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Effects of the Cerro Grande Fire (Smoke and Fallout Ash) on Soil Chemical Properties Within and Around Los Alamos National Laboratory

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ABSTRACT

Soil surface (0- to 2-in. depth) samples were collected from areas within and around Los Alamos National Laboratory (LANL) just after the Cerro Grande fire, analyzed for radionuclides, radioactivity, and trace elements (heavy metals), and compared to soil samples collected in 1999 from the same sites. In addition, many types of organic substances (volatile and semivolatile organic compounds, organochlorine pesticides, polychlorinated biphenyls, high explosives, and dioxin and dioxin-like compounds) were assessed in soils from LANL, perimeter, and regional sites after the fire. Results show that impacts to regional, perimeter, and on-site (mesa top) areas from smoke and fallout ash as a result of the Cerro Grande fire were minimal.

INTRODUCTION

On May 4, 2000, the National Park Service started a prescribed burn on Cerro Grande (CG) peak within Bandelier National Monument. The fire, located approximately 3.5 mi (5.6 km) west of Los Alamos National Laboratory (LANL), quickly grew out of control and eventually burned nearly 50,000 acres in and around Los Alamos, New Mexico (LANL, 2000) (Figure 1). The fire was fully contained by June 6.

Because the fire burned over 7,000 acres of LANL lands and some areas are known to contain radionuclides and chemicals in soils and plants above background concentrations (Fresquez et al., 1998; Gonzales et al., 2000), some of these materials via smoke and ash may have been suspended and transported by wind. As part of the Environmental Surveillance Program at LANL, soil surface samples have been collected for radionuclide and nonradionuclide (trace metals) analysis from 12 on-site (LANL), 10 perimeter (PM), and three regional background (BG) areas on an annual basis since the early 1970s (Purtymun et al., 1980; Purtymun et al., 1987; Fresquez et al., 1998). The objective of this study then was to

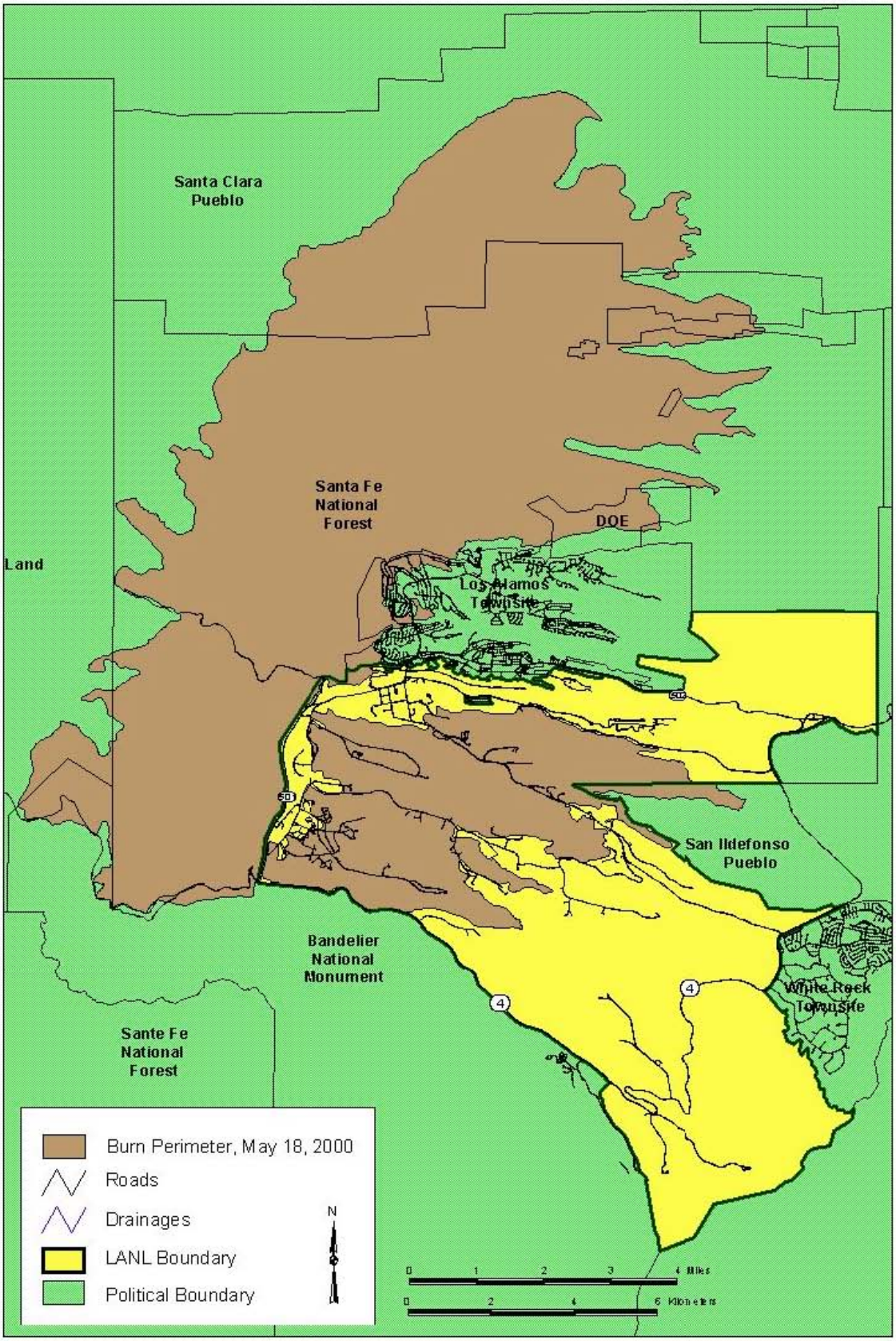

Figure 1. Cerro Grande Fire, total area burned.

compare radionuclides and nonradionuclides in soil samples collected directly after the fire to soil samples collected in 1999 (Fresquez and Gonzales, 2000). In addition, many organic substances—volatile (VOC), semivolatile (SVOC), organochlorine pesticides (PEST), polychlorinated biphenyls (PCBs), high explosives (HE), and dioxin and dioxin-like compounds—were assessed in soils from LANL, PM, and BG after the fire.

METHODS AND MATERIALS

Soil samples were collected after the fire on June 1–19, 2000, from relatively level and open areas from 12 LANL, 10 PM, and three BG locations (Figure 2). The sites sampled at LANL were not from areas where solid and/or liquid wastes have been released (e.g., firing sites, waste disposal sites, outfalls, etc.). Rather, these areas were located on the mesa tops downwind from major facilities and/or operations in an effort to assess "contamination" as a result of air stack emissions and fugitive dust (e.g., the resuspension of dust from contaminated areas—firing sites, waste disposal sites, outfalls, etc.). And, in the case of the CG fire, to smoke and fallout ash. Similarly, most PM stations were located on the downwind side of LANL (four sites mostly located on the north/northeast side and four sites located on the east side) and one each on the west (U. S. Forest Service) and south (U. S. Park Service—Bandelier National Monument) side of the Laboratory to provide comprehensive coverage. (Note: The predominant direction of the fire plume was toward the northeast.) All BG sites ranged from 20 mi (32 km) to 60 mi (96 km) away from the Laboratory on all sides and were beyond the likely range of significant impacts from LANL operations; and thus, radionuclides and nonradionuclides in soils from these sites would be mostly a result of worldwide fallout and/or to naturally occurring materials in the earth's crust.

At each site, soil surface samples were collected for radionuclides and nonradionuclides from the center and corners of a square area 33 ft (10 m) per side using a stainless steel soil ring 4 in. (101 mm) in diameter pushed 2 in. (51 mm) deep (ASTM 1990). The five subsamples were combined and mixed thoroughly in a large Ziploc bag to form a composite sample. Samples were poured into a 500-mL polybottle for radionuclides, a 125-mL polybottle for trace elements, and a 125-mL polybottle for strontium (^{90}Sr) analysis. Soil samples were submitted to an environmental chemistry group at LANL for the analysis of

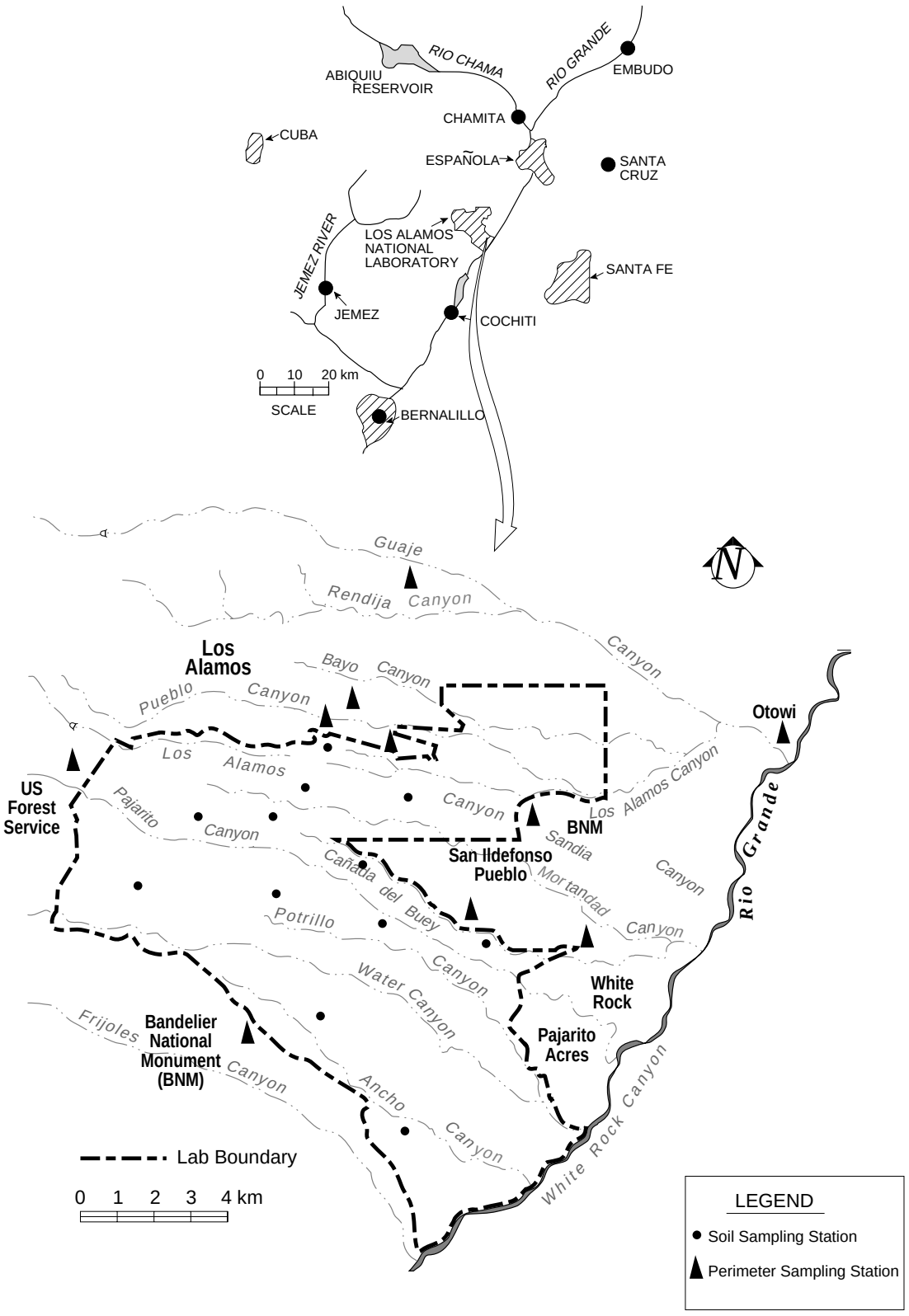

Figure 2. Regional (top) and perimeter and on-site (bottom) Laboratory soil sampling locations.

tritium (^{3}H), cesium (^{137}Cs), plutonium (^{238}Pu and $^{239,240}Pu$), americium (^{241}Am), and total uranium (^{tot}U) and gross alpha (α), beta (β), and gamma (γ) radioactivity. Trace elements included silver (Ag), aluminum (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), thallium (Tl), vanadium (V), Zinc (Zn), and cyanide (CN). Strontium-90 was analyzed by Paragon Analytics Inc., of Fort Collins, CO. All methods of analysis for radionuclides and trace elements have been previously reported (Purtymun et al., 1980; Purtymun et al., 1987; Fresquez et al., 1996). (Note: All analytical results can be found at the Ecology Group, Mail Stop M887, for reference.)

Soil (grab) samples for organic analysis from selected sites at LANL, PM, and BG were collected with a Teflon scoop at the 0- to 6-in. depth and placed into the appropriate containers for analysis: a 250-mL amber glass bottle fitted with a septum lid was employed for VOC; a 500-mL amber glass bottle for SVOC; a 500-mL amber glass bottle for PEST, PCBs, and HE; and, a 125-mL amber glass bottle was used for dioxin and dioxin-like compounds. All samples were transported to the laboratory in an ice chest cooled to 4˚C. VOC (36 compounds), SVOC (71 compounds), PEST (21 compounds), PCBs (7 compounds), and HE (14 compounds) were analyzed by Paragon Analytics, Inc., and Alta Analytical Laboratory, Inc., of El Dorado Hills, CA, analyzed the soils for dioxin (2,3,7,8-tetrachlorodibenzodioxin [TCDD]) and dioxin-like compounds (7 compounds). (Note: All analytical results can be found at the Ecology Group, Mail Stop M887, for reference.)

RESULTS AND DISCUSSION

Mean results of radionuclides and trace elements in soils collected before and after the CG fire from 12 LANL and 10 PM sites can be found in Tables 1 and 2, respectively. Because only one BG site, Embudo, was predominantly downwind of the fire, it was the only regional station compared to pre-fire soil conditions. With the exception of the regional BG station, statistical comparisons were made within LANL and PM sites and years (1999 and 2000) using a nonparametric Wilcoxon Rank Sum test at the 0.05 probability level (Gilbert, 1987).

All mean radionuclide and radioactivity concentrations/activity in soils collected from PM and LANL areas collected after the

Table 1. Mean (±SD) Radionuclide Activity in Surface (0- to 2-in. depth) Soils Collected from Regional, Perimeter, and On-Site Stations Before (1999) and After (6/1-19/00) the Cerro Grande Fire

Location	^{3}H pCi/mL	^{90}Sr pCi/g dry	^{137}Cs pCi/g dry	^{tot}U μg/g dry	^{238}Pu pCi/g dry	$^{239,240}Pu$ pCi/g dry	^{241}Am pCi/g dry	Alpha pCi/g dry	Beta pCi/g dry	Gamma pCi/g dry
Regional Background Stations[1]										
Pre[2]	0.21	0.30	0.23	1.78	0.001	0.012	0.011	3.1	2.8	2.1
	(0.64)	(0.07)	(0.06)	(0.18)	(0.001)	(0.002)	(0.003)	(0.6)	(0.3)	(0.2)
Post	0.03	0.34	0.31	1.57	0.002	0.006	0.014	4.1	3.2	2.5
	(0.45)	(0.09)	(0.05)	(0.16)	(0.001)	(0.001)	(0.004)	(1.3)	(1.0)	(0.2)
ULB[3]	0.60	0.71	0.51	3.30	0.008	0.019	0.013	8.4	7.2	4.1
Perimeter Stations[4]										
Pre[2]	0.32	0.34	0.45	2.93	0.007	0.039	0.007	5.0	4.3	4.4
	(0.09)	(0.18)	(0.29)	(0.58)	(0.006)	(0.040)	(0.004)	(1.1)	(1.2)	(1.6)
Post	0.23	0.29	0.28	2.99	0.002	0.033	0.009	5.6	3.7	3.1
	(0.13)	(0.08)	(0.13)	(1.23)	(0.001)	(0.036)	(0.014)	(1.7)	(1.0)	(0.6)
On-Site Stations (LANL)[5]										
Pre[2]	0.39	0.42	0.36	4.12	0.005	0.025	0.014	5.9	4.1	3.4
	(0.59)	(0.18)	(0.16)	(1.75)	(0.006)	(0.015)	(0.015)	(1.4)	(1.2)	(0.7)
Post	0.59	0.27	0.30	3.50	0.003	0.032	0.013	6.3	4.0	3.2
	(0.60)	(0.10)	(0.14)	(0.78)	(0.004)	(0.023)	(0.015)	(1.7)	(1.0)	(0.2)

[1]Represents Embudo only; this was the only regional station out of three that was located predominantly downwind of the Cerro Grande fire (and LANL).
[2]Fresquez, P.R. and G.J. Gonzales. 2000. Soil, Foodstuffs, and Associated Biota. In: Environmental Surveillance at Los Alamos during 1999. *Los Alamos National Laboratory report (unpublished data)*, Los Alamos, NM.
[3]ULB = upper limit background (mean plus two sigma from 1995–1999 data averaged over three regional areas).
[4]Represents 10 perimeter stations; four located on north side, three on east side, one on west side, and one on southwest side of LANL.
[5]Represents 12 on-site (LANL) stations.

Table 2. Mean (±SD) Trace Element Concentrations in Surface (0- to 2-in. depth) Soils Collected from Regional, Perimeter, and On-Site Stations Before (1999) and After (6/1-19/00) the Cerro Grande Fire[1]

Location	Ag	Al	As	Ba	Be	Cd	Co	Cr	Cu	Fe	Hg
Regional Background Station[2]											
Pre[3]	1.0	2.9	1.0	87	0.62	0.20	4.3	12.0	5.7	1.4	0.01
Post	1.0	0.6	1.1	79	0.41	0.20	3.7	7.0	3.7	0.8	0.01
Perimeter Stations[4]											
Pre[3]	1.0	3.3	1.9	91	0.84	0.23	4.7	8.1	5.9	1.2	0.02
	(0.00)	(0.09)	(0.8)	(29)	(0.25)	(0.09)	(1.7)	(3.2)	(1.5)	(0.23)	(0.01)
Post	1.0	0.9	2.1	106	0.85	0.20	6.1	8.6	5.5	1.0	0.01
	(0.00)	(0.02)	(0.7)	(35)	(0.22)	(0.00)	(3.1)	(1.9)	(1.0)	(0.02)	(0.01)
On-site Stations (LANL)[5]											
Pre[3]	1.0	3.4	2.4	109	0.87	0.23	5.2	7.7	6.0	1.3	0.05
	(0.0)	(0.46)	(0.7)	(29)	(0.16)	(0.09)	(1.4)	(2.5)	(1.8)	(0.25)	(0.13)
Post	1.0	1.1	2.3	109	0.82	0.23	5.5	8.9	4.6	1.1	0.02
	(0.0)	(0.04)	(1.0)	(34)	(0.16)	(0.10)	(1.9)	(3.9)	(1.7)	(0.03)	(0.01)

Location	Mn	Ni	Pb	Sb	Se	Tl	V	Zn	CN
Regional Background Stations[2]									
Pre[3]	229	6.4	12	0.1	0.2	0.1	20	26	
Post	190	5.1	7	0.1	0.4	0.1	12	23	0.01
Perimeter Stations[4]									
Pre[3]	382	4.8	20	0.1	0.2	0.2	15	33	
	(135)	(2.2)	(7.8)	(0.07)	(0.00)	(0.08)	(6.7)	(8.4)	
Post	443	7.3	17	0.1	0.5	0.2	16	40	0.03
	(280)	(2.6)	(4.0)	(0.00)	(0.10)	(0.10)	(4.5)	(12.2)	(0.03)
On-site Stations (LANL)[5]									
Pre[3]	349	5.2	14	0.2	0.2	0.2	21	34	
	(129)	(1.7)	(2.8)	(0.00)	(0.00)	(0.06)	(4.5)	(7.4)	
Post	347	6.3	15	0.1	0.5	0.3	16	32	0.02
	(111)	(2.4)	(5.0)	(0.00)	(0.20)	(0.20)	(7.1)	(6.5)	(0.01)

[1]All trace elements, with the exception of Al, Fe and CN are reported on a ppm basis. Al and Fe are reported on a percent basis and CN is reported in mg/L.
[2]Represents Embudo only; this was the only regional station out of three that was located predominantly downwind of the Cerro Grande fire (and LANL).
[3]Fresquez, P.R. and G.J. Gonzales. 2000. Soil, Foodstuffs, and Associated Biota. In: Environmental Surveillance at Los Alamos during 1999. *Los Alamos National Laboratory report (unpublished data)*, Los Alamos, NM.
[4]Represents 10 perimeter stations; four located on north side, three on east side, one on west side, and one on southwest side of LANL.
[5]Represents 12 on-site (LANL) stations.

CG fire were statistically similar to soils collected before the fire in 1999 (Table 1). Similarly, all mean trace elements in soils collected from PM and LANL areas collected after the CG fire were statistically similar to soils collected before the fire in 1999 (Table 2). Although the regional BG site could not be statistically compared between years, all of the elements in soils collected after the fire were equal to concentrations in soils collected before the fire in 1999 and well within the long-term background statistical range (Fresquez et al., 1998). Also, CN, albeit no data exists before the fire, appears to be similar between all three sites.

Individual soil stations in LANL technical areas (TAs) most affected by the fire—TA-06, TA-15, and TA-16—contained radionuclides, radioactivity, and trace elements similar to concentrations in soils collected in 1999. Similarly, soils collected from the perimeter of LANL lands directly within the predominant path of the smoke plume (Airport area, North Mesa area, Sportsman's Club area, Tsankawi area), contained radionuclides, radioactivity, and trace elements similar to concentrations in soils collected in 1999.

Organic compounds—VOC, SVOC, PEST, PCB, and HE—were not detected above reporting limits in any of the soils collected within or around LANL (Table 3). Similarly, dioxin (TCDD) was not detected in any of the five soil samples analyzed. Of the other less toxic dioxin-like compounds analyzed, OCDD (1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin) and, to a lesser extent, HpCDD (1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin) were detected above reporting limits in most of the soil samples analyzed. These compounds, the least toxic of the six dioxin-like compounds analyzed, are by-products of natural (forest fires [recent studies show, however, that dioxin emissions from forest fires could represent resuspended material from aerial deposits rather than originally formed material]) and human-made (residential wood burning, municipal and industrial waste, etc.) sources. And the highest amounts detected in the soil collected near the airport (3.7 parts per trillion [ppt] of HpCDD, which is equal to 0 ppt toxicity equivalents [TEQ], plus 29.1 ppt of OCDD, which is equal to 0.029 ppt TEQ, equals 0.029 ppt total TEQ) were very far below the Agency for Toxic Substances and Disease Registry's soil screening level of 50 ppt TEQs (ATSDR, 1997). Since OCDD was detected upwind as well as downwind of the CG fire (and LANL) (concentrations

Table 3. Organic Compound Concentrations in Surface (0- to 6-in. depth) Soils Collected from Regional, Perimeter, and On-Site Stations After (6/1-19/00) the Cerro Grande Fire

Location	VOC[1] (ppb)	SVOC[2] (ppb)	PEST[3] (ppb)	PCB[4] (ppb)	HE[5] (ppb)	Dioxins[6] (ppt)
Regional Background Stations:						
Embudo	ND	ND[7]				OCDD (13.6)[8]
Cochiti	ND	ND				OCDD (12.0)
Jemez	ND	ND				
Cerro Grande			ND	ND	ND	ND
Perimeter Stations:						
Otowi	ND	ND				
TA-8 (GT Site)	ND	ND				
Near TA-49 (BNP)	ND	ND				
East Airport	ND	ND				
West Airport	ND	ND	ND	ND	ND	HpCDD (3.7)[9] OCDD (28.1)
North Mesa	ND	ND				
Sportsman's Club	ND	ND				
Tsankawi/PM-1	ND	ND				
White Rock (East)	ND	ND	ND	ND	ND	
San Ildefonso	ND	ND				
On-Site Stations:						
TA-16 (S-Site)	ND	ND	ND	ND	ND	OCDD (10.0)[10]
TA-21 (DP-Site)	ND	ND				
Near TA-33	ND	ND				
TA-50	ND	ND				
TA-51	ND	ND				
West of TA-53	ND	ND				
East of TA-53	ND	ND				
East of TA-54	ND	ND				
Potrillo Drive/TA-36	ND	ND				
Near Test Well DT-9	ND	ND				
R-Site Road East	ND	ND	ND	ND	ND	OCDD (10.0)[10]
Two-Mile Mesa	ND	ND	ND	ND	ND	OCDD (10.0)[10]

[1]VOC = Volatile Organic Compounds (36 compounds); [2]SVOC = Semivolatile Organic Compounds (71 compounds); [3]PEST= Pesticides (organochlorine) (21 compounds); [4]PCB = Polychlorinated biphenyls (7 compounds); [5]HE = High Explosives (14 compounds); [6]Dioxin and dioxin-like compounds (7 compounds); [7]ND = Not Detected above reporting limits; [8]OCDD = 1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin; [9]HpCDD = 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin; [10]these data reflect concentrations of OCDD detected in a composite sample that was comprised of soil from TA-16 (S-Site), R-Site Road East, and Two-Mile Mesa soil.

ranged from 9.9 to 22.4 ppt), it was therefore probably not related to the fire (Fresquez et al., 2000). (Note: The average soil concentration of dioxins in North America is 8.0 ± 6.0 ppt TEQ, and uptake from water into food crops is insignificant because of the hydrophobic nature of these compounds [EPA, 1994].)

CONCLUSIONS

Based on all available data, impacts to regional, perimeter, and on-site (mesa top) areas from radionuclides, radioactivity, trace elements, and organic compounds as a result of the CG fire, via smoke and fallout ash, were minimal.

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