

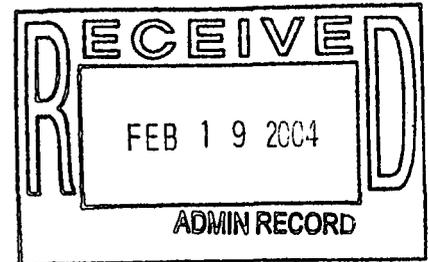
APPENDIX D
ANALYSIS OF ASSESSMENT NEEDS
FOR ROCKY FLATS PLUTONIUM

Introduction

In order to carry out its original mission, the Rocky Flats Environmental Technology Site (RFETS) handled plutonium in fabricating nuclear components. The plutonium used in these operations contained different isotopes of plutonium as well as americium. Rocky Flats plutonium used in the fabrication process was comprised of Pu-238, Pu-239, Pu-240, Pu-241 and Pu-242 (DOE, 1980). Am-241 is also contained in this mix of plutonium due to its ingrowth from Pu-241 (DOE, 1980). The plutonium found in the environment though will have different activities of plutonium and americium than what is found in the fabrication process because of radionuclide decay and ingrowth over time. In examining this decay and ingrowth along with each radionuclides toxicity, it will be shown that only Pu-239/240 and Am-241 need to be assessed within the environment for Rocky Flats plutonium. Uranium will not be discussed in this appendix since all RFETS specific uranium isotopes will be assessed in the environment.

Composition of Rocky Flats Plutonium

The following table outlines the composition of plutonium at RFETS during fabrication processes (DOE, 1980). This table includes an activity for Am-241. The Am-241 activity was derived assuming that the plutonium was produced 10 years before fabrication processes were begun, and Am-241 had this 10 years to ingrow in the Rocky Flats plutonium (DOE, 1980).



Radionuclide	Composition of Rocky Flats Plutonium (% by Weight)	Activity in Rocky Flats Plutonium (Ci/gram)	Half-Life (years)
Pu-238	0.01	1.7E-3	87.74
Pu-239	93.79	5.8E-2	24065
Pu-240	5.8	1.3E-2	6537
Pu-241	0.36	3.7E-1	14.4
Pu-242	0.03	1.2E-6	376300
Am-241		7.5E-3	432.2

The activity found in Rocky Flats plutonium during fabrication processes though is not what is found in the environment. For instance, the plutonium at and around the 903 Pad area of the plant was due to operations occurring primarily in the 1960s. Therefore, this plutonium was deposited in the environment 25 to over 35 years ago. Table 1, "Comparison of Plutonium Relative Activity With Action Levels Over Time", outlines the plutonium and americium activity of Rocky Flats plutonium released to the environment over time. The activity of Rocky Flats plutonium is assessed at years 0, 20, 40, 60, 80, 100, 200, 500 and 1,000 after a release.

In Table 1, the units of the plutonium and americium activity are in picocuries per gram of soil. It has been assumed that the relative activity between the different isotopes in Rocky Flats plutonium stay constant from the fabrication process to initial deposition in the environment. Therefore, there is a linear relationship between the number of curies per gram of Rocky Flats plutonium in the fabrication process to the number of picocuries per gram of Rocky Flats plutonium in soils.

There are a number of trends that can be surmised by examining the radionuclide activities over time.

For Pu-239, Pu-240 and Pu-242, the activity over the 1,000 year period does not change significantly due to the very long half-life of the radionuclides. The Pu-238 activity drops off fairly steadily over the 1,000 year period due to its relatively short half-life of 87.74 years. For Pu-241, the activity drops off quickly over the 1,000 year period due to its short half-life of 14.4 years. Since Am-241 ingrows from the decay of Pu-241, Am-241 activity actually increases in the short term. The Am-241 activity peaks around 70 years after the initial release to the environment and decays away slowly within the 1,000 year assessment period. This slow decay is due to the relatively long half-life of Am-241 of 432.2 years.

Toxicity of Rocky Flats Plutonium

It is important to assess each radionuclides toxicity along with their activity in the environment since different radionuclides have different biological effects. This means that a radionuclide present that has a low activity and a high toxicity may have the same biological effect as a radionuclide present with a high activity and a low toxicity. To assess the toxicity of each radionuclide, the radiation dose based tier I action levels for the residential exposure scenario will be used. The tier I, residential action levels are the radionuclide activities in soil that would impart a radiation dose of 85 millirem to a residential receptor for each radionuclide.

A "Sum of Ratios" method will be used to assess which radionuclides within Rocky Flats plutonium are the major contributors to radiation dose over the 1,000 year assessment period. For a full explanation of this method with an example, see Section 5, "Action Level Development." For this appendix, it can be stated that the radionuclide activity in soil will be divided by the tier I, residential action level. This ratio actually represents the fraction of the radiation dose (85 millirem) imparted to a hypothetical resident at the tier I action level. Therefore, when the ratio from each radionuclide is summed, this sum is the fraction of the tier I, residential action level contributed by all radionuclides present. Table 1 gives the ratio of the soil concentration to the action level for each radionuclide in Rocky Flats plutonium along with the sum of these ratios.

Table 1 also contains the percent contribution to radiation dose from each radionuclide in Rocky Flats plutonium. The percent contribution was found by dividing the ratio of the soil concentration to the action level for a given radionuclide by the sum of all radionuclide ratios within the year of interest. The percent contribution to radiation dose is important since it shows which radionuclides are significant on a human health basis.

Rocky Flats Plutonium Assessment Requirements

In order to ascertain the relative importance of each radionuclide in the Rocky Flats plutonium mix over time, it is necessary to examine the percent contribution to radiation dose of each radionuclide. Also, the percent contribution to radiation dose from a number of radionuclides could be summed for this assessment.

At the time that Rocky Flats plutonium was placed in the environment (Time=0), the sum of the radiation dose contributions from Pu-239, Pu-240, Pu-241 and Am-241 is 98.9%. The contribution to radiation dose from Pu-238 and Pu-242 at this initial time is only 1.1%. Since the contribution to the total radiation dose from Pu-238 and Pu-242 is so small, it is not necessary to assess Pu-238 and Pu-242 in the environment as part of the Rocky Flats plutonium mix on a human health basis. The percent contribution to radiation dose from Pu-238 and Pu-242 over the 1,000 year assessment period steadily decreases. This further supports the premise that the contribution to radiation dose from these radionuclides is insignificant and that these radionuclides do not need to be assessed over the 1,000 year assessment period.

As time proceeds from the initial placement of Rocky Flats plutonium in the environment, the activity of Am-241 increases and the activity of Pu-241 decreases. This means that the relative contribution to radiation dose from Pu-241 decreases over time and that the relative contribution to radiation dose from Am-241 increases over time. 40 years after placement of the Rocky Flats plutonium in the soil, the percent contribution to radiation dose from Pu-241 has dropped from 17.9% to 2.0%. By year

60, the percent contribution from Pu-241 has been reduced to 0.8% and continues to decline after that. Since Rocky Flats plutonium placed in the environment is currently approaching the 40 year mark and is anticipated to be under DOE control well into the next century, it is also not necessary to assess Pu-241 in the environment as part of the Rocky Flats plutonium mix on a human health basis.

The percent contribution to radiation dose from Am-241 increases from year 0 to around year 80 and then decreases as the 1,000 year mark approaches. Therefore, Am-241 contributes a significant percentage of radiation dose over the 1,000 year period of interest. The percent contribution to radiation dose from the sum of Pu-239, Pu-240 and Am-241 needs to be examined since all of these isotopes contribute significantly to radiation dose. At year 40, 97.3% of the radiation dose is contributed by Pu-239, Pu-240 and Am-241. This percentage increases to 98.7% at year 60 and keeps increasing past that point. Due to this, it is necessary to assess the Pu-239, Pu-240 and Am-241 components of Rocky Flats plutonium in the environment in order to assure that human health is protected.

References

DOE, 1980 - Final Environmental Impact Statement, Rocky Flats Plant Site, Golden, CO, US
Department of Energy, DOE/EIS-0064, April 1980

Tables

Table D1 - Comparison of Plutonium Activity With Action Levels Over Time

**TABLE D1
COMPARISON OF PLUTONIUM ACTIVITY
WITH ACTION LEVELS OVER TIME**

PLUTONIUM ACTIVITY & ACTION LEVEL COMPARISON

Radionuclide	Tier I Residential Action Level (pCi/gram)	Time = 0 Years			Time = 20 Years			Time = 40 Years		
		Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)
Plutonium-238	1529	1.7E-3	1.1E-6	1.1	1.5E-3	9.5E-7	0.7	1.2E-3	8.1E-7	0.6
Plutonium-239	1429	5.8E-2	4.1E-5	38.8	5.8E-2	4.1E-5	32.1	5.8E-2	4.1E-5	30.5
Plutonium-240	1432	1.3E-2	9.1E-6	8.7	1.3E-2	9.1E-6	7.2	1.3E-2	9.0E-6	8.8
Plutonium-241	18830	3.7E-1	1.9E-5	17.9	1.4E-1	7.1E-6	5.6	5.4E-2	2.7E-6	2.0
Plutonium-242	1506	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0
Americium-241	215	7.5E-3	3.5E-5	33.8	1.5E-2	6.9E-5	54.4	1.7E-2	8.0E-5	60.1
TOTAL			1.0E-4	100.0		1.3E-4	100.0		1.3E-4	100.0
		% (Pu-239+Pu-240+Am241)		81.1	% (Pu-239+Pu-240+Am241)		83.6	% (Pu-239+Pu-240+Am241)		87.3

Radionuclide	Tier I Residential Action Level (pCi/gram)	Time = 60 Years			Time = 80 Years			Time = 100 Years		
		Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)
Plutonium-238	1529	1.1E-3	6.9E-7	0.5	9.0E-4	5.9E-7	0.4	7.7E-4	5.0E-7	0.4
Plutonium-239	1429	5.8E-2	4.1E-5	30.3	5.8E-2	4.1E-5	30.6	5.8E-2	4.0E-5	31.1
Plutonium-240	1432	1.3E-2	9.0E-6	6.7	1.3E-2	9.0E-6	6.8	1.3E-2	9.0E-6	8.9
Plutonium-241	18830	2.1E-2	1.0E-6	0.8	7.9E-3	4.0E-7	0.3	3.0E-3	1.5E-7	0.1
Plutonium-242	1506	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0
Americium-241	215	1.8E-2	8.2E-5	61.6	1.8E-2	8.2E-5	61.8	1.7E-2	8.0E-5	61.5
TOTAL			1.3E-4	100.0		1.3E-4	100.0		1.3E-4	100.0
		% (Pu-239+Pu-240+Am241)		98.7	% (Pu-239+Pu-240+Am241)		99.3	% (Pu-239+Pu-240+Am241)		99.5

Radionuclide	Tier I Residential Action Level (pCi/gram)	Time = 200 Years			Time = 500 Years			Time = 1000 Years		
		Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)	Rocky Flats Pu Activity (pCi/gram)	Rocky Flats Pu Activity to Action Level Ratio	Rocky Flats Pu Contribution to Radiation Dose (Percent)
Plutonium-238	1529	3.5E-4	2.3E-7	0.2	3.3E-5	2.1E-8	0.0	6.3E-7	4.1E-10	0.0
Plutonium-239	1429	5.8E-2	4.0E-5	34.3	5.7E-2	4.0E-5	44.0	5.8E-2	3.9E-5	59.2
Plutonium-240	1432	1.3E-2	8.9E-6	7.5	1.2E-2	8.6E-6	9.4	1.2E-2	8.2E-6	12.3
Plutonium-241	18830	2.4E-5	1.2E-9	0.0	1.3E-11	6.6E-16	0.0	4.7E-22	2.3E-26	0.0
Plutonium-242	1506	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0	1.2E-6	8.0E-10	0.0
Americium-241	215	1.5E-2	6.8E-5	58.0	9.1E-3	4.2E-5	48.5	4.1E-3	1.9E-5	28.5
TOTAL			1.2E-4	100.0		9.1E-5	100.0		6.7E-5	100.0
		% (Pu-239+Pu-240+Am241)		99.8	% (Pu-239+Pu-240+Am241)		100.0	% (Pu-239+Pu-240+Am241)		100.0

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