Response to the Government Accountability Project, GAP
LA-UR 08-07159
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Note: this document is intended for the web with links to appendixes, references, and web sites, both internal and external.

The Government Accountability Project, GAP, collected 76 samples from the environment around the Los Alamos National Laboratory (LANL) and measured the radioactivity. Reports on their website http://www.whistleblower.org/ state that some of the radionuclides "are man-made and most likely were generated at the Los Alamos National Laboratory." They conclude that "a broader and more extensive study is needed."

In response, we have broadened our environmental studies to address the specific points raised by the GAP, as follows.

The GAP press release
http://www.whistleblower.org/content/press_detail.cfm?press_id=1083
refers to "elevated and potentially harmful levels of radioactivity." We have examined the GAP data and added to our existing data to investigate the cases identified by the GAP. Our investigations show that:

- more than 99% of the radioactivity and more than 99% of the dose is from natural radioactive material;
- less than 1% of the dose is from global fallout;
- there is a LANL contribution in a few cases within Los Alamos County; in these cases, the dose is much less than 1% of the total; and
- the levels are far below the LANL action levels.

In some cases, the GAP compared the data with background concentrations. The plutonium concentrations are above the global-fallout background in some cases, in particular near the historical plutonium facilities of TA-1 and TA-21, and also downstream of the historical water outfalls from TA-1, TA-21, and TA-45. However, the potential dose is less than 1 mrem/year, which is much less than 1% of that from the natural radioactivity. Click here for more details about natural radioactivity.

In some cases, the GAP compared with a Regional Statistical Reference Level, RSRL. This standard is only applicable to a specific set of conditions. There are many locations and situations where natural radioactivity exceeds the RSRL. These are discussed in the sections titled "Natural Radioactivity," "Global Fallout," (page 5) "Radon," (page 6) and "Other Radioactive Materials" (page 8). As described in Appendix B, especially high concentrations are possible in dust.

In the following paragraphs, we respond specifically to the GAP reports, The first of the GAP findings is as follows (indented.)

"• **Indoor dust samples had higher radiation levels than surrounding soils**:

"One notable sample included an interior dust sample collected from the washroom at the New Mexico Environment Department offices in White Rock, NM. The measured activity from this interior dust sample was the highest of the entire study set.

"Dust from a vacuum bag of Los Alamos's newspaper, the Los Alamos Monitor, yielded one of the highest radiation counts of alpha and beta radiation. The Los Alamos Monitor is located across the street from LANL acre legacy waste site, known as MDA B, which is slated for cleanup, and is east of Technical Area 21, the location of the plutonium facilities."

The statement about the sample from the Los Alamos Monitor is puzzling because the results were about average. The GAP data for this sample are reported as 1 dpm/g alpha and 51 dpm/g beta, which are slightly below the averages of 1.7 dpm/g alpha and 64 dpm/g beta. Out of 76 samples, 33 had less alpha activity, 20 were the same, and 23 had more. Also, 27 samples had less beta activity, 4 were the same, and 45 had more.

In response to the GAP report, we took similar samples from these two locations and sent them to Paragon Analytical Lab., an independent laboratory in Fort Collins. Our findings are as follows.

- More than 99% of the radioactivity in the samples was natural.
- More than 99% of the dose is from natural radioactivity.
- Indoor dust is more radioactive than outdoor soil because of radon decay products.
- The potential doses are typical of indoor locations throughout the western US.

For more details on these investigations, click here .

The second GAP finding was as follows (indented.)

"• **Significant plutonium 239/240 detections were found."**

"Three of the test sites near LANL exceeded state standards for plutonium 239/240. Portrillo Canyon sediment slightly exceeded the reference value. A sample of wood ash from the San Ildefonso Pueblo was double the plutonium reference value."

The "state standard" referred to is the average value for global fallout. Plutonium 239/240 in sediment has been extensively investigated and reported in the LANL environmental surveillance reports. Concentrations are higher than the global-fallout average in many locations downstream of the historical water outfalls. The plutonium south of the Los Alamos Inn is legacy contamination from the 1940s. The potential dose from this plutonium is less than 1 mrem/year, which is less than 1% of the dose from natural background.

The measurement in wood ash was 0.026 ± 0.014 pCi/g, which is not statistically different from the global fallout average near Los Alamos of 0.015 pCi/g. Furthermore,

plutonium and many other substances are concentrated in wood ash. The "reference value" referred to is for soil in conditions similar to the samples reported in Chapter 7 of the LANL Environmental Surveillance Reports and is not appropriate for wood ash. There are many mechanisms by which the global-fallout concentrations are increased above these reference values. For details, click here. Throughout the world, wood ash contains much higher concentrations than the reference values for soil, as stated on page 15 of the GAP report.

> "Most alarming, in downtown Los Alamos, soils in publicly-accessible areas were found to have the highest plutonium values of the entire study sample set – more than two orders of magnitude above the expected value. For example, a soil sample from an area next to the parking lot of the Los Alamos Inn was more than 200 times the state standard.

The "expected value" and the "state standard" are average values for global fallout in soil. The plutonium at this location came from a historical water outfall from TA-1. It has been extensively investigated and documented. It is less than 1% of the risk-based standard and the potential dose is less than 1% of that from natural background.

> "Strontium-90, a man-made radionuclide, was also found at locations over 42 miles away on or near Picuris lands and in the dusts of homes there.

The strontium-90 concentrations measured at these locations are typical of global fallout at high elevations and are far lower than the concentrations routinely measured in ash. In contrast, the concentrations that would result from airborne emissions from LANL are a million times smaller. For details, click here . We conclude that the strontium-90 is the result of global fallout and not from LANL.

Radioactivity near Los Alamos National Laboratory

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Introduction

The Government Accountability Project (GAP) http://www.whistleblower.org/doc/FinalLANLReport.pdf found that "indoor dust samples have higher radiation levels than surrounding soils." They also found plutonium and strontium-90 in samples of soil and dust with higher concentrations than the LANL Regional Statistical Reference Levels (RSRL).
(for RSRL, see the LANL Environmental Surveillance Reports http://www.lanl.gov/environment/all/esr.shtml , specifically: LA-14369-ENV Chapter 7 page 252 http://www.lanl.gov/environment/all/docs/reports/2007ESR_6-9.pdf).

The New Mexico Environment Department Oversight Bureau (NMED/OB) also found concentrations above the RSRL for cesium-137, plutonium, and strontium-90, at a location near Trampas Lake, a high-elevation depression about 40 miles northeast of LANL.

This document addresses the question of how it is possible for high concentrations of radioactive material to occur. Natural radioactivity and global fallout are described and mechanisms that concentrate radioactive materials are discussed. .

Natural Radioactivity

This section describes the types and amounts of natural radioactivity and discusses how and why the concentrations vary by location. In some locations, it is possible to find concentrations much higher than the LANL reference levels (RSRLs), which are based on a limited subset of data.

All soil contains natural radioactive material such as potassium-40, uranium, thorium, and their decay products. Their concentrations within the United States are shown on maps available from the USGS:

http://energy.cr.usgs.gov/radon/usak.gif
http://energy.cr.usgs.gov/radon/usaeu.gif
http://energy.cr.usgs.gov/radon/usaeth.gif .

They are also described in NCRP Report No 94 (NCRP 1987.)

Near Los Alamos, the concentrations of radioactivity in soil are approximately as follows.
natural potassium, ^{40}K: 10-30 pCi/g
total natural uranium, ^{nat}U: 0.5-3 pCi/g
total natural thorium, ^{nat}Th: 0.5 to 3 pCi/g

For more details, see Appendix A, attached.

The concentrations vary from one location to another. For example, the map http://www.lanl.gov/environment/air/maps/terrestrial_exposure_contour_map.pdf shows the terrestrial exposure rate at LANL (DOE 1998.) Notice that the exposure rates from natural radioactivity vary by more than a factor of two, from 8-10 μR/h on the mesa tops to 15-25 μR/h in the canyons toward the east.

The natural terrestrial radiation http://www.lanl.gov/environment/air/maps/terrestrial_exposure_contour_map.pdf results primarily from 10-30 pCi/g of potassium-40, 0.5-3 pCi/g of natural uranium, and 0.5-3 pCi/g of natural thorium (LANL 2001.) (For details, see Appendix A, attached.) These are natural, and are accompanied by decay products such as radium (Ra), radon (Rn), and polonium (Po). Each pCi of uranium is accompanied by about one additional pCi of alpha emitters as well as beta emitters such as protactinium (Pa), while each pCi of thorium is accompanied by about one additional pCi of alpha emitters as well as beta emitters such as actinium, so the total radioactivity in soil ranges from 2 to 12 pCi/g of alpha emitters and from 1 to 6 pCi/g of beta emitters (BEIR-IV 1988, Purtymun 1994, Schlein 1998, NCRP 1988, NCRP 1989, Warren 1997.)

The concentrations of radioactive materials are modified by many processes. For example, natural uranium ore with concentrations in the range of 100-1000 pCi/g (NCRP 1976, NCRP 1984a Report No. 77) can be found in northern New Mexico http://geoinfo.nmt.edu/publications/decisionmakers/2002/dmfg2002_chap1.pdf and http://geoinfo.nmt.edu/faq/mining/Ur_20Dec04.pdf .

Global Fallout

This section describes how global fallout contributes to radioactivity throughout the world and how the concentrations vary.

Global fallout is a legacy of early-stage nuclear weapons testing. According to UNSCEAR 2000 http://www.unscear.org/unscear/en/publications/2000_1.html , above-ground nuclear tests conducted by various countries worldwide resulted in "unrestrained release into the environment of radioactive materials, which were widely dispersed in the atmosphere and deposited everywhere on the Earth's surface" (p. 5). The major radionuclides that remain are those with relatively long half lives, primarily: strontium-90, cesium-137, and plutonium-239.

The UNSCEAR-2000 report and Appendix B of NCRP 1988 Report No. 97 contain detailed descriptions of the dispersion process and the resulting concentrations of radioactive substances. The concentrations in soil depend on latitude, elevation, rainfall, snowfall, the permeability of the soil, and the shape of the terrain. Within Los Alamos county, the average concentrations from fallout are typically about 0.4 pCi/g of strontium-90, 0.5 pCi/g of cesium-137, and 0.015 pCi/g of plutonium, with variations of about a factor of 3 above and below these values. For example, according to ENV-

RCRA-QP-011 Attachment 5, http://int.lanl.gov/training/env-courses/45700/env-rcra-sop-011.pdf , the background concentrations are: 1.31 pCi/g of Strontium-90; 1.65 pCi/g; and 0.054 pCi/g of plutonium-239. (For details refer to Ryti 1998 and Fresquez 1996 LA-13149-MS, Fresquez 1998.)

It is possible to find much larger concentrations, especially at high elevations. For example, data from Colorado State University (Ulsh 2000) show concentrations of as much as 20 pCi/g of cesium-137 at high elevations.

These radioactive materials are also taken up by vegetation and concentrated in ash. They are also concentrated in bowl-shaped areas, especially when surrounded by relatively impermeable hillsides. This is because the rain containing the fallout radionuclides will run off the impermeable slopes and collects in the low-lying areas.

Radon

The GAP report noted that indoor dust contains more radioactivity than outdoor soil. Indoor dust is especially affected by radon and its decay products, which are discussed in this section.

Radon is a decay product of uranium and thorium. It diffuses out of the ground and concentrates in buildings. The radon concentrations depend on the amount of uranium and thorium in the soil, the permeability of the soil, and the ventilation of the buildings. http://www.epa.gov/radon/

The largest concentrations of radioactive material indoors are a result of radon decay products. A close examination of the behavior of these radon decay products shows that they are the cause of the higher radioactivity on indoor dust compared outdoor soil, as noted in the GAP report. http://www.whistleblower.org/doc/FinalLANLReport.pdf

Maps of radon concentrations have been published by the EPA (http://www.epa.gov/radon/zonemap.html .) Generally, concentrations in New Mexico http://www.epa.gov/radon/images/nmexico.gif are higher than the national average because of the higher concentrations of naturally-occurring uranium and thorium in the soil (EPA 1992 402-R-92-011, Marcinowski 1994, Nero 1986, Pawel 2004.)

Measurements near Los Alamos are in progress using alpha-track radon monitors http://rssi.us/shop/index.php?l=product_list&c=3 (Yeager 1994) and Femto-Tech CRM-510 airborne alpha detectors http://www.femto-tech.com/products.asp .

Preliminary results in Los Alamos show radon concentrations that range from 0.2 pCi/L in well-ventilated rooms to about 4 pCi/L in poorly-ventilated offices and warehouses. In some cases, the concentrations exceed the Environmental Protection Agency action level of 4 pCi/L **http://www.epa.gov/radon/** (Manchego 1989.)

Radon decay products are electrically charged and stick to dust particles in the air. Assuming a typical radon concentration of 1 pCi/L and a typical indoor-dust concentration of 20 μg/m^3 the concentration of each of the short-lived radon decay products on the dust is about

$$\frac{1\,\text{pCi}}{\text{L}} \cdot \frac{1000\,\text{L}}{\text{m}^3} \cdot \frac{\text{m}^3}{20\,\mu\text{g}} = 50\,\frac{\text{pCi}}{\mu\text{g}}$$

This calculation was confirmed by measurements at LANL in "The Cave" (TA-54-1001 of LANL). (see Appendix B, attached.) The health consequences of this radioactivity are well known and the resulting dose is about 200 to 300 mrem/year (NCRP Reports No. 78, 93, 94, 97, 103.)

We have also used a Bladewerx® SabreAlert detector (http://www.bladewerx.com/SabreAlert2.htm) to study the content of this radioactive dust. The first few decay products are short lived so after about a week of decay (i.e., after the pump is shutdown), the only remaining decay products are the beta emitters: lead-210 and bismuth-210, and the alpha emitter: polonium-210 (NCRP 1988, NCRP 1989, and Shlein 1998.) The activity of these longer-lived radionuclides is calculated using the ratio of the 3.8-day half life of radon-222 and the 22-year half life of lead-210 (Appendix A.) Thus, the resulting activity of each of these decay products (lead-210 and bismuth-210, and polonium-210) is 20,000 pCi/g of dust.

Most of the radon decay products are attached to very small dust particles (NCRP 1984b, NCRP 1987b, NCRP 1988.) In a typical room, there are millions of barely visible dust particles with a total surface area of 1 cm^2, and also billions of invisible dust particles with a total surface area of 100 cm^2. The larger particles settle in a few hours, whereas the smaller particles remain suspended for days and are re-suspended by human actions such as sweeping or dusting. Because of their larger area and longer time in the air, the smaller particles collect most of the radon decay products. However, they are extremely difficult to collect because they cannot be brushed into a sample bottle and they remain embedded in the walls of a vacuum-cleaner bag, so the results varied depending on the particle size and the collection technique.

Nevertheless, the results were generally consistent with the GAP data, as described in Appendix D.

Other Naturally-Occurring Radioactive Materials

There are many other types of natural radioactive material. For example, beryllium-7 is listed in Table 1 and is produced by cosmic rays. (NCRP 1976, NCRP1987b, Eisenbud and Gesell 1997, page 180.) Another example is potassium chloride, which is widely available in grocery stores as a dietary substitute for sodium chloride and is also available from hardware stores to melt ice. All potassium contains natural potassium-40 and the radioactive concentration in potassium chloride is 440 pCi/g.

In many cases, these radioactive materials are found in high concentrations in the environment. For example, sylvite, which has an activity of about 400 pCi/g, is mined at the Carlsbad Potash Mines in New Mexico.
http://www.planetware.com/carlsbad/potash-mines-us-nm-pota.htm
http://geoinfo.nmt.edu/publications/decisionmakers/2002/dmfg2002_chap1.pdf
http://geoinfo.nmt.edu/faq/mining/Ur_20Dec04.pdf)

Wild fires also concentrate radioactive material because most of the non-radioactive material such as water becomes airborne while radioactive material such as strontium-90 and cesium-137 remain in the ash. For example, Stewart Farber has reported cesium-137 concentrations of 25 pCi/g in wood ash in Florida. (Farber 1990.)

Radioactivity from LANL

There is residual radioactive contamination at locations associated with LANL and the Manhattan Project, and in some cases radioactive contamination has migrated from the original sites. Almost all of this migration is water borne and follows the canyons down hill and down stream.

Airborne re-suspension and deposition are ineffective at moving radioactive material. For example, consider uranium-238. Assume a typical soil concentration of 2 pCi/g and a typical concentration of soil in air of 1E-5 g/m^3(as measured by the LANL "Tapered Element Oscillating Microbalance," TEOM, http://newnet.lanl.gov/Teom/teom.asp http://www.lanl.gov/environment/all/esr.shtml). It follows that a typical airborne concentration is

$$(2\ \text{pCi/g})(1\text{E-5 g/m}^3) = 2\text{E-5 pCi/m}^3.$$

Such concentrations are routinely monitored and measured by the AIRNET system. (see the LANL Environmental Surveillance Reports
http://www.lanl.gov/environment/all/esr.shtml .)

Assume a typical deposition velocity of 0.003 m/s, (as used by Hotspot https://www-gs.llnl.gov/hotspot/index.htm and Napier 2004) the deposition is

$$(20\ \text{aCi/m}^3)(0.003\ \text{m/s}) = 0.06\ \text{aCi/s}\cdot\text{m}^2.$$

(Note: CAP88 http://www.epa.gov/rpdweb00/assessment/CAP88/index.html and RESRAD-Offsite http://web.ead.anl.gov/resrad/home2/ use similar velocities. CAP88 uses 0.0018 m/s and RESRAD-Offsite uses 0.001 m/s.)

Assuming a worst-case period of 30 years (1E10 s) the total re-suspension and deposition is

$$(0.06\ \text{aCi/s}\cdot\text{m}^2)(1\text{E10 s}) = 6\text{E8 aCi/m}^2 = 60\ \text{fCi/cm}^2.$$

Using standard LANL soil-sampling to a depth of 5 cm and assuming a density of 1.5 g/cm^3, the resulting soil concentration is

$$(60\ \text{fCi/cm}^2)/[(5\ \text{cm})(1.5\ \text{g/cm}^3)] = 8\ \text{fCi/g}.$$

This is small compared with the original 2 pCi/g.

In Appendix C (attached) the standard models, CAP88 and Hotspot, are used to model airborne transport of radioactive materials from LANL. The models predict concentrations that are less than one millionth of those reported by the GAP at Llano, Picuris Pueblo, and nearby locations, and by NMED at Trampas Lake (latitude 35.99303, longitude -105.63714.)

Conclusion

Radioactive material occurs throughout the world. In Northern New Mexico, concentrations much higher than the LANL regional statistical reference level, RSRL, may be the result of many processes, both natural and anthropogenic.

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NCRP 1984a, NCRP Report No. 77, "Exposures from the Uranium Series with Emphasis on Radon and its Daughters," 1984; notes: on p24 it says phosphate mines contain uranium activity of 6 to 22 pCi/g; however, NCRP No. 94 says radium activity is 40 pCi/g; see pp33 and following pages for discussion of radon in buildings; see also NCRP Report No. 103.

NCRP 1984b, NCRP Report No. 78, "Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States," 1984; see p 69 Fig. 6.4 for particle sizes; median diameter 0.09 to 0.3 micrometer; compare with NCRP Reports No. 94 p 91 and No. 97 p 75.

NCRP 1987a, NCRP Report No. 93, "Ionizing Radiation Exposure of the Population of the United States," 1987.

NCRP 1987b, NCRP Report No. 94, "Exposure of the Population in the United States and Canada from Natural Background Radiation," 1987; notes: includes all the decay chains; ^{7}Be is discussed on p 25 and pp 33-34, 41, 43; p57: US beach sand is 6 ppm Th, 3 ppm U. (Monazite is 10% Th dioxide); p61 concentrations of U, Th, K, Rb87; p91 dust 0.1 to 0.2 micrometer diameter, see also No. 78 p 69 and No. 97 p 75-6; 10,000 to 1 million dust particles per cm^{3}, compare No. 97 p 88; p117: potassium in men and women as a function of age; 1.2% in elderly women, 2.2% in young men; appendix B discusses fallout.

NCRP 1988, NCRP Report No. 97, "Measurement of Radon and Radon Daughters in Air,"1988; notes: shows decay series; p29: Rn outdoors is 200 pCi/m3; (100 to 400); p 30: 10 times greater during an inversion; underground radon is 0.8 to 3 microCi/m3, i.e., factor of 10,000; p 75: particle sizes, see also No. 78 p 69 and No. 94 p 91, bimodal distribution, mostly about 0.1 micrometer, some 0.01 micrometer.

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Appendix A: Calculations of Radioactivity

Introduction

The basic equation of radioactive decay is

$$dN/dt = -\lambda N$$

where N is the number of atoms, t is time, and λ is the decay constant in the same units as t^{-1}. The number of atoms, N, is

$$N = m\, N_A/A$$

where m is the mass in grams N_A is Avogadro's number (6.02E23 atoms/mol) and A is the mass number (e.g., for potassium40, A = 40 grams/mol).

If the half life of a decay product is much shorter than the parent, the decay product reaches secular equilibrium, which means that the activities are the same.

For example, for natural uranium, the activity of ^{234}U is normally the same as that for ^{238}U. However, there are some processes that can change the relative activities of these two. For example, ^{234}U is often dislodged from the lattice by the decay process of ^{238}U so it normally is more readily dissolved. Therefore, in ground water the ^{234}U activity is normally higher than the ^{238}U activity. The same is true of the vegetation irrigated by the water.

If the half life of a decay product is much longer than the parent, the number of atoms of the decay product will be equal to the original number of atoms of the parent: $N_1 = N_2$. It follows that the relative activities are in the ratio of the decay constants and in the inverse ratio of the half lives.

For example, consider the decay of 1 Bq of ^{222}Rn. The decay constant is

$$\lambda = \ln(2)/(3.82*24*3600) = 2.1E\text{-}6\ s^{-1}$$

so the number of atoms is

$$N = (1\ Bq)/(2.1E\text{-}6\ s^{-1}) = 4.76E5.$$

After a day, essentially all these will decay to ^{210}Pb, for which the decay constant is

$$\lambda = \ln(2)/(22.3*365*24*3600) = 9.86E\text{-}10\ s^{-1}$$

so the activity of ^{210}Pb is

$$-dN/dt = \lambda N = (9.86E\text{-}10\ s^{-1})(4.76E5) = 4.69E\text{-}4\ Bq.$$

Notice, the ratio of the activities is equal to the ratio of the half lives: 2.13E3.

Potassium-40 in plants and ash

Potassium is present in soil, with typical concentrations of about 1% to 5% by mass.

Potassium is a necessary ingredient for life and it is present in all living things. Typical concentrations are about 0.1% to 0.6% by mass. Generally, it is lower in vegetation with high water content, such as iceberg lettuce (0.14% according to the USDA), higher in bananas (0.36%) and highest in beans, nuts, and meat (0.4 to 0.6%.)

Potassium-40 is 0.0117% or 0.0118% of the total potassium, and the half life of potassium-40 is 1.26E9 to 1.28E9 y (depending on which references you choose.) The decay constant, λ, is ln(2)/(1.27E9*365*24*3600) = 1.73E-17 s^{-1}.

The specific activity of potassium-40 is calculated as follows.

$$dN/dt = (1.73E\text{-}17\ s^{-1})(6.02E23\ \text{atoms/mol})/(40\ \text{g/mol}) = 2.60E5\ \text{Bq/g}.$$

Potassium-40 is 0.0118% of potassium, so the specific activity of natural potassium is:

$$(0.0118E\text{-}2)(2.60E5\ \text{Bq/g}) = 31\ \text{Bq/g} = 830\ \text{pCi/g}.$$

Plants contains 0.1% to 0.6% potassium, so their activity is 0.8 to 5 pCi/g.

According to Fresquez LA-UR-99-253 and LA-UR-07-0280, the ratio of wet weight to ash weigh is about 30 to 50, so the activity of ash ranges from 24 to 250 pCi/g.

According to the following reference, wood ash contains 12% potassium.
http://www.anl.gov/PCS/acsfuel/preprint%20archive/Files/36_3_NEW%20YORK_08-91_0892.pdf
In this case, the specific activity is 12% of 830 pCi/g = 100 pCi/g.

Therefore, if the soil contains 3% potassium, the potassium activity is 25 pCi/g.

(Note: phosphate ore contains 8 to 400 ppm U, see Eisenbud and Gesell, page 172.)

Notes on uranium

The specific activity of ^{238}U is 0.335 µCi/g.

Natural uranium contains 0.0055% ^{234}U with a specific activity of 6.2 mCi/g so ^{234}U contributes an additional 0.335 µCi/g to the total activity.

Natural uranium also contains 0.72% 235U with a specific activity of 2.2 µCi/g so it contributes 0.016 µCi/g to the total activity.

The total is 0.335 + 0.335 + 0.016 = 0.686 µCi/g.

Therefore, if the uranium concentration is 5 ppm, the uranium activity is 3.4 pCi/g. In addition, there is 0.335 µCi/g of each of ^{230}Th and ^{226}Ra, as well as smaller amounts of ^{222}Rn, ^{218}Po, ^{214}Po, etc., so the total alpha activity is about 7 pCi/g.

Furthermore, there is 0.335 µCi/g of each of ^{234}Th, ^{234m}Pa, and smaller amounts of ^{214}Pb, ^{214}Bi, etc., so the beta activity is about 4 pCi/g.

Notes on uranium isotopes

In natural uranium, ^{234}U is in normally in secular equilibrium with ^{238}U so the concentrations in pCi/g are similar, within the statistical uncertainties. As mentioned above, ^{234}U may be dislodged from the lattice by the decay process of ^{238}U so it normally is more readily dissolved. Therefore, in ground water the ^{234}U activity is normally higher than the ^{238}U activity. In theory, the residual soil could be depleted in ^{234}U. However, this is usually a small effect because only a small fraction of the uranium in soil is dissolved.

The ^{235}U content of natural uranium contains is 0.72% by weight, which corresponds to 0.73% of the atoms. The ^{238}U half life is 6.35 times that of ^{235}U, so (using the equations above) the ^{235}U activity is $6.35 \times 0.73\% \approx 5\%$ of the ^{238}U activity.

Notes on thorium

The specific activity of $^{23}2Th$ is 0.109 μCi/g. Natural thorium includes 0.109 μCi/g of ^{228}Th amounting to a total of 0.22 μCi/g.

The total alpha activity also includes contributions from several alpha emitters such as ^{224}Ra, ^{220}Rn, ^{216}Po, ^{212}Po, etc., as well as several beta emitters such as ^{228}Ra, ^{228}Ac, ^{212}Pb, ^{212}Bi, etc.

Thus, 10 ppm thorium results in 3 to 6 pCi/g total alpha activity and 2 to 4 pCi/g total beta activity.

Additional References that address soil concentrations near Los Alamos

LA-13330-MS, "Baseline Geochemistry of Soil and Bedrock, Tshirege Member of Bandelier Tuff," by Richard G Warren, Eric McDonald, Randall Ryti, 1997

LA-12733-MS "Source document compilation : Los Alamos investigations related to the environment, engineering, geology, and hydrology : 1961-1991," published in 1994 by William D. Purtymun. See page 31-7 and Chapter 3 page 7

Appendix B: Experiment to Measure the Radioactivity in Indoor Airborne Dust
Mike McNaughton, Shannon Allen, Melissa Coronado, Joan Lujan, Jake Martinez, Ernestine Naranjo, Brian Suazo

Date: The experiments were performed in August, 2008.

Location: The apparatus was installed inside TA-54-1001, known as The Cave, which is the home base of the AIRNET Project at Los Alamos National Laboratory, LANL.

Apparatus

The apparatus consisted of the following:

- a Tapered Element Oscillating Microbalance, TEOM, in The Cave;
- an AIRNET system, also installed in The Cave;
- a standard AIRNET air-flow measuring system;
- an SHP380AB alpha-beta detector with E600 readout; and
- a stop watch.

The purpose of each item is as follows.

- The TEOM measured the amount of dust in the air.
- The AIRNET system collected the dust on a filter.
- The air-flow measuring system measured the volume of air passing through the filter.
- The alpha-beta detector measured the amount of radioactivity on the dust as a function of time.

Method

The TEOM http://www.lanl.gov/environment/all/esr.shtml data were recorded at the beginning (14.5 $\mu g/m^3$) and the end (16.4 $\mu g/m^3$) of the experiment and the average value (15.5 ±1 $\mu g/m^3$) was used.

The alpha-beta detector was checked and background data were recorded with the detector placed close to the AIRNET filter while the pump was switched off. The background data are listed in Table 1. in units of disintegrations per minute, dpm.

	alpha (dpm)	beta (dpm)
1st count	226	1258
2nd count	233	1439
3rd count	157	1455
averages	205	1384

Table 1. Alpha and beta background data and average values in disintegrations per minute, dpm.

The AIRNET pump was switched on and a stop watch was started at the same time. Every few minutes after the pump was switched on, the air flow rate and the alpha and beta activities on the filter were measured during a 1-minute count . The data are listed in Table 2 and displayed in Figures 1 and 2.

Time (min.)	Alpha (dpm)	Net Alpha (dpm)	Beta (dpm)	Net Beta (dpm)	Air flow (ft^3/min.)
3	1001	796	3840	2456	4.0
7	1732	1527	6430	5046	4.0
9	2290	2085	8800	7416	4.0
12	2620	2415	10990	9606	4.0

Table 2. Alpha and beta data (dpm) as a function of time (minutes) after the pump was switched on. Net alpha and beta results are the data after subtracting background.

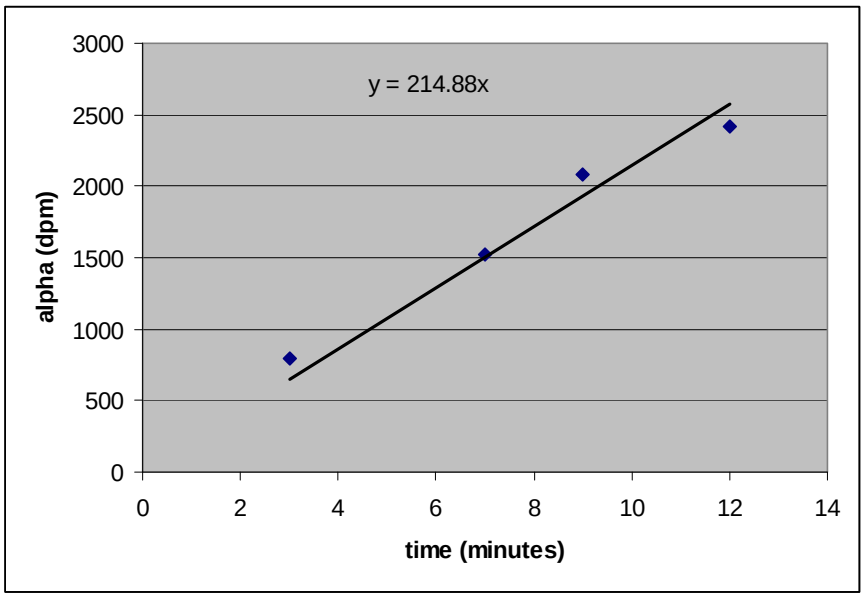

Figure 1. Net (background-subtracted) alpha rate (dpm) as a function of time (minutes.) The equation of the line is $y = 214.88x$ so the slope of the line is approximately 215 dpm/minute.

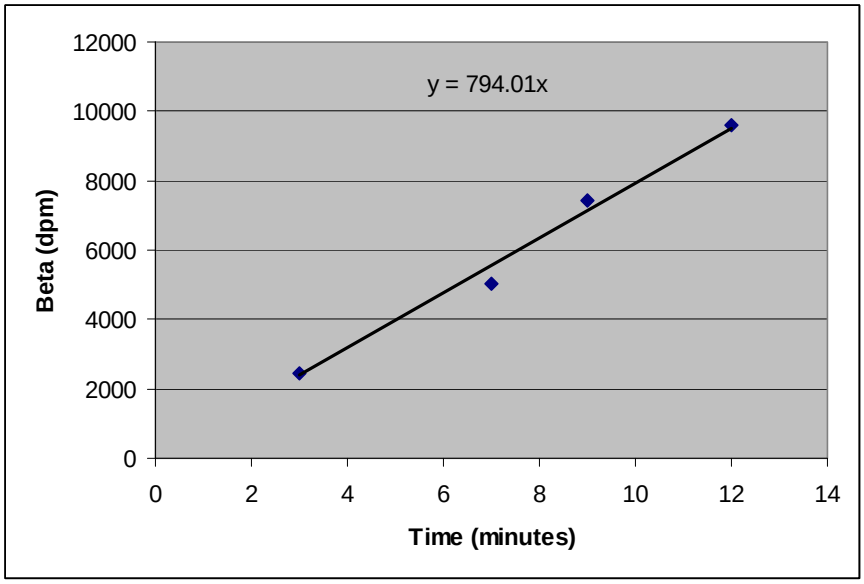

Figure 2. Net (background-subtracted) beta rate (dpm) as a function of time (minutes.) The equation of the line is $y = 794.01x$ so the slope of the line is approximately 794 dpm/minute.

Discussion

The alpha and beta count rates increase as dust accumulates on the filter. The rate of increase is not exactly linear because radioactive decay is combined with the accumulation. However, the straight line fits shown in figures 1 and 2 are reasonable approximations that underestimate the accumulated radioactivity by up to about 40% for alpha and 3% for beta. The alpha data are especially affected by the decay of the short-lived Po218, which has a 3-minute half life.

The slope of each graph is the accumulation rate of radioactivity (dpm) on the filter:

- alpha: 215 dpm/minute
- beta: 794 dpm/minute

The air concentration is calculated by dividing by the flow rate, 4 ft^3/minute:
alpha: (215 dpm/minute)/(4 ft^3/minute) = 54 dpm/ft^3; and
beta: (794 dpm/minute)/(4 ft^3/minute) = 199 dpm/ft^3.

For comparison with the radon concentration, these values are converted to pCi/L.
(54 dpm/ft^3)(0.035 L/ft^3)/(2.22 dpm/pCi) = 0.9 pCi/L
(199 dpm/ft^3)(0.035 L/ft^3)/(2.22 dpm/pCi) = 3.1 pCi/L

The lower alpha value results from decay of the short-lived Po218 and also particle burial in the filter.

Radon-222 produces several short lived decay products (Po218, Pb214, Bi214, Po214) which emit two alpha and two beta particles, so the results are reasonably consistent with the measured radon-222 concentration of 2.5 pCi/L.

The accumulation rate of dust on the filter is the air flow rate,
(4 ft^3/minute)(0.028 m^3/ft^3) = 0.11 m^3/minute,
multiplied by the concentration of dust in the air, 1.6E-5 g/m^3:
(0.11 m^3/minute)(1.6E-5 g/m^3) = 1.8E-6 g/minute = 1.8 µg/minute.

The concentration of radioactivity on the dust is equal to the accumulation rate of radioactivity divided by the accumulation rate of dust:
alpha: (215 dpm/minute)/(1.8 µg/minute) = 119 dpm/µg = 54 pCi/µg
beta: (794 dpm/minute)/(1.8 µg/minute) = 441 dpm/µg = 199 pCi/µg

As shown in Figures 3 and 4, the radioactivity decayed with a half life of about 50 ± 20 minutes, confirming that it consisted of a combination of the short-lived radon decay products: ^{218}Po (3 minutes), ^{214}Pb (27 minutes), ^{214}Bi (20 minutes), and ^{214}Po (0.2 ms). The predominance of radon was also confirmed with Bladwerx SabreAlert and Femto-Tech CRM510 radon monitors.

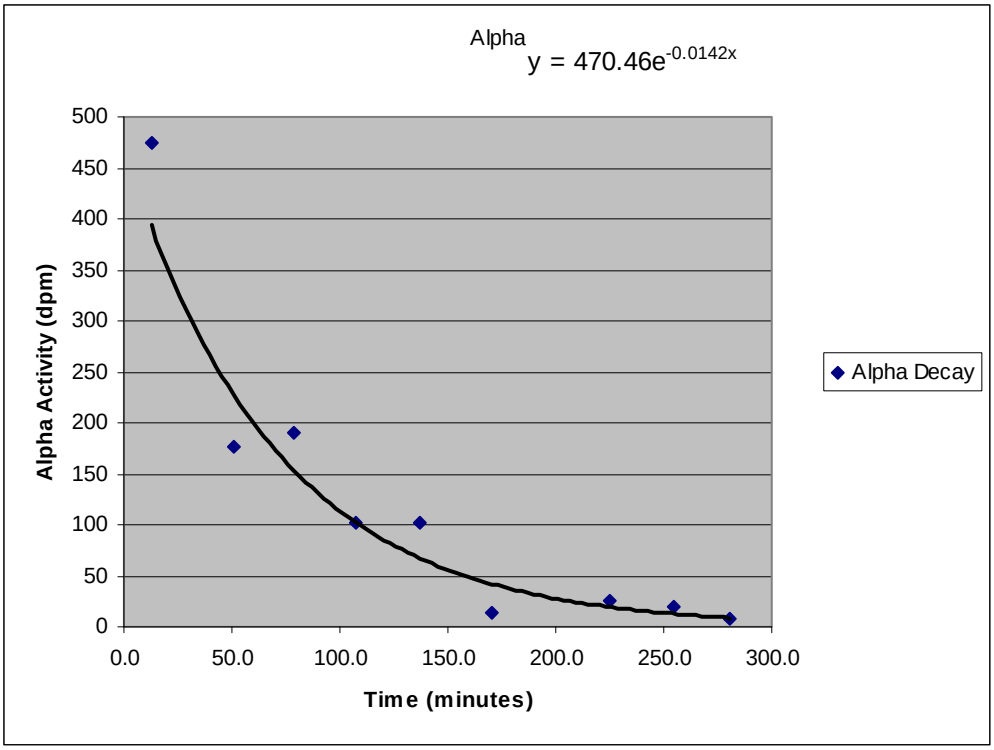

Figure 3. Decay of the alpha activity on the filter. The decay constant, 0.0142 $minutes^{-1}$, corresponds to a half life of ln(2)/0.0142 = 49 minutes.

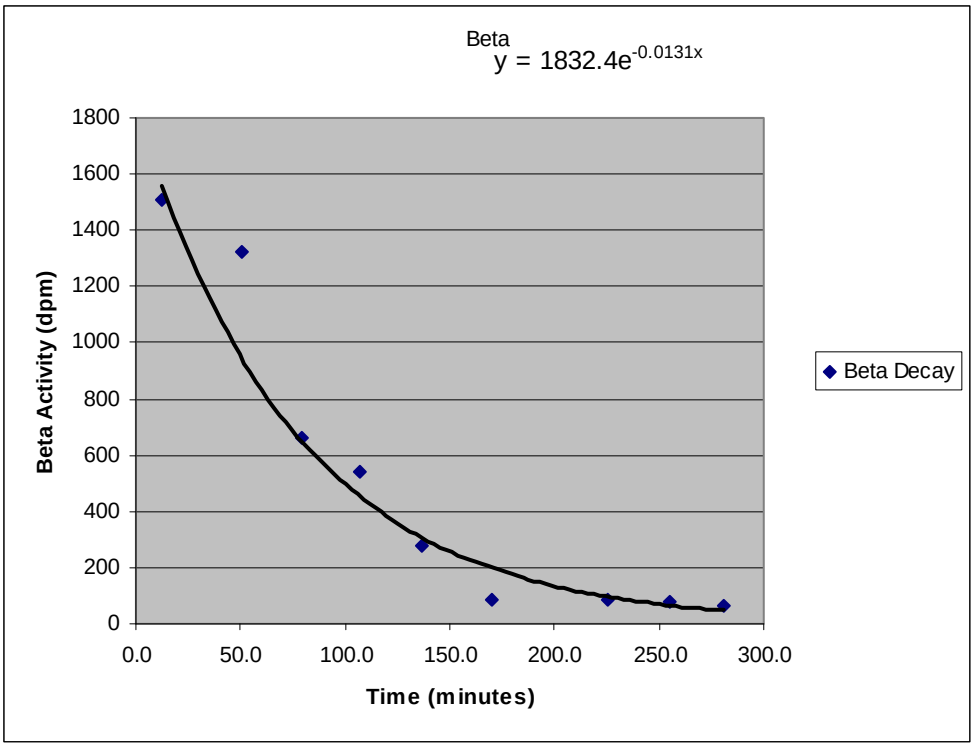

Figure 4. Decay of the beta activity on the filter. The decay constant, 0.0131 minutes^{-1}, corresponds to a half life of ln(2)/0.0131 = 53 minutes.

Accuracy

The simple methods used in this experiment limit the accuracy to about a factor of 3. In particular, the following limitations have been discussed:

- the activity on the filter is not a linear function of time;
- particles are buried in the filter, which results in attenuation of alphas and betas;
- some radon decay products are not attached to dust particles.

Generally, these limitations result in an underestimate of the concentrations.

Conclusion

The concentrations of radon decay products in air and dust were measured. Results for alpha and beta emitting radionuclides were as follows.

- alpha emitting radionuclides in air: 0.9 pCi/L
- beta emitting radionuclides in air: 3.1 pCi/L

These results compare reasonably, within about a factor of 3, with the measured radon concentration of 2.5 pCi/L.

The concentrations in the dust were as follows.

- alpha emitting radionuclides in dust: 119 dpm/μg = 54 pCi/μg
- alpha emitting radionuclides in dust: 441 dpm/μg = 199 pCi/μg

Although these concentrations are larger than those usually encountered in the environment, there is no credible scenario that could result in a major health hazard. According to NCRP Reports No. 77, 93, and 94, the radiological dose that results from inhalation of typical indoor dust containing these radon decay products is approximately 200-300 mrem/year.

Appendix C: Contamination from LANL

This section addresses the general question: how is contamination dispersed from LANL? It also addresses the specific question: is it possible that radioactivity detected in the vicinity of the Embudo Valley, Picuris Pueblo, Llano, and Trampas Lake came from LANL?

There are two pathways by which contamination could be transported off-site: air and water. Waterborne contamination travels downstream and downhill and does not contribute to radioactive material upstream and uphill. Therefore, we focus on the air pathway.

There are many computer programs that calculate the dispersion of airborne contamination. In this section, we focus on two: The standard EPA code, CAP88 http://www.epa.gov/rpdweb00/assessment/CAP88/index.html , and the LLNL code, Hotspot https://www-gs.llnl.gov/hotspot/index.htm .

The following calculations use worst-case assumptions. Both codes predict contamination less than 0.0001% of the measured radioactive material. In contrast, the hypothesis that the radioactive material is the result of global fallout is in good agreement with the measurements.

Hotspot and CAP88

Hotspot predicts larger deposition amounts than CAP88 for two reasons. Hotspot assumes the wind is always blowing directly from the source to the receptor, whereas CAP88 takes account of the observed variations in wind direction. Also, Hotspot assumes a constant wind speed whereas CAP88 assumes the wind speed varies. So most of the calculations were made with Hotspot using worst-case conditions.

Cesium-137

Cesium-137 occurs primarily in liquid waste streams, especially from TA-21, TA35, and TA-50, (refer to L.A. Emelity, LA-UR-96-1283, and to the "Work Plan for Mortandad Canyon", LA-UR-97-3291) so cesium-137 contamination is mostly confined to the canyons. The largest amount of cesium-137 is in reach M3E of Mortandad Canyon (refer to "Mortandad Canyon Investigation Report," LA-UR-06-6752 http://www.lanl.gov/environment/cleanup/docs/IR-Mortandad-LA-UR-06-6752.pdf .) (600 m by 60 m = 3.6 ha, see p 40, Fig. 7.1-3, Fig 7.1-19) where the total inventory is 800 mCi (Fig. 7.1-18) and the average concentration is 72 pCi/g (Table 8.2-14.)

Consider re-suspension of dust. Use a typical airborne dust concentration measured by a LANL TEOM http://newnet.lanl.gov/Teom/teom.asp of 15 $\mu g/m^3$. If all this dust is from the contaminated soil, the cesium-137 concentration in the air is:

$$(72\ pCi/g)(15\ \mu g/m^3)(1E\text{-}6\ g/\mu g) = 1\ fCi/m^3.$$

Most of this dust is coarse and settles rapidly at locations close to the point of origin. Furthermore, such a high concentration would be obvious both in the gross-beta measurements and in the specific cesium-137 isotopic analysis (cesium-137 detection limit = 2 pCi/2E4 m^3 = 0.1 fCi/m^3.)

The re-suspension rate is the product of the concentration, the area, and the re-suspension velocity (3 mm/s from Hotspot and Napier PNNL-14599; CAP88 uses 1.8 mm/s; Resrad-Offsite uses 1 mm/s; Till and Grogan 2008 suggests 1 mm/s.):
http://www.pnl.gov/main/publications/external/technical_reports/PNNl-14599Rev0.pdf

$$(3.6E4\ m^2)(1\ fCi/m^3)(3E\text{-}3\ m/s) = 100\ fCi/s.$$

Assume this dust persists for 30 years (1E9 s). Then the total re-suspended cesium-137 is

$$(100\ fCi/s)(1E9\ s)(1E\text{-}12\ mCi/fCi) = 0.1\ mCi.$$

Larger values are obtained from a worst-case fire scenario. The bioaccumulation factor is in the range 0.01 to 0.06 (refer to:
LA-14284 http://www.osti.gov/bridge/servlets/purl/881275-5L3oK8/881275.PDF
LA-UR-05-4699 http://www.lanl.gov/environment/compliance/docs/LA-UR-05-4699.pdf
LA-UR-08-2783 http://www.lanl.gov/environment/compliance/docs/LA-UR-08-2783.pdf
http://www.osti.gov/bridge/servlets/purl/881275-5L3oK8/881275.PDF ,
http://www.lanl.gov/environment/compliance/docs/LA-UR-05-4699.pdf ,
http://www.lanl.gov/environment/compliance/docs/LA-UR-08-2783.pdf)
so the concentration in the trees is (72 pCi/g)(0.06) = 4 pCi/g.

According to the EPA, (AP-42 http://www.epa.gov/ttn/chief/ap42/) the average fuel loading ranges from 22 Mg/ha in New Mexico to 67 Mg/ha in the Rocky Mountains. Using the higher number, the mass is (67 Mg/ha)(3.6 ha) = 240 Mg = 2.4E8 g and the cesium-137 content is

$$(4\ pCi/g)(2.4E8\ g) = 1.0E9\ pCi = 1\ mCi.$$

Most of the cesium-137 remains in the ash (refer to Coles 1979, Hasanen 1986, Jantunen 1992, Pennisi 1988, in the list of references).

According to David Englert of NMED/OB, the Embudo watershed is approximately 40 miles NE of LANL. For the following worst-case calculations, assume the distance is 50 km and the wind is constant from LANL to the receptor.

At this distance, the ground deposition is not very sensitive to the input variables. Choose 0.001 Ci of Cs-137, 300 m radius, and 30 m for "Height of Fire" and the effective release height. For meteorology, choose either "Sun high in the sky" or "Sun low in the sky" or "Night" and vary the wind speed. The stability class is automatically selected. The values for the deposition are listed in the table below in units of μCi/m^2.

Wind (m/s)	Sun high	Sun low	Night
1	6E-10	5E-10	6E-10
3	8E-10	2E-9	8E-10
6	4E-9	2E-9	4E-9

10	4E-9	4E-9	4E-9
20	3E-9	5E-9	3E-9

Choose the highest value, 5E-9 μCi/m^2 and convert to pCi/cm^2:

$$(5E\text{-}9\ \mu Ci/m^2)(1E6\ pCi/\mu Ci)(1E\text{-}4\ m^2/cm^2) = 5E\text{-}7\ pCi/cm^2$$

If there is no runoff and the soil sample is 5 cm deep this corresponds to the following concentration.

$$(5E\text{-}7\ pCi/cm^2)/(5\ cm) = 1E\text{-}7\ pCi/cm^3$$

If the density is 1.5 g/cm^3 the concentration is

$$(1E\text{-}7\ pCi/cm^3)/(1.5\ g/cm^3) = 7E\text{-}8\ pCi/g.$$

Larger concentrations will occur if the sample is shallow and if there is run off from the surrounding hillsides that results in accumulation of the radioactive material in low lying areas. Assume these increase the concentration by a factor of ten. Then the concentration would be 7E-7 pCi/g. This is less than 0.0001% of the concentration measured by NMED at Trampas Lake.

We conclude that LANL is not the source of cesium-137 at Trampas Lake.

Other radionuclides

Strontium-90

Compare strontium-90 with cesium-137.

In Mortandad Canyon, the strontium-90 activity is generally less than 10% of the cesium-137 activity. On the other hand, the uptake into plants is generally a factor of ten larger, so the release during a fire would be comparable.

The strontium-90 concentrations are much higher than the cesium-137 concentrations at the locations associated with the radioactive lanthanum (RaLa) project: TA-10 and Ten Site. However, the areas contaminated with strontium-90 are smaller than the contaminated areas of Mortandad Canyon and the total curie content is similar, on the order of a curie.

Therefore, the strontium-90 emissions are likely to be similar, within about an order of magnitude, to the cesium-137 emissions, and LANL emissions cannot be the source of the strontium-90 detected at a residence in Llano. The concentration (1.5 pCi/g) is more likely to be the result of global fallout at high elevations, perhaps concentrated in wood ash.

Plutonium

Historically, the airborne emissions of plutonium have been much higher than those of cesium-137. This is not consistent with the radionuclides observed offsite, which are

approximately in the ratio expected from global fallout. Airborne deposition of plutonium from LANL has not been observed more than 1 mile from Los Alamos County.

For example, consider the historical emissions from TA-21. The exact number of curies is not known but it is generally agreed that it is more than a curie, which is more than a thousand times the amount of cesium-137 calculated above. Furthermore, plutonium can be detected at concentrations of 0.001 pCi/g, which is a thousand times smaller than cesium-137. Airborne plutonium has been studied extensively both by LANL and by the LAHDRA project http://www.lahdra.org/ and airborne plutonium has not been confirmed beyond the boundaries of Los Alamos county.

Uranium

The total number of curies of uranium expended at the LANL firing sites is on the order of tens of curies. Depleted uranium is frequently detected on site, sometimes with airborne concentrations of several fCi/m^3. However, airborne emissions of depleted uranium have not been detected outside the boundaries of Los Alamos county.

Sodium-22, Manganese-54, and Cobalt-60

According to DOE 1998, sodium-22, manganese-54, and cobalt-60 were the predominant radionuclides at TA-2 and TA-53. The radiation from these locations is apparent as concentric black and red circles on the contour map. The TA-53 radiation is the highest radiation level on the map
http://www.lanl.gov/environment/air/maps/terrestrial_exposure_contour_map.pdf .
However, there is no sign of radioactivity downwind and these radionuclides have not been detected off site, although 3 fCi/m3of cobalt-60 was detected near TA-2 during the remediation in 2003 (LANL 2004.)

Conclusion

Airborne contamination has not been detected more than 1 mile from the boundaries of Los Alamos County. The observed radioanuclides, strontium-90, cesium-137, plutonium, and americium, are consistent with global fallout. On the other hand, they are not consistent with the expected LANL contamination, which is expected to be below detection limits. If detection limits could be improved, the largest amounts from LANL would be uranium-238, plutonium-239, americium-241, and cobalt-60. The observation of cesium-137 as the predominant radionuclide is consistent with global fallout and not consistent with LANL contamination.

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http://www.lanl.gov/environment/cleanup/docs/IR-Mortandad-LA-UR-06-6752.pdf .)

Appendix D
Analysis of Dust Samples

In response to the GAP study, four samples of dust were obtained within the Los Alamos and White Rock townsites and submitted to Paragon analytical laboratory (Fort Collins, Colorado) to determine the specific radionuclides in the dust. The samples were obtained at the following locations.

1. Los Alamos Monitor offices, floor vacuum cleaner;
2. Los Alamos Monitor offices, furnace.
3. White Rock, NMED/OB offices, shelf tops;
4. White Rock, NMED/OB offices, bathroom fan;

The results are summarized in the table below.

Nuclide	floor pCi/g	1 s.d. pCi/g	furnace pCi/g	1 s.d. pCi/g	shelf pCi/g	1 s.d. pCi/g	fan pCi/g	1 s.d. pCi/g
Am241	0.0109	0.0033	0.0084	0.0032	-0.005	0.013	0.034	0.012
Pu238	0.0005	0.0013	0.0026	0.0014	0.021	0.017	0	0.014
Pu239	0.0157	0.0035	0.0847	0.0096	0.028	0.017	0.024	0.015
U234	0.425	0.039	0.614	0.051	1.01	0.10	0.643	0.071
U235	0.0224	0.0047	0.0335	0.005	0.04	0.019	0.016	0.014
U238	0.434	0.04	0.674	0.056	0.811	0.089	0.619	0.068
Po210	3.70	0.33	10.07	0.78	343	25	25.4	1.9
Sr90	0.03	0.015	0.03	0.015	0.144	0.09	0.117	0.06
Ac228	0.65	0.14	0.9	0.12				
Be7	2.08	0.41	4.12	0.40				
Bi214	0.424	0.094	0.49	0.12				
Cs137	0.013	0.029	0.112	0.022				
K40	12.4	1.1	15.3	1.2				
Pb212	0.546	0.068	0.888	0.085				
Pb214	0.435	0.088	0.643	0.076				
Ra224	0.546	0.068	0.888	0.085				
Th234	0.84	0.41	1.5	0.36				
Tl208	0.162	0.06	0.287	0.049				

Table 1. Concentrations (pCi/g) of individual radionuclides for the four samples described in the text: floor vacuum cleaner; furnace; shelf tops; and bathroom fan. The one-standard-deviation uncertainties are listed in the column marked "1 s.d."

Discussion of Results

Most of the radioactivity listed in Table 1 is from the natural sources discussed in previous sections. Most samples also include small amounts of americium-241 (Am241), plutonium (Pu), strontium-90 (Sr90), and cesium-137 (Cs-137) from global fallout. The plutonium-239 (Pu239) concentration in the sample from the furnace is similar to the soil concentrations in the vicinity of DP Road and the Los Alamos airport, and is a result of emissions during the 1940s and 1950s from LANL TA-21. The uranium isotopic ratios

are consistent with natural uranium.

The "shelf" and "fan" samples were only analyzed for the first eight nuclides in the table because the samples were too small for the gamma-spectroscopy method used for the other nuclides. These nuclides (Ac228 through Tl208) are all natural.

The most interesting results are for polonium-210 (Po210). As discussed previously, polonium-210 concentrations (in pCi/g) depend on the particle size. In all cases, the dust particles were visible and were large enough to fall into the sample bottle, so the particle diameters were greater than a few micrometers; smaller dust particles fall too slowly to fall into the sample bottle within a few minutes. Most of the polonium-210 attaches to dust particles with diameters less than 1 micrometer (NCRP 78, 94, 97) so most of the polonium-210 was not captured in these samples. As described in Appendix B, much higher concentrations are possible.

The highest concentration in Table 1, 343 pCi/g, was in the dust collected from the shelf tops. Many of these dust particles were small, but the smallest dust particles may have been imbedded into the bag and filter material making it difficult to remove them from the vacuum cleaner bag. The dust particles sent for analysis were removed by tapping the bag; they were visible; and they fell from the bag into the sample bottle in a few seconds. These observations indicate that the particle diameters were larger than a few micrometers because smaller particles are not visible to the naked eye and they fall with a terminal velocity of less than 1 mm/s.

The largest particles were collected from the floor, and were probably tracked in on shoes instead of settling from the air. As expected, these particles had the lowest Po210 concentrations.

Comparison with GAP data

In this section, the data reported above are compared with the alpha and beta activity measurements reported by the Government Accountability Project, GAP. The GAP data were reported in units of disintegrations per minute, dpm, so in this section concentrations are reported in dpm/g. Note that 1 pCi = 2.22 dpm.

The largest alpha and beta activities reported by the GAP were from the NMED/OB offices: 21 dpm/g of alpha activity and 397 dpm/g of beta activity. As reported in Table 1 (above) samples from these offices contained Po210 concentrations of 25.4 pCi/g and 343 pCi/g, which correspond to 56 dpm/g and 760 dpm/g. Polonium-210 is accompanied by equal concentrations of two beta-emitting nuclides: lead-210 and bismuth-210, so the data reported in Table 1 generally reveal larger concentrations than the GAP data and indicate that almost all the radioactivity is natural.

For the Los Alamos Monitor offices, the GAP reported an alpha activity of 1 dpm/g and a beta activity of 51 dpm/g. The nuclides listed in Table 1, together with their decay products such as Pa-234m, Th-230, Ra-226, etc., amount to alpha activities of 16 to 32

dpm/g and beta activities of 45 to 70 dpm/g in the samples from these offices. (For more details, see Appendix A.) As at the NMED/OB offices, the data in Table 1 reveal larger concentrations than the GAP data and show that most of the radioactivity is natural.

At other locations, the GAP results vary by more than an order of magnitude. For example, the beta activities measured by GAP range from 12 dpm/g near the Los Alamos air strip to a high of 397 dpm/g in the NMED/OB offices. An examination of all the samples reveals no obvious trend as a function of distance from LANL.

The highest activities were measured in dust samples, especially those likely to include small particles, e.g., from fans, HVAC systems, refrigerator coils, etc. Such samples are especially likely to attract radon decay products from the air.

The GAP report contains several examples of data that appear to be associated with wood ash. The total radioactivity of these data are not unusually high, perhaps because the polonium and bismuth are volatilized by fire. However, they are likely to contain relatively high concentrations of strontium-90 and cesium-137, especially if the wood was obtained at high elevations.

The GAP reported plutonium data at several locations. Plutonium contamination from historical air emissions can be found in the soil within 1 mile of the historical laboratory boundary, and water-borne plutonium can be found downstream of the historical outfalls. Generally, these are below the LANL screening action levels (30 pCi/g for residential areas and 280 pCi/g for recreational areas.)

The GAP reported strontium-90 data at several locations. As reported in the annual report "Environmental Surveillance at Los Alamos," strontium-90 contamination from LANL operations can be found within the areas of historical laboratory operations and water-borne contamination is found downstream of historical laboratory areas. Generally, these are below the screening action levels. The strontium-90 reported by the GAP appears to be from global fallout**,** which is more concentrated at high elevations (refer to Brant Ulsh, Steven Rademacher, F. Ward Whicker, 2000) and is further concentrated by a factor of 50 in ash (PR Fresquez and JK Ferenbaugh, "Moisture Conversion Ratios for the Biota Environmental Surveillance Programs at LANL," LA-UR-99-253 and LA-UR-07-0280.)

The GAP reported uranium at several locations. Natural uranium occurs throughout the world, sometimes resulting in both alpha and beta activities more than 1,000 dpm/g. Generally, uranium contamination from DOE operations is depleted uranium, which has not been observed off site. In contrast, the isotopic content of the GAP data indicates natural uranium. The ratios of ^{234}U : ^{235}U : ^{238}U are 1.1 : 0.05 : 0.90, which is consistent with natural uranium, see Appendix A.

Only one of the 13 GAP samples is in-consistent with natural uranium, namely sample LA077. The isotopic uranium results were as follows.
^{234}U 1.21 pCi/g
^{235}U 0.08 pCi/g

^{238}U 0.26 pCi/g

In this sample, the concentrations of ^{234}U and ^{235}U are typical of the region, but the ^{238}U concentration is unusually low. This remains a puzzle.