UPDATED CALCULATION OF THE INHALATION DOSE FROM THE CERRO GRANDE FIRE BASED ON FINAL AIR DATA

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INTRODUCTION

In the aftermath of the Cerro Grande fire, which occurred during May, 2000, there was considerable interest in describing the potential radiological impacts of the fire itself and of any radionuclides of Los Alamos National Laboratory (LANL) origin that may have been dispersed during the fire. A preliminary dose assessment was prepared to calculate the inhalation dose received by fire workers or members of the public during the fire (Kraig et.al 2000). At the time that study was completed, only preliminary air monitoring data were available. The current report describes recalculations based on final air monitoring data.

In the original calculation, two doses were calculated; to the hypothetical maximally exposed firemen or volunteer who was working actively in the Los Alamos area throughout the worst of the burn duration, and to the maximally exposed member of the public outside Los Alamos. Those calculations are updated here and a third is added; to a fireman or other worker in the vicinity of AIRNET (LANL's ambient air monitoring network) Station #23 in Mortandad Canyon where elevated levels of LANL-derived airborne uranium occurred during the peak of the fire.

The data for the inhalation calculation were collected by the AIRNET system run by ESH-17. A summary of the completeness of data collection for each AIRNET station is included in the ESH-17 web site: http://www.air-quality.lanl.gov/CerroGrandeFire/StaRunTime.htm. AIRNET station #6, which had the highest concentrations of the primary dose-causing radionuclides in the Los Alamos Town-site during the fire, had 100 % data completeness for that period. Data used in the original calculation were preliminary and some changes have occurred in the data set since then. A modified process for including "blank" subtractions from the analytical counts resulted in slightly different concentration values in some cases. Additionally, since the first calculations, ESH-17 determined that some of the earlier reported uncertainty values were not consistently reported as equivalent to two standard deviations. It is important to note that the uncertainties propagated through the calculations below are analytical laboratory uncertainties, primarily counting uncertainty. The uncertainty associated with flow measurements in the field and those associated with time- and location-varying concentrations are not quantified.

METHODS

The radiological dose calculations presented here were based on air monitoring data available as of December 2000 that were collected by the LANL AIRNET system during the Cerro Grande fire. In addition to the analyses performed routinely for uranium isotopes, plutonium isotopes, ^{241}Am, and tritium, some of the samples taken during the

fire were analyzed for ^{210}Po and ^{210}Pb. Lead and polonium were evaluated because of the likelihood that increases in gross alpha and gross beta activity during the fire may have resulted from increased atmospheric suspension of these and other radionuclides in the natural ^{222}Rn decay series. As radon gas decays in the atmosphere, its decay products attach to particles in the air, many of which deposit on plants and the soil. Because most of these particles are attached to vegetation or soil, most are not normally seen in our air sampling results. It appears that the heat and turbulence associated with the fire were very effective at stripping radioactive elements from the surfaces of vegetation and soil, as well as incinerating the vegetation and soil on which the radionuclides were located. These products of radon decay became airborne and probably caused most of the large increases in alpha and beta air concentrations during the Cerro Grande fire.

To calculate radiological dose from air contaminants, air concentrations at the location of the hypothetical receptor, the duration that these concentrations were experienced, and the breathing rate during that time must be quantified or assumed. Air concentrations derived from air sampling during the fire primarily between May 9th and May 13th were used. These samples provided concentrations of ^{210}Po, ^{210}Pb, ^{238}Pu, $^{239\&240}$Pu, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, and ^{3}H at selected locations around LANL and Los Alamos County.

The dose that is calculated here is the committed effective dose equivalent (CEDE), which is the dose quantity used by federal and state agencies. This CEDE is the dose received during the 50 years following the inhalation of radionuclides into the body.

Maximally Exposed Person Within Los Alamos Area

These calculations considered the dose contributions from naturally occurring radionuclides, such as uranium and those in the radon decay chain, and from potentially LANL-derived radionuclides including plutonium, uranium, and americium. Measured concentrations of radionuclides in the natural ^{222}Rn decay series were approximately 1000 times greater than those of potential LANL origin. Samples of uranium isotopes in areas of public access indicate that only natural uranium was seen in the air and therefore uranium was not included in the LANL contribution but was included in the contribution from natural radionuclides.

The greatest measured radionuclide concentrations that occurred in public areas were in the western area of Los Alamos town site between May 9th and May 11th. After that time, concentrations decreased as the fire center moved north. Based on discussions with officials from the Los Alamos Fire Department, no individual could have been in that area for more than 60 hours during the period from May 8th through May 13th. Doses were calculated assuming that an individual worked in the western area for 60 hours.

Because of the short sampling times during the fire, the uncertainties associated with the plutonium and americium analyses were very large compared to the calculated concentrations. If the uncertainty of a number is larger than the number itself, the number is generally not considered quantitative. For the sake of conservatism regarding potential LANL contributions during the fire, the calculated concentrations for ^{238}Pu, $^{239\&240}$Pu, and ^{241}Am in the Los Alamos area during the peak of the fire were used to calculate a dose. For each non-natural radionuclide (^{238}Pu, $^{239\&240}$Pu, and ^{241}Am), the values at each of 12 AIRNET stations in the Los Alamos area were averaged for the peak fire period. Because of the very large uncertainty of any single concentration value for these radionuclides, averages were used because they are better estimates (with less

uncertainty) of concentrations that may have occurred. Averages for these radionuclides for the three-year period 1997-1999 at these same stations were used to subtract background values for each radionuclide. Total (gross) doses for polonium, lead, and bismuth are reported because background values are not available for AIRNET stations.

LANL-Derived Radionuclides	**Dose[1,2] (mrem)**	**Natural[3] Radionuclides**	**Dose[1,4] (mrem)**
Americium-241	- 0.0028 (0.005)	Polonium-210	0.14 (0.005)
Plutonium-238	0.00053 (0.002)	Lead-210	0.057 (0.011)
Plutonium-239&240	0.0026 (0.004)	Bismuth-210	0.00083 (0.00016)
	0.0003 (0.007)	Uranium-234	0.0043 (0.0040)
		Uranium-235	- 0.0001 (0.0011)
		Uranium-238	0.0043 (0.0038)
			0.2 (0.01)

The doses from three uranium isotopes are shown with the natural radionuclides because the isotopic ratio of ^{238}U to ^{234}U indicates that the airborne uranium was of natural, not LANL, origin. This conclusion is reached by comparing the dose (or activity concentration of) from ^{234}U and ^{238}U, which are about equal in natural uranium. The calculated doses from americium and plutonium show the large uncertainty with extremely small numbers and are not statistically significant. The doses from polonium, lead, and bismuth are statistically significant (because the concentration is much larger than its uncertainty) and represent the increase in airborne concentrations of these natural radon products during the fire. However, these calculations didn't include subtraction of background, normal radon products because no data on pre-fire air concentrations for these radionuclides were available. The actual doses from the radionuclides tabulated above were less than those reported, but, these doses do not include other radionuclides in the ^{222}Rn decay series, which are too short-lived to evaluate in this way. Tritium was not included in this analysis because none of the AIRNET stations showed tritium above background levels during the fire.

To put some perspective on these doses, a person travelling on a two- hour flight in a jet airliner would receive approximately 1 mrem, and people living in the Los Alamos area receive about 360 mrem from natural sources each year. No health effects are expected from the short-term increase in natural radioactivity associated with the Cerro Grande fire. There was no measurable increase in LANL-derived airborne radionuclides in the Los Alamos town-site or residential areas during the fire.

Maximally Exposed Person Outside the Los Alamos Area

Outside of Los Alamos, Espanola had the highest concentrations of gross alpha and gross beta radiation and these occurred between May 8th and May 11th. In fact, the local gross alpha concentrations do not appear to have increased above normal levels other than during this period. The concentrations of individual radionuclides from May 8th to May 11th were used to calculate the dose someone might have received had they been outside throughout that 72-hour period. The results of these dose calculations are

summarized below. Background concentrations (what are normally seen) were not subtracted from the polonium, lead, or bismuth concentrations to make these calculations.

LANL-Derived Radionuclides	**Dose[1,2] (mrem)**	**Natural[3] Radionuclides**	**Dose[1,4] (mrem)**
Americium-241	-0.003 (0.01)	Polonium-210	0.022 (0.001)
Plutonium-238	-0.003 (0.004)	Lead-210	0.030 (0.011)
Plutonium-239&240	-0.001 (0.008)	Bismuth-210	0.00044 (0.00016)
	-0.007 (0.2)	Uranium-234	0.0019 (0.0034)
		Uranium-235	0.0002 (0.003)
		Uranium-238	0.0027 (0.0029)
			0.06 (0.01)

The doses from lead, polonium, and bismuth are quite small, barely above those that would have been experienced had the Cerro Grande fire never happened, and are due to the slight increases in airborne natural radioactive elements. The negative doses for plutonium and americium are obviously meaningless but result from the large uncertainties in these numbers.

As described above, these doses may be compared with the approximately 360 mrem dose received each year from natural background radiation in northern New Mexico, primarily form cosmic radiation and naturally occurring radioactive materials in soil and food. The calculations indicate that the doses are insignificant. No health effects are expected to occur as a result of radiological intakes during the Cerro Grande fire.

Worker Exposed to Elevated Uranium Near AIRNET Station #23, Technical Area #5

The AIRNET Station # 5 showed elevated uranium levels during the sampling period ending May 13th. Significantly, the ^{238}U air concentration was more than double the ^{234}U concentration, indicating a likely LANL source for some of the airborne ^{234}U and ^{238}U. Based on the ambient air measurements and the assumption that depleted uranium from LANL is approximately 30% ^{234}U, by activity, the calculated LANL contribution to the elevated ^{234}U and ^{238}U concentrations at Station #5 were approximately 1,221 and 3,700 aCi m^{-3}, respectively. The doses from these concentrations were calculated to evaluate the LANL contribution to worker doses in that location. A worker was assumed to be breathing these concentrations for 60 hours, even though it is very unlikely that this occurred. The radiological doses from ^{234}U and ^{238}U were determined to be 0.024 (0.001) and 0.067 (0.003) mrem, respectively with the one standard deviation value in parentheses. The doses from ^{235}U would have been much smaller than those from the other two isotopes. These are very small radiological doses and no health effects would be expected from them.

For uranium, toxicological effects should be considered as well as the radiological effects. It is appropriate to compare the concentrations and total intakes of uranium during the fire with standards based on toxicological effects. The total intake of uranium during the assumed 60 hours of exposure was calculated to be 0.002 mg and the average air concentration of total uranium was about 0.00001 mg m^{-3}. The average air

concentration was many orders of magnitude below any published limits for workplace or other exposure. For example, the American Council of Industrial Hygienists has a time-weighted average limit of 0.2 mg m^{-3} for workday exposure to uranium compounds (compiled in the NIOSH Pocket Guide to Chemical Hazards, US Dept, of Health and Human Services 1985). The Agency for Toxic Substances and Disease Registry (ATSDR) developed Minimal Risk Levels (MRLs) to estimate exposure levels that represent minimal non-cancer health risks. For insoluble uranium compounds inhaled for more than a day, their published MRL is 0.008 mg m^{-3} (these are available at site: http://www.atsdr.cdc.gov/mrls.html). Sixty hours of exposure at the MRL air concentration would result in a total intake of 1.2 mg (assuming a breathing rate of 2.5 m^3 h^{-1}. Sixty hours of intake at the concentrations of uranium at AIRNET Station #23 would have resulted in an intake of 0.0017 mg, several orders of magnitude below the MRL. No radiological or toxicological health effects are expected from these potential exposures.

[1] *The values in parentheses equal one standard deviation, in mrem, of the reported numbers.*

[2] *Uranium is not included here because the air sampling results indicate that all sampled uranium was natural in origin.*

[3] *This analysis does not include other natural radionuclides that may have contributed to the dose. Radionuclides from the ^{220}Rn decay series are not included because they are too short lived to be evaluated with the analytical methods we used even though they probably caused some of the increased gross alpha concentrations for samples counted shortly after they were collected. Because of extremely large temporal and spatial variations in the amount of natural uranium present in the atmosphere a value representative of the increase during the fire cannot be calculated. Because of temporal variations, using an historical average at several sites would tend to underestimate the airborne uranium that would be expected during the high winds that coincided with the fire. Additionally, no consistent appropriate background value are available because the areas around, but fairly distant from Los Alamos, which are usually used as background stations for other radionuclides, have higher natural airborne uranium concentrations than the Los Alamos area.*

[4] *Normally, "composite" samples are composited for three months before they are analyzed isotopically. These composite samples represent 12,000 to 14,000 m^3 of air sampled. Typically, plutonium and americium air concentrations are equal to or slightly less than their associated uncertainties. During the Cerro Grande fire, sampler filters were changed out after only about three days and individual samples were sent immediately for isotopic analyses. No filters were composited. These samples represented about 200 m^3 of air. Because the samples represented much smaller air volumes than normal samples, the uncertainties associated with the isotopic analyses of plutonium and americium were more than an order of magnitude larger than our usual uncertainties. Because there was so much more airborne ^{210}Po and ^{210}Pb than plutonium or americium, the uncertainties associated with the Pb and Po were a much smaller fraction of the reported concentration than they were for plutonium and americium. In other words, the polonium and lead data were very significant whereas most of the plutonium and americium values were on the same order of or smaller than their associated uncertainty, and are not considered significant statistically.*

References

US Department of Health and Human Services, NIOSH Pocket Guide to Chemical Hazards, US Dept. of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-210, 1985.

Kraig, D.H., E.S. Gladney, and C.F. Eberhart, Inhalation Dose from the Cerro Grande Fire, LA-UR-00-3941, Los Alamos National Laboratory, August, 2000.