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Title: Biota Dose Assessment at LANL for 2011

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Introduction

As required by DOE Order 458.1, and as described in LANL 2009a and LANL 2009b, we use DOE-STD-1153-2002 (DOE 2002) and RESRAD-Biota to demonstrate compliance with the DOE dose limits for biota. The first comprehensive biota-dose assessment was described in McNaughton 2005. This assessment concluded that there were no locations near Los Alamos where the DOE biota dose limits were exceeded. Annually, we consider new measurements and update the biota dose assessment as needed. During 2011, the most significant changes resulted from the Las Conchas fire and subsequent storm-water runoff.

Overview

Beginning with the Manhattan Project, the earliest work with radioactive material was located in what is now the center of Los Alamos townsite, and some of those materials were released into the environment or disposed of as waste. These radioactive materials have been extensively studied and assessed in many reports during the past 60 years. The assessments consider many activities relevant to dose assessment, such as adventurous children who burrow into and eat the soil, as well as the activities of pets and wildlife. Even for the most extreme scenarios, the doses are less than a few mrem per year, well below the DOE limit for the public, and four orders of magnitude below the DOE limit to terrestrial animals, which is 0.1 rad per day.

Locations that pose even a very small risk to humans or pets are fenced, locked, and posted as controlled areas. However, it is recognized that biota such as plants, birds, mice, and worms live in these controlled areas. The DOE standard is intended to protect these biota.

Contaminated sites in and near Los Alamos consist of areas known as solid waste management units (SWMU) and areas of concern (AoC) that have been identified and studied extensively in many reports. LA-UR-90-4300 lists these locations, and many subsequent reports provide extensive details and assessments. Between these areas, the levels of detectable radioactive materials are many orders of magnitude smaller. Because they are not a focus of concern, the areas outside of SWMUs and AoCs have not been as extensively studied or sampled.

The highest concentrations of radioactive materials resulting from historic LANL operations are buried in material disposal areas (MDAs) such as MDA A, B, C, G, T, etc. Much of this material is sealed in containers that are not accessible to biota (McNaughton 2005). In some cases, it is buried below the reach of tree roots or burrowing animals, and in some cases it is encased or embedded in concrete.

Of particular relevance to the present report, the hills to the west of LANL, where the Las Conchas fire burned, are not contaminated with LANL-derived substances. The radioactivity in these hills consists of naturally occurring radioactive material (NORM) and global fallout.

Background

According to DOE-STD-1153-2002 (DOE 2002), "background levels may be taken into account when determining compliance of DOE activities with the biota dose limits." DOE 2002 continues "For example, this may be a consideration for the two isotopes of radium" (Module 1 Section 6.1.2.)

Natural uranium and its decay products such as radium are distinguished from the uranium used at LANL by methods such as process knowledge, isotopic analysis, and by the presence of Pb-214 and Bi-214 in natural uranium. Pb-214 and Bi-214 are removed from LANL uranium during the refinement process and remain with the mill tailings, together with their parents, Th-230 and Ra-226. The Pb-214 and Bi-214 decay products grow in with a half-life of 75,000 years so they are undetectable in the refined uranium used at many DOE sites.

In storm water, global-fallout radionuclides are likely to have higher concentrations than average for the following reasons.

- Fallout was deposited on the surface and usually remains near the surface, so it is preferentially swept into storm water.
- Fallout is mostly brought to earth by rain and snow fall, which are often higher than average in the foothills west of LANL.
- Fallout often washes off rocky or impermeable slopes and accumulates in low-lying areas and in the path of storm-water runoff.
- Concentrations in ash are especially high because most fallout materials are refractory.

Global fallout may be distinguished from local contamination by methods such as process knowledge, isotopic analysis, and by the ratios of radionuclides, especially Pu-239,40, Am-241, and Cs-137.

Pre-screening

Each year, there are more than a million new measurements at thousands of locations, as listed in Table 1-2 of the annual Environmental Reports (LANL 2011 and 2012.) It is impractical to run RESRAD-Biota for every location, so we begin with pre-screening, as described in the Environmental Reports, to select locations that could approach the DOE limits. Locations with significant concentrations are investigated in more detail.

Most of the results reported in the 2011 Environmental Report (LANL 2012) are similar to previous years and are far below screening levels. As reported in Chapter 6, the most significant change was in storm water, and resulted from the Las Conchas fire.

Las Conchas Fire

The Las Conchas fire is discussed in the Environmental Report for 2011 (LANL 2012) and additional reports referenced therein. Briefly, it burned during late June and early July immediately before the seasonal rainstorms that began in July. The burned areas on LANL property included one or two acres along the southern edge of technical area TA-49, and the area to the west of State Road 501, which runs close to the western boundary of LANL.

The ash from any fire contains concentrated, naturally-occurring radioactive material (NORM) such as potassium-40, uranium, thorium, and their decay products. It also contains concentrated radioactive material from global fallout: americium, plutonium, cesium-137, and strontium-90. Near Los Alamos, the concentrations of potassium-40, uranium, and thorium are higher than the regional average because of the geology (McNaughton 2008.) Near the mountains, the concentrations of global fallout are higher than the regional average because fallout is brought to earth by "wet-deposition," by rain and snowfall. In the hills where the fire burned, rain and snowfall are higher than the regional average. Most of the fallout remains near the surface, for example on forest litter, and is further concentrated in the ash that remains after the fire. Many of the elements are refractory, which means they remain with the ash. Thus, the concentrations of naturally-occurring radioactive materials and fallout radionuclides in the ash are much higher than the regional averages.

Storm Water

After a fire, surface vegetation is replaced by ash so the material on the surface is easily mobilized during a rain storm. Consequently, the storm-water runoff from burned areas is laden with sediment and ash. Furthermore, in burned areas the surface soil is relatively impermeable, which results in increased storm-water runoff. Following the Las Conchas fire, the concentrations of radioactive materials in unfiltered storm-water samples at some locations exceeded LANL screening levels for a short time, typically less than an hour.

Most of these locations are not aquatic or riparian habitats because the flow is ephemeral. For these locations, we consider terrestrial plants and animals. Even locations with perennial flow do not support a typical riparian habitat because there is almost no aquatic life for a riparian animal to eat. For example, there are no fish in any of the streams that flow through LANL. Thus, many of the generic bioaccumulation factors in DOE 2002 and RESRAD-Biota do not apply at Los Alamos. Site-representative factors are discussed in McNaughton et al. 2013.

The aquatic life that does exist at some locations consists mostly of insect larvae. In this case there is not enough biota mass to measure the concentration ratios and deduce site-specific bioaccumulation factors, so we rely on models. Large bioaccumulation factors typically occur where there is a complex food chain, and they depend on the availability of essential nutrients. For example, cesium bioaccumulates in locations that are deficient in potassium, and strontium or radium bio-accumulate in locations that are deficient in calcium. In contrast, the LANL environment is rich in potassium and calcium (McNaughton 2008, 2013.) Cesium and strontium have been studied in the LANL environment (Salazar 2006) though radium has not.

Water Canyon

Consider the data for the storm water at Water Canyon near State Road 501 (RA110402.) Following a rainstorm on August 3, 2011, the suspended sediment concentration was high: 200 g/L. With this high sediment load, the analytical laboratory had difficulty obtaining a homogeneous mixture, extracting uniform aliquots, and dissolving all of the sediment, so the data are not internally consistent. For example, total uranium is reported as 31.7 micro-grams/L, which is not consistent with the isotopic results listed below. The isotopic results indicate naturally occurring uranium, together with plutonium-239, strontium-90, and cesium-137 from global fallout in ash.

The RESRAD-Biota "Aquatic BCG Report for Level 1" (Table 1) lists a "Sum of Total Ratio" equal to 5.95.

Aquatic BCG Report for Level 1

Title: Water Canyon near S.R. 501, Aug 3, 2011

Sum of Total Ratio: **5.95E+00**

Sum of Water Ratio: **5.92E+00**

Sum of Sediment Ratio: 2.91E-02

Table 1. Aquatic BCG Report for Level 1 at Water Canyon near State Road 501 on Aug 3, 2011

Aquatic Animal								
	Water				Sediment			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	1.02	4.38E+02	2.33E-03	Yes	5.1	7.04E+05	7.25E-06	No
Cs-137	80.7	1.05E+03	7.71E-02	No	40.35	4.93E+04	8.19E-04	No
Pu-239	4.4	1.87E+02	2.36E-02	Yes	8.8	7.04E+06	1.25E-06	No
Sr-90	27.1	5.39E+04	5.03E-04	No	0.813	3.52E+04	2.31E-05	No
U-234	398	2.02E+02	1.97E+00	Yes	19.9	3.08E+06	6.46E-06	No
U-235	19	2.17E+02	8.74E-02	Yes	0.95	1.05E+05	9.06E-06	No
U-238	412	2.23E+02	1.84E+00	Yes	20.6	4.28E+04	4.81E-04	No
Summed	-	-	4.01E+00	-	-	-	1.35E-03	-

Riparian Animal								
	Water				Sediment			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	1.02	1.46E+03	6.97E-04	No	5.1	5.15E+03	9.90E-04	Yes
Cs-137	80.7	4.26E+01	1.89E+00	Yes	40.35	3.12E+03	1.29E-02	Yes
Pu-239	4.4	6.22E+02	7.08E-03	No	8.8	5.86E+03	1.50E-03	Yes
Sr-90	27.1	2.78E+02	9.73E-02	Yes	0.813	5.82E+02	1.40E-03	Yes
U-234	398	6.83E+02	5.83E-01	No	19.9	5.27E+03	3.78E-03	Yes
U-235	19	7.36E+02	2.58E-02	No	0.95	3.73E+03	2.55E-04	Yes
U-238	412	7.56E+02	5.45E-01	No	20.6	2.49E+03	8.28E-03	Yes
Summed	-	-	3.15E+00	-	-	-	2.91E-02	-

Table 1 continued. Aquatic BCG Report for Level 1 at Water Canyon near State Road 501 on Aug 3, 2011

This “Sum of Total Ratio” triggered a level-2 assessment. For the Level-2 assessment, we entered the Site-specific bioaccumulation factors for Cs-137 and Sr-90, obtained from McNaughton et al., 2013, to obtain the results listed in Table 2, below.

Aquatic Dose Report for Level 2 in rad/d

Title: Water Canyon near S.R. 501, Aug 3, 2011

Aquatic Animal			
Nuclide	**Water**	**Sediment**	**Summed**
Am-241	2.33E-03	7.24E-06	2.33E-03
Cs-137	7.02E-04	8.18E-04	1.52E-03
Pu-239	2.35E-02	1.25E-06	2.35E-02
Sr-90	1.58E-04	2.31E-05	1.81E-04
U-234	1.97E+00	6.46E-06	1.97E+00
U-235	8.73E-02	9.06E-06	8.73E-02
U-238	1.84E+00	4.80E-04	1.84E+00
Summed	3.93E+00	1.35E-03	3.93E+00

Riparian Animal			
Nuclide	**Water**	**Sediment**	**Summed**
Am-241	2.09E-07	2.97E-07	5.06E-07
Cs-137	2.11E-06	3.87E-06	5.98E-06
Pu-239	2.12E-06	4.50E-07	2.57E-06
Sr-90	1.88E-06	4.19E-07	2.30E-06
U-234	1.75E-04	1.13E-06	1.76E-04
U-235	7.73E-06	7.65E-08	7.81E-06
U-238	1.63E-04	2.48E-06	1.66E-04
Summed	3.52E-04	8.72E-06	3.61E-04

Table 2. Aquatic Dose Report for Level 2 in rad/day.

According to the level-2 report (Table 2) the summed dose for aquatic animals, if extended over a 24-hour period, would be 3.93 rad, almost all from natural uranium. These concentrations are typical of any fire.

To confirm this, we calculated the concentration in the suspended solid material by combining the measurement of suspended sediment concentration, 209 g/L, and the U-238 concentration, 448 pCi/L, to calculate the concentration in units of pCi/g, as follows.

(448 pCi/L) ÷ (208 g/L) = 2.15 pCi/g.

This is a typical concentration of natural uranium in soil or sediment near Los Alamos.

The August-3 storm lasted about an hour. There were less than 30 such storms during 2011, each lasting less than 2.5 hours, so storm water runoff is present for less than 30×2.5 = 75 hours per year, which is less than 1% of the 8760 hours in a year. The August-3 storm produced the most runoff and the largest concentrations. Normal base-flow concentrations of radionuclides are less than 0.1% of those listed above. So the average aquatic dose rate for the year is less than 1% of the 3.93 rad/day reported above, i.e., less than 0.0393 rad/day. This is well below the DOE limit of 1 rad/day for aquatic animals.

The terrestrial dose report is shown below. There is no soil contamination near this location so soil concentrations are set to zero.

Terrestrial Dose Report for Level 2 in rad/d

Title: Water Canyon near S.R. 501, Aug 3 2011

Terrestrial Animal			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	5.04E-07	0.00E+00	5.04E-07
Cs-137	1.35E-05	0.00E+00	1.35E-05
Pu-239	2.19E-06	0.00E+00	2.19E-06
Sr-90	4.97E-05	0.00E+00	4.97E-05
U-234	9.83E-05	0.00E+00	9.83E-05
U-235	4.53E-06	0.00E+00	4.53E-06
U-238	1.01E-04	0.00E+00	1.01E-04
Summed	2.70E-04	0.00E+00	2.70E-04

Terrestrial Plant			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	1.45E-09	0.00E+00	1.45E-09
Cs-137	1.64E-06	0.00E+00	1.64E-06
Pu-239	6.24E-10	0.00E+00	6.24E-10
Sr-90	7.69E-07	0.00E+00	7.69E-07
U-234	1.29E-07	0.00E+00	1.29E-07
U-235	1.81E-07	0.00E+00	1.81E-07
U-238	9.61E-06	0.00E+00	9.61E-06
Summed	1.23E-05	0.00E+00	1.23E-05

Table 3. Terrestrial Dose Report for Level 2 in rad/day.

The terrestrial dose rates are much less than the DOE limit of 0.1 rad/day for terrestrial animals and 1 rad/day for plants.

Note that almost all the dose was a result of naturally occurring radioactive material, with a small contribution from global fallout. There is no LANL contamination at or upstream of this location.

Los Alamos Canyon above Low-Head Weir

Flow at the location “Los Alamos above low-head weir” is ephemeral so we run RESRAD-Biota for terrestrial animals and plants. The results are listed in Tables 4 and 5, below.

Terrestrial BCG Report for Level 2

Title: LA above Low-Head Weir, Aug 22, 2011

Sum of Total Ratio: 3.23E-03

Sum of Water Ratio: 3.23E-03

Sum of Soil Ratio: 0.00E+00

Table 4. BCG Report at Los Alamos Canyon above Low-Head Weir for August 22, 2011

Terrestrial Animal								
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.6	2.02E+05	7.72E-05	Yes	0	3.90E+03	0.00E+00	Yes
Pu-238	3.57	1.89E+05	1.89E-05	Yes	0	5.27E+03	0.00E+00	Yes
Pu-239	98.9	2.01E+05	4.93E-04	Yes	0	6.12E+03	0.00E+00	Yes
Sr-90	34.5	5.45E+04	6.33E-04	Yes	0	2.25E+01	0.00E+00	Yes
U-234	398	4.05E+05	9.83E-04	Yes	0	5.14E+03	0.00E+00	Yes
U-235	18.6	4.20E+05	4.43E-05	Yes	0	2.77E+03	0.00E+00	Yes
U-238	400	4.06E+05	9.84E-04	Yes	0	1.58E+03	0.00E+00	Yes
Summed	-	-	3.23E-03	-	-	-	0.00E+00	-

Terrestrial Plant								
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.6	7.05E+08	2.21E-08	No	0	2.16E+04	0.00E+00	No
Pu-238	3.57	3.95E+09	9.05E-10	No	0	1.75E+04	0.00E+00	No
Pu-239	98.9	7.05E+09	1.40E-08	No	0	1.27E+04	0.00E+00	No
Sr-90	34.5	3.52E+07	9.79E-07	No	0	3.58E+03	0.00E+00	No
U-234	398	3.08E+09	1.29E-07	No	0	5.17E+04	0.00E+00	No
U-235	18.6	1.05E+08	1.77E-07	No	0	2.75E+04	0.00E+00	No
U-238	400	4.29E+07	9.33E-06	No	0	1.57E+04	0.00E+00	No
Summed	-	-	1.06E-05	-	-	-	0.00E+00	-

Table 4 continued. BCG Report at Los Alamos Canyon above Low-Head Weir for August 22, 2011

Terrestrial Dose Report for Level 2 in rad/d

Title: LA above Low-Head Weir, Aug 22, 2011

Terrestrial Animal			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	7.72E-06	0.00E+00	7.72E-06
Pu-238	1.89E-06	0.00E+00	1.89E-06
Pu-239	4.93E-05	0.00E+00	4.93E-05
Sr-90	6.33E-05	0.00E+00	6.33E-05
U-234	9.83E-05	0.00E+00	9.83E-05
U-235	4.43E-06	0.00E+00	4.43E-06
U-238	9.84E-05	0.00E+00	9.84E-05
Summed	3.23E-04	0.00E+00	3.23E-04

Terrestrial Plant			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	2.21E-08	0.00E+00	2.21E-08
Pu-238	9.05E-10	0.00E+00	9.05E-10
Pu-239	1.40E-08	0.00E+00	1.40E-08
Sr-90	9.79E-07	0.00E+00	9.79E-07
U-234	1.29E-07	0.00E+00	1.29E-07
U-235	1.77E-07	0.00E+00	1.77E-07
U-238	9.33E-06	0.00E+00	9.33E-06
Summed	1.06E-05	0.00E+00	1.06E-05

Table 5. Dose Report at Los Alamos Canyon above Low-Head Weir for August 22, 2011

The results are well below the DOE limits of 0.1 rad/day for terrestrial animals and 1 rad/day for plants.

Los Alamos Canyon above Rio Grande

The flow at the location “Los Alamos above Rio Grande” is ephemeral so we run RESRAD-Biota for terrestrial animals and plants. The results (Tables 6 and 7) show that the dose rate is well below the DOE limits, even without time averaging. Putting it another way, the acute dose is below the limit, so according to DOE 2002 there is no need to calculate the average chronic dose.

Table 6. BCG Report at Los Alamos Canyon above Rio Grande for August 22, 2011

Terrestrial BCG Report for Level 2

Title: LA above Rio Grande Aug 22, 2011

Sum of Total Ratio: 1.84E-02

Sum of Water Ratio: 1.84E-02

Sum of Soil Ratio: 0.00E+00

	Terrestrial Animal							
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.7	2.02E+05	7.76E-05	Yes	0	3.90E+03	0.00E+00	Yes
Cs-137	158	5.99E+05	2.64E-04	Yes	0	2.08E+01	0.00E+00	Yes
Pu-238	3.09	1.89E+05	1.63E-05	Yes	0	5.27E+03	0.00E+00	Yes
Pu-239	46.3	2.01E+05	2.31E-04	Yes	0	6.12E+03	0.00E+00	Yes
Ra-226	54.9	8.11E+03	6.77E-03	Yes	0	5.06E+01	0.00E+00	Yes
Ra-228	54.2	6.76E+03	8.02E-03	Yes	0	4.38E+01	0.00E+00	Yes
Sr-90	46.6	5.45E+04	8.55E-04	Yes	0	2.25E+01	0.00E+00	Yes
U-234	416	4.05E+05	1.03E-03	Yes	0	5.14E+03	0.00E+00	Yes
U-235	27.3	4.20E+05	6.51E-05	Yes	0	2.77E+03	0.00E+00	Yes
U-238	448	4.06E+05	1.10E-03	Yes	0	1.58E+03	0.00E+00	Yes
Summed	-	-	1.84E-02	-	-	-	0.00E+00	-

	Terrestrial Plant							
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.7	7.05E+08	2.23E-08	No	0	2.16E+04	0.00E+00	No
Cs-137	158	4.93E+07	3.20E-06	No	0	2.21E+03	0.00E+00	No
Pu-238	3.09	3.95E+09	7.83E-10	No	0	1.75E+04	0.00E+00	No
Pu-239	46.3	7.05E+09	6.57E-09	No	0	1.27E+04	0.00E+00	No
Ra-226	54.9	1.45E+07	3.79E-06	No	0	2.88E+02	0.00E+00	No
Ra-228	54.2	2.90E+07	1.87E-06	No	0	2.45E+02	0.00E+00	No
Sr-90	46.6	3.52E+07	1.32E-06	No	0	3.58E+03	0.00E+00	No
U-234	416	3.08E+09	1.35E-07	No	0	5.17E+04	0.00E+00	No
U-235	27.3	1.05E+08	2.60E-07	No	0	2.75E+04	0.00E+00	No
U-238	448	4.29E+07	1.04E-05	No	0	1.57E+04	0.00E+00	No
Summed	-	-	2.11E-05	-	-	-	0.00E+00	-

Table 6 continued. BCG Report at Los Alamos Canyon above Rio Grande for August 22, 2011

Terrestrial Dose Report for Level 2 in rad/d

Title: LA above Rio Grande Aug 22, 2011

Terrestrial Animal			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	7.76E-06	0.00E+00	7.76E-06
Cs-137	2.64E-05	0.00E+00	2.64E-05
Pu-238	1.63E-06	0.00E+00	1.63E-06
Pu-239	2.31E-05	0.00E+00	2.31E-05
Ra-226	6.77E-04	0.00E+00	6.77E-04
Ra-228	8.02E-04	0.00E+00	8.02E-04
Sr-90	8.55E-05	0.00E+00	8.55E-05
U-234	1.03E-04	0.00E+00	1.03E-04
U-235	6.51E-06	0.00E+00	6.51E-06
U-238	1.10E-04	0.00E+00	1.10E-04
Summed	1.84E-03	0.00E+00	1.84E-03

Terrestrial Plant			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	2.23E-08	0.00E+00	2.23E-08
Cs-137	3.20E-06	0.00E+00	3.20E-06
Pu-238	7.83E-10	0.00E+00	7.83E-10
Pu-239	6.57E-09	0.00E+00	6.57E-09
Ra-226	3.79E-06	0.00E+00	3.79E-06
Ra-228	1.87E-06	0.00E+00	1.87E-06
Sr-90	1.32E-06	0.00E+00	1.32E-06
U-234	1.35E-07	0.00E+00	1.35E-07
U-235	2.60E-07	0.00E+00	2.60E-07
U-238	1.04E-05	0.00E+00	1.04E-05
Summed	2.11E-05	0.00E+00	2.11E-05

Table 7. Dose Report at Los Alamos Canyon above Rio Grande for August 22, 2011

The results are well below the DOE limits of 0.1 rad/day for terrestrial animals and 1 rad/day for plants.

Pajarito Canyon

The flow at the location “E240 Pajarito below SR 501” is ephemeral so we run RESRAD-Biota for terrestrial animals and plants and report the results in Tables 8 and 9, below.

Terrestrial BCG Report for Level 2

Title: E240 Pajarito below SR 502, Aug 5

Sum of Total Ratio: 1.94E-03

Sum of Water Ratio: 1.68E-03

Sum of Soil Ratio: 2.56E-04

Table 8. BCG Report at E240 Pajarito Canyon below SR 501 for August 5, 2011

	Terrestrial Animal							
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.2	2.02E+05	7.52E-05	Yes	1	3.90E+03	2.56E-04	Yes
Cs-137	57.3	5.99E+05	9.56E-05	Yes	0	2.08E+01	0.00E+00	Yes
Pu-239	32.8	2.01E+05	1.63E-04	Yes	0	6.12E+03	0.00E+00	Yes
Sr-90	20.8	5.45E+04	3.82E-04	Yes	0	2.25E+01	0.00E+00	Yes
U-234	176	4.05E+05	4.35E-04	Yes	0	5.14E+03	0.00E+00	Yes
U-235	9.2	4.20E+05	2.19E-05	Yes	0	2.77E+03	0.00E+00	Yes
U-238	206	4.06E+05	5.07E-04	Yes	0	1.58E+03	0.00E+00	Yes
Summed	-	-	1.68E-03	-	-	-	2.56E-04	-

	Terrestrial Plant							
	Water				Soil			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Am-241	15.2	7.05E+08	2.16E-08	No	1	2.16E+04	4.64E-05	No
Cs-137	57.3	4.93E+07	1.16E-06	No	0	2.21E+03	0.00E+00	No
Pu-239	32.8	7.05E+09	4.65E-09	No	0	1.27E+04	0.00E+00	No
Sr-90	20.8	3.52E+07	5.90E-07	No	0	3.58E+03	0.00E+00	No
U-234	176	3.08E+09	5.71E-08	No	0	5.17E+04	0.00E+00	No
U-235	9.2	1.05E+08	8.78E-08	No	0	2.75E+04	0.00E+00	No
U-238	206	4.29E+07	4.80E-06	No	0	1.57E+04	0.00E+00	No
Summed	-	-	6.73E-06	-	-	-	4.64E-05	-

Table 8 continued. BCG Report at E240 Pajarito Canyon below SR 501 for August 5, 2011

Terrestrial Dose Report for Level 2 in rad/d

Title: E240 Pajarito below 502, Aug 5, 2011

Terrestrial Animal			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	7.52E-06	2.56E-05	3.32E-05
Cs-137	9.56E-06	0.00E+00	9.56E-06
Pu-239	1.63E-05	0.00E+00	1.63E-05
Sr-90	3.82E-05	0.00E+00	3.82E-05
U-234	4.35E-05	0.00E+00	4.35E-05
U-235	2.19E-06	0.00E+00	2.19E-06
U-238	5.07E-05	0.00E+00	5.07E-05
Summed	1.68E-04	2.56E-05	1.94E-04

Terrestrial Plant			
Nuclide	**Water**	**Soil**	**Summed**
Am-241	2.16E-08	4.64E-05	4.64E-05
Cs-137	1.16E-06	0.00E+00	1.16E-06
Pu-239	4.65E-09	0.00E+00	4.65E-09
Sr-90	5.90E-07	0.00E+00	5.90E-07
U-234	5.71E-08	0.00E+00	5.71E-08
U-235	8.78E-08	0.00E+00	8.78E-08
U-238	4.80E-06	0.00E+00	4.80E-06
Summed	6.73E-06	4.64E-05	5.31E-05

Table 9. Dose Report at E240 Pajarito below SR 501 for August 5, 2011

The results are well below the DOE limits of 0.1 rad/day for terrestrial animals and 1 rad/day for plants.

These Tables demonstrates compliance with DOE Order 5400.5 and DOE Order 458.1. Most of the biota dose is from natural uranium in suspended sediment, so as suggested by DOE 2002, we continue with a consideration of naturally-occurring radioactive material, NORM.

NORM

The perennial reaches of Water Canyon are near State Road 501, upstream of LANL influence, so the radioactive materials consists of NORM and global fallout. In this case, the DOE Standard, DOE 2002, asks for an assessment to consider possible impacts on biota from all NORM. Because the measurements were focused on compliance, they focused on radionuclides such as uranium-238 rather than its decay products such as radium-226. Before it is delivered to Los Alamos, LANL uranium is

chemically refined to remove other chemical elements such as radium. However, because the sediment in Water canyon was NORM, it included radium-226 in secular equilibrium with uranium-238 and uranium-234. This was not measured but its presence is inferred.

Radium-226

If we include radium-226, the level-2 assessment of aquatic dose increases by a factor of 16 to an annual average of 0.6 rad/day. This dose is below the DOE limit for aquatic animals. Nevertheless, it is interesting to consider why the inclusion of radium-226 makes such a large difference, whether this is realistic, and whether the acute dose might be harmful.

The reason is that radium is chemically similar to calcium so it bioaccumulates under some conditions, and the DOE standard assumes the worst-case conditions. This raises the question: are these conditions applicable?

Radium is absorbed into living cells through the same biological process that absorbs calcium (IAEA 1984.) Most eukaryotes have some ability to discriminate between radium and calcium, so the absorption of radium depends on the concentration of calcium in the underlying media: soil, sediment, or water. The highest bioaccumulation occurs when the calcium concentrations are low. In the case of the storm water considered above, calcium concentrations were high, 1.75 g/L, so bioaccumulation is low.

Strontium is also chemically similar to calcium, and strontium is also absorbed when calcium concentrations are low. This possibility was studied and reported in McNaughton et al. 2013 and Salazar 2006, with the conclusion that the plant-to-soil concentration ratio for strontium is approximately unity.

This raises the question of whether the radium in suspended sediment bioaccumulates in the same way as radium in solution. There are locations in New Mexico and in the world where the concentrations of natural uranium are much higher than they are near Los Alamos. At these locations, is the suspended sediment harmful to biota?

In the case of storm water within LANL, these questions are academic. They may be more relevant in streams and rivers containing fish, such as the Rio Grande. It would be difficult to measure radium in the biota of Water Canyon because it would be difficult to collect enough biota mass to measure. It would be easier to measure radium in fish taken from the Rio Grande. We recommend that the radium concentration ratio should be measured in future years.

Conclusion

- The biota doses at LANL are well below the DOE limits.
- It would be interesting to measure radium-226 bioaccumulation factor in the Rio Grande or other rivers with high concentrations of natural uranium.

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