.0	5.38E 01	4.66E 01	3.34E 01	4.67E-01	4.56E-04	2.14E-04
AM241	0.0	1.30E-01	3.70E-01	8.08E-01	1.69E 00	4.05E-01	2.15E-04
AM242M	0.0	5.95E-03	5.87E-03	5.68E-03	3.77E-03	6.22E-05	9.29E-23
AM242	0.0	5.95E-03	5.87E-03	5.68E-03	3.77E-03	6.22E-05	9.29E-23
AM243	0.0	6.81E-03	6.81E-03	6.81E-03	6.75E-03	6.22E-03	2.75E-03
CM242	0.0	5.08E 00	5.28E-02	4.66E-03	3.09E-03	5.10E-05	7.64E-23
CM244	0.0	7.54E-01	6.72E-01	5.14E-01	1.64E-02	2.87E-17	1.10E-16
SUBTOT	0.0	6.11E 01	4.91E 01	3.61E 01	3.06E 00	7.79E-01	2.06E-01
TOTALS	1.80E 00	6.11E 01	4.91E 01	3.61E 01	3.06E 00	7.83E-01	2.10E-01

Table B.9. Curies of fission product isotopes in the cladding waste from one metric ton of uranium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SR 90	0.0	3.09E 01	2.87E 01	2.42E 01	2.62E 00	5.99E-10	0.0
Y 90	0.0	3.09E 01	2.87E 01	2.42E 01	2.62E 00	5.99E-10	0.0
ZR 93	0.0	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.19E-03
NB 95	0.0	1.64E 02	1.72E-03	3.04E-15	0.0	0.0	0.0
TC 99	0.0	6.03E-03	6.03E-03	6.03E-03	6.03E-03	6.01E-03	5.84E-03
RU106	0.0	1.51E 02	1.93E 01	1.58E-01	2.39E-28	0.0	0.0
RH106	0.0	1.51E 02	1.93E 01	1.58E-01	2.39E-28	0.0	0.0
AG110	0.0	2.33E 01	1.14E 00	1.01E-03	0.0	0.0	0.0
CD113M	0.0	1.37E-02	1.19E-02	8.54E-03	1.19E-04	3.18E-23	0.0
SN123	0.0	6.44E-01	1.79E-03	1.94E-09	0.0	0.0	0.0
SB125	0.0	3.62E 00	1.69E 00	2.86E-01	3.40E-11	0.0	0.0
TE125M	0.0	8.67E-01	4.13E-01	6.98E-02	8.30E-12	0.0	0.0
TE127	0.0	1.80E 00	1.69E-03	1.47E-10	0.0	0.0	0.0
TE127M	0.0	1.83E 00	1.73E-03	1.50E-10	0.0	0.0	0.0
CS134	0.0	8.25E 01	3.01E 01	2.85E 00	2.11E-13	0.0	0.0
CS137	0.0	4.47E 01	4.17E 01	3.55E 01	4.47E 00	4.45E-09	0.0
BA137M	0.0	4.23E 01	3.94E 01	3.36E 01	4.23E 00	4.21E-09	0.0
CE144	0.0	2.57E 02	1.78E 01	3.49E-02	0.0	0.0	0.0
PR144	0.0	2.57E 02	1.78E 01	3.49E-02	0.0	0.0	0.0
PR144M	0.0	3.08E 00	2.13E-01	4.19E-04	0.0	0.0	0.0
PM147	0.0	3.98E 01	1.80E 01	2.83E 00	1.32E-10	0.0	0.0
SM151	0.0	4.86E-01	4.76E-01	4.51E-01	2.31E-01	2.79E-04	0.0
EU152	0.0	5.77E-03	4.91E-03	3.38E-03	2.78E-05	3.88E-26	0.0
EU154	0.0	4.75E 00	3.73E 00	2.12E 00	1.50E-03	0.0	0.0
EU155	0.0	1.01E 00	6.55E-01	2.38E-01	5.36E-07	0.0	0.0
SUBTOT	0.0	1.29E 03	2.69E 02	1.27E 02	1.42E 01	7.49E-03	7.03E-03
TOTALS	0.0	1.54E 03	2.69E 02	1.27E 02	1.42E 01	9.59E-03	9.07E-03

Table B.10. Curies of induced radioactivity in the cladding waste from one metric ton of plutonium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
MN 54	0.0	7.68E 02	6.26E 01	1.80E-01	C.0	0.0	0.0
FE 55	0.0	3.32E 03	1.49E 03	2.31E 02	8.76E-09	C.0	0.0
CO 58	0.0	1.15E 03	2.71E-02	4.34E-13	0.0	0.0	0.0
CO 60	0.0	3.93E 03	2.65E 03	1.05E 03	7.42E-03	0.0	0.0
NI 59	0.0	8.27E-01	8.27E-01	8.26E-01	8.26E-01	8.19E-01	7.58E-01
NI 63	0.0	1.30E 02	1.27E 02	1.20E 02	6.11E 01	6.91E-02	0.0
ZN 65	0.0	3.89E-02	1.75E-03	1.26E-06	0.0	0.0	0.0
ZR 93	0.0	8.56E-02	8.56E-02	8.56E-02	8.56E-02	8.56E-02	8.53E-02
ZR 95	0.0	3.90E 03	3.28E-02	4.73E-14	C.0	0.0	0.0
NB 93M	0.0	8.66E-03	1.96E-02	3.94E-02	8.52E-02	8.56E-02	8.53E-02
NB 95	0.0	7.25E 03	6.97E-02	1.00E-13	0.0	0.0	0.0
SN119M	0.0	7.92E 00	3.79E-01	3.17E-04	0.0	0.0	0.0
SN121M	0.0	3.64E-01	3.55E-01	3.33E-01	1.46E-01	3.95E-05	0.0
SN123	2.83E 06	7.41E 02	1.70E 00	1.18E-06	0.0	0.0	0.0
SB124	0.0	3.79E 03	1.20E-02	1.78E-15	0.0	0.0	0.0
SB125	0.0	1.54E 04	7.13E 03	1.18E 03	1.09E-07	0.0	0.0
TE125M	0.0	6.26E 03	2.96E 03	4.90E 02	4.51E-08	0.0	0.0
SUBTOT	2.83E 06	4.66E 04	1.44E 04	3.08E 03	6.22E 01	1.06E 00	9.28E-01
TOTALS	2.83E 06	4.69E 04	1.44E 04	3.08E 03	6.22E 01	1.06E 00	9.28E-01

Table B.11. Curies of heavy isotopes in the cladding waste from one metric ton of plutonium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
U237	0.0	5.99E-03	5.19E-03	3.72E-03	5.21E-05	2.00E-07	9.41E-08
NP239	0.0	1.09E-01	1.09E-01	1.08E-01	1.08E-01	9.92E-02	4.39E-02
PU238	1.75E 04	9.47E 00	9.54E 00	9.04E 00	4.52E 00	6.34E-03	3.58E-21
PU239	1.17E 03	2.92E-01	2.92E-01	2.92E-01	2.92E-01	2.87E-01	2.37E-01
PU240	2.37E 03	9.44E-01	9.49E-01	9.60E-01	9.85E-01	9.00E-01	3.57E-01
PU241	5.30E 05	2.49E 02	2.16E 02	1.55E 02	2.17E 00	8.34E-03	3.92E-03
PU242	1.23E 01	7.49E-03	7.49E-03	7.49E-03	7.49E-03	7.49E-03	7.38E-03
AM241	0.0	1.12E 00	2.23E 00	4.25E 00	8.28E 00	1.98E 00	3.92E-03
AM242M	0.0	1.16E-01	1.14E-01	1.10E-01	7.32E-02	1.21E-03	1.80E-21
AM242	0.0	1.16E-01	1.14E-01	1.10E-01	7.32E-02	1.21E-03	1.80E-21
AM243	0.0	1.09E-01	1.09E-01	1.08E-01	1.08E-01	9.92E-02	4.39E-02
CM242	0.0	5.79E 01	6.41E-01	9.06E-02	6.01E-02	9.91E-04	1.48E-21
CM243	0.0	8.72E-03	8.17E-03	7.02E-03	1.00E-03	3.41E-12	0.0
CM244	0.0	1.96E 01	1.75E 01	1.34E 01	4.26E-01	7.87E-16	3.27E-15
CM245	0.0	9.05E-03	9.05E-03	9.04E-03	8.98E-03	8.32E-03	3.91E-03
CM246	0.0	1.66E-03	1.66E-03	1.66E-03	1.63E-03	1.43E-03	3.81E-04
SUBTOT	5.51E 05	3.39E 02	2.47E 02	1.83E 02	1.71E 01	3.40E 00	7.02E-01
TOTALS	5.51E 05	3.39E 02	2.47E 02	1.83E 02	1.71E 01	3.41E 00	7.14E-01

Table B.12. Curies of fission product isotopes in the cladding waste from one metric ton of plutonium-enriched BWR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SR 90	0.0	1.87E 01	1.73E 01	1.46E 01	1.58E 00	3.61E-10	0.0
Y 90	0.0	1.87E 01	1.73E 01	1.46E 01	1.58E 00	3.61E-10	0.0
NB 95	0.0	1.51E 02	1.59E-03	2.81E-15	0.0	0.0	0.0
TC 99	0.0	6.07E-03	6.07E-03	6.07E-03	6.06E-03	6.05E-03	5.87E-03
RU106	0.0	2.25E 02	2.88E 01	2.36E-01	3.56E-28	0.0	0.0
RH106	0.0	2.25E 02	2.88E 01	2.36E-01	3.56E-28	0.0	0.0
AG110	0.0	4.56E 01	2.24E 00	1.97E-03	0.0	0.0	0.0
CD113M	0.0	2.33E-02	2.02E-02	1.45E-02	2.01E-04	5.39E-23	0.0
SN119M	0.0	2.54E-02	1.14E-03	8.26E-07	0.0	0.0	0.0
SN123	0.0	7.57E-01	2.10E-03	2.28E-09	0.0	0.0	0.0
SB125	0.0	5.37E 00	2.51E 00	4.24E-01	5.04E-11	0.0	0.0
TE125M	0.0	1.29E 00	6.13E-01	1.04E-01	1.23E-11	0.0	0.0
TE127	0.0	2.19E 00	2.07E-03	1.79E-10	0.0	0.0	0.0
TE127M	0.0	2.24E 00	2.11E-03	1.83E-10	0.0	0.0	0.0
CS134	0.0	7.90E 01	2.88E 01	2.73E 00	1.94E-13	0.0	0.0
CS137	0.0	4.56E 01	4.26E 01	3.62E 01	4.56E 00	4.55E-09	0.0
BA137M	0.0	4.32E 01	4.03E 01	3.43E 01	4.31E 00	4.30E-09	0.0
CE144	0.0	2.27E 02	1.57E 01	3.08E-02	0.0	0.0	0.0
PR144	0.0	2.27E 02	1.57E 01	3.08E-02	0.0	0.0	0.0
PR144M	0.0	2.72E 00	1.88E-01	3.69E-04	0.0	0.0	0.0
PM147	0.0	4.05E 01	1.84E 01	2.89E 00	1.35E-10	0.0	0.0
SM151	0.0	6.07E-01	5.93E-01	5.63E-01	2.88E-01	3.49E-04	0.0
EU152	0.0	1.42E-02	1.21E-02	8.34E-03	6.85E-05	9.56E-26	0.0
EU154	0.0	6.49E 00	5.10E 00	2.90E 00	2.04E-03	0.0	0.0
EU155	0.0	1.45E 00	9.40E-01	3.42E-01	7.70E-07	0.0	0.0
SUBTOT	0.0	1.37E 03	2.66E 02	1.10E 02	1.23E 01	6.40E-03	5.87E-03
TOTALS	0.0	1.60E 03	2.66E 02	1.10E 02	1.23E 01	9.65E-03	9.05E-03

Table B.13. Curies of induced radioactivity in the cladding waste from one metric ton of blended LMFBR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
C 14	0.0	1.97E-01	1.97E-01	1.97E-01	1.95E-01	1.75E-01	5.88E-02
NA 22	0.0	2.86E-01	1.29E-01	2.03E-02	9.24E-13	0.0	0.0
V 49	0.0	4.24E-02	4.24E-03	1.97E-05	0.0	0.0	0.0
MN 54	0.0	1.06E 05	8.63E 03	2.49E 01	0.0	0.0	0.0
FE 55	0.0	7.18E 04	3.23E 04	4.99E 03	1.89E-07	0.0	0.0
CO 58	0.0	2.12E 05	5.02E 00	8.04E-11	0.0	0.0	0.0
CO 60	0.0	1.75E 03	1.18E 03	4.68E 02	3.31E-03	0.0	0.0
NI 59	0.0	3.96E 00	3.96E 00	3.96E 00	3.96E 00	3.93E 00	3.63E 00
NI 63	0.0	1.26E 02	1.23E 02	1.17E 02	5.92E 01	6.71E-02	0.0
NB 93M	0.0	2.32E-01	6.77E-01	1.48E 00	3.33E 00	3.12E 00	1.56E 00
MO 93	0.0	3.96E 00	3.96E 00	3.96E 00	3.93E 00	3.67E 00	1.83E 00
TC 99	0.0	3.85E-01	3.85E-01	3.85E-01	3.84E-01	3.83E-01	3.72E-01
SUBTOT	0.0	3.92E 05	4.22E 04	5.61E 03	7.10E 01	1.13E 01	7.46E 00
TOTALS	2.11E 06	3.99E 05	4.22E 04	5.61E 03	7.10E 01	1.13E 01	7.46E 00

Table B.14. Curies of heavy isotopes in the cladding waste from one metric ton of blended LMFBR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
U237	0.0	1.78E-02	6.17E-03	4.42E-03	6.17E-05	9.82E-10	4.62E-10
NP239	0.0	2.71E-02	2.71E-02	2.70E-02	2.68E-02	2.47E-02	1.09E-02
PU238	2.73E 04	9.40E 00	9.32E 00	8.83E 00	4.40E 00	5.09E-03	1.75E-21
PU239	3.21E 03	1.93E 00	1.93E 00	1.93E 00	1.92E 00	1.87E 00	1.45E 00
PU240	4.66E 03	2.62E 00	2.62E 00	2.62E 00	2.60E 00	2.37E 00	9.41E-01
PU241	1.00E 06	2.96E 02	2.57E 02	1.84E 02	2.57E 00	4.09E-05	1.92E-05
PU242	1.32E 01	7.17E-03	7.17E-03	7.17E-03	7.17E-03	7.16E-03	7.05E-03
AM241	0.0	1.13E 00	2.44E 00	4.85E 00	9.67E 00	2.31E 00	2.05E-05
AM242M	0.0	5.64E-02	5.57E-02	5.39E-02	3.58E-02	5.90E-04	8.81E-22
AM242	0.0	5.64E-02	5.57E-02	5.39E-02	3.58E-02	5.90E-04	8.81E-22
AM243	0.0	2.71E-02	2.71E-02	2.70E-02	2.68E-02	2.47E-02	1.09E-02
CM242	0.0	2.77E 01	3.07E-01	4.42E-02	2.93E-02	4.84E-04	7.25E-22
CM243	0.0	2.26E-02	2.12E-02	1.82E-02	2.60E-03	8.85E-12	0.0
CM244	0.0	7.39E-01	6.59E-01	5.04E-01	1.60E-02	1.95E-13	1.95E-13
SUBTOT	1.03E 06	3.40E 02	2.74E 02	2.03E 02	2.13E 01	6.61E 00	2.42E 00
TOTALS	1.03E 06	3.40E 02	2.74E 02	2.03E 02	2.13E 01	6.62E 00	2.44E 00

Table B.15. Curies of fission product isotopes in the cladding waste from one metric ton of blended LMFBR fuel as a function of time

	CHARGE	DISCHARGE	3. Y	10. Y	100. Y	1000. Y	10000. Y
SR 90	0.0	2.36E 01	2.19E 01	1.84E 01	2.00E 00	4.57E-10	0.0
Y 90	0.0	2.36E 01	2.19E 01	1.84E 01	2.00E 00	4.57E-10	0.0
ZR 93	0.0	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.19E-03
ZR 95	0.0	3.79E 02	3.49E-03	6.17E-15	0.0	0.0	0.0
NB 95	0.0	6.25E 02	7.52E-03	1.33E-14	0.0	0.0	0.0
TC 99	0.0	7.99E-03	7.99E-03	7.99E-03	7.99E-03	7.97E-03	7.73E-03
RU106	0.0	5.43E 02	6.93E 01	5.68E-01	8.59E-28	0.0	0.0
RH106	0.0	5.43E 02	6.93E 01	5.68E-01	8.59E-28	0.0	0.0
AG110	0.0	1.20E 01	5.90E-01	5.21E-04	0.0	0.0	0.0
CD113M	0.0	9.06E-02	7.86E-02	5.64E-02	7.83E-04	2.10E-22	0.0
SN119M	0.0	1.46E-01	6.58E-03	4.75E-06	0.0	0.0	0.0
SN123	0.0	4.76E 00	1.32E-02	1.44E-08	0.0	0.0	0.0
SB125	0.0	1.28E 01	5.96E 00	1.01E 00	1.20E-10	0.0	0.0
TE125M	0.0	2.94E 00	1.46E 00	2.46E-01	2.92E-11	0.0	0.0
TE127	0.0	8.77E 00	8.26E-03	7.17E-10	0.0	0.0	0.0
TE127M	0.0	8.95E 00	8.43E-03	7.32E-10	0.0	0.0	0.0
CS134	0.0	1.56E 01	5.67E 00	5.38E-01	3.78E-14	0.0	0.0
CS137	0.0	6.06E 01	5.65E 01	4.81E 01	6.05E 00	6.03E-09	0.0
BA137M	0.0	5.73E 01	5.35E 01	4.55E 01	5.73E 00	5.71E-09	0.0
CE144	0.0	5.15E 02	3.57E 01	7.01E-02	0.0	0.0	0.0
PR144	0.0	5.15E 02	3.57E 01	7.01E-02	0.0	0.0	0.0
PR144M	0.0	6.19E 00	4.28E-01	8.41E-04	0.0	0.0	0.0
PM147	0.0	1.63E 02	7.37E 01	1.16E 01	5.42E-10	0.0	0.0
SM151	0.0	2.38E 00	2.33E 00	2.21E 00	1.13E 00	1.37E-03	0.0
EU152	0.0	7.05E-03	6.01E-03	4.14E-03	3.40E-05	4.75E-26	0.0
EU154	0.0	1.15E 00	8.99E-01	5.11E-01	3.62E-04	0.0	0.0
EU155	0.0	1.02E 01	6.60E 00	2.40E 00	5.41E-06	0.0	0.0
SUBTOT	0.0	3.53E 03	4.62E 02	1.50E 02	1.69E 01	1.05E-02	8.93E-03
TOTALS	0.0	4.65E 03	4.62E 02	1.50E 02	1.69E 01	1.43E-02	1.26E-02

Table B.16. Thermal power as a function of time in the fuel structural materials associated with one ton of spent fuel[a]

Time since reprocessing[b] (years)	PWR-U	PWR-Pu	BWR-U	BWR-Pu	LMFBR
			Light elements		
0	2.37 + 2	2.05 + 2	3.16 + 2	2.64 + 2	3.92 + 3
3	4.14 + 1	3.26 + 1	9.91 + 1	7.53 + 1	1.30 + 2
10	7.99 + 0	6.09 + 0	3.01 + 1	2.20 + 1	1.41 + 1
100	4.17 - 2[c]	1.77 - 2	2.28 - 2	1.01 - 2	2.12 - 2
1,000	2.00 - 4	1.09 - 4	8.37 - 5	5.12 - 5	1.09 - 2
10,000	1.03 - 4	6.44 - 5	5.80 - 5	3.99 - 5	5.77 - 3
			Fission products[d]		
0	9.41 + 0	1.00 + 1	6.79 + 0	7.19 + 0	1.81 + 1
3	1.44 + 0	1.46 + 0	1.09 + 0	1.11 + 0	1.52 + 0
10	4.73 - 1	4.02 - 1	3.83 - 1	3.29 - 1	3.78 - 1
100	4.73 - 2	3.88 - 2	3.88 - 2	3.23 - 2	4.23 - 2
1,000	9.87 - 6	1.24 - 5	8.34 - 6	1.03 - 5	1.65 - 5
10,000	9.41 - 6	1.18 - 5	7.95 - 6	9.78 - 6	1.56 - 5
			Actinides[e]		
0	3.15 - 1	4.46 + 0	2.66 - 1	3.23 + 0	1.55 + 0
3	7.09 - 2	1.32 + 0	8.53 - 2	1.08 + 0	5.79 - 1
10	7.69 - 2	1.16 + 0	9.03 - 2	9.63 - 1	6.25 - 1
100	8.23 - 2	5.40 - 1	8.52 - 2	4.88 - 1	6.12 - 1
1,000	2.75 - 2	1.23 - 1	2.51 - 2	1.08 - 1	2.11 - 1
10,000	6.78 - 3	2.34 - 2	6.42 - 3	2.09 - 2	7.54 - 2

[a] PWR fuels are irradiated to 33,000 MWd/ton at 30 MW/ton; BWR fuels are irradiated to 27,500 MWd/ton at 20.7 MW/ton; HTGR fuels are irradiated to 94,270 MWd/ton at 64.6 MW/ton; LMFBR core and blankets are irradiated to an average of 37,120 MWd/ton at 64.6 MW/ton.

[b] Fuels are reprocessed 160, 250, and 90 days after discharge from LWRs, HTGRs, and LMFBRs, respectively.

[c] Read as 4.17×10^{-2}

[d] Assumes that 0.05% of all nonvolatile fission products are associated with the fuel structural materials.

[e] Assumes that 0.05% of all actinides in the spent fuel are associated with the fuel structural materials.

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