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Surface Radioactivity at the Plowshare Gas-Stimulation Test Sites: Gasbuggy, Rulison, Rio Blanco

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S.H. Faller
Environmental Protection Agency
P.O. Box 93478
Las Vegas, Nevada 89193-3478

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
LAS VEGAS, NEVADA 89193-3478

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ABSTRACT

A surface soil characterization was conducted at three former underground nuclear test sites; Gasbuggy, New Mexico, Rulison, Colorado, and Rio Blanco, Colorado. The abundances of man-made and naturally occurring radionuclides were determined with their contributions to total exposure rates. ^{137}Cs was the only man-made radionuclide detected in the study and was highest at undisturbed locations with forest litter cover. The amounts observed are consistent with radiocesium fallout concentrations observed in other parts of the United States.

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INTRODUCTION

The Plowshare Program, which was initiated to investigate the feasibility of the use of nuclear explosions for peaceful purposes, included the study of large scale stimulation of low-productivity natural gas reservoirs. Three of these projects were conducted within the United States; Gasbuggy in northwestern New Mexico, and Rulison and Rio Blanco in central western Colorado (Figure 1). At each site, a nuclear device (or devices) was detonated in deep geological formations to shatter the surrounding rock and create artificial cavities for the accumulation of gas. Drill-back operations following the operations brought some radioactivity to the surface, and low concentrations of radionuclides were released in stack tests of the liberated gas. Decontamination and decommissioning projects were conducted at all three sites in which buildings, equipment, fluids, and soils were screened for allowable radioactive concentrations or surface activities. The nuclide of primary concern was tritium, but levels of alpha- and gamma-ray emitting isotopes were also determined. All contaminated substances were either removed from the sites for burial in low-level waste dumps or injected into project wells as slurry. Most building and testing materials have been removed from the sites, and the surface locations have been graded and reseeded (Chapman 1991, U.S. AEC 1973, U.S. DOE 1978, U.S. DOE 1983).

In 1991, a series of surface monitoring missions were begun to assess the extent of contamination at all former underground nuclear test locations away from the Nevada Test Site (Faller 1992,1994). The goal was to obtain data on the amounts and types of radionuclides at the sites for use in future remediation activities. In June of 1993, a characterization of selected locations at and around the original surface areas of these three sites was conducted.

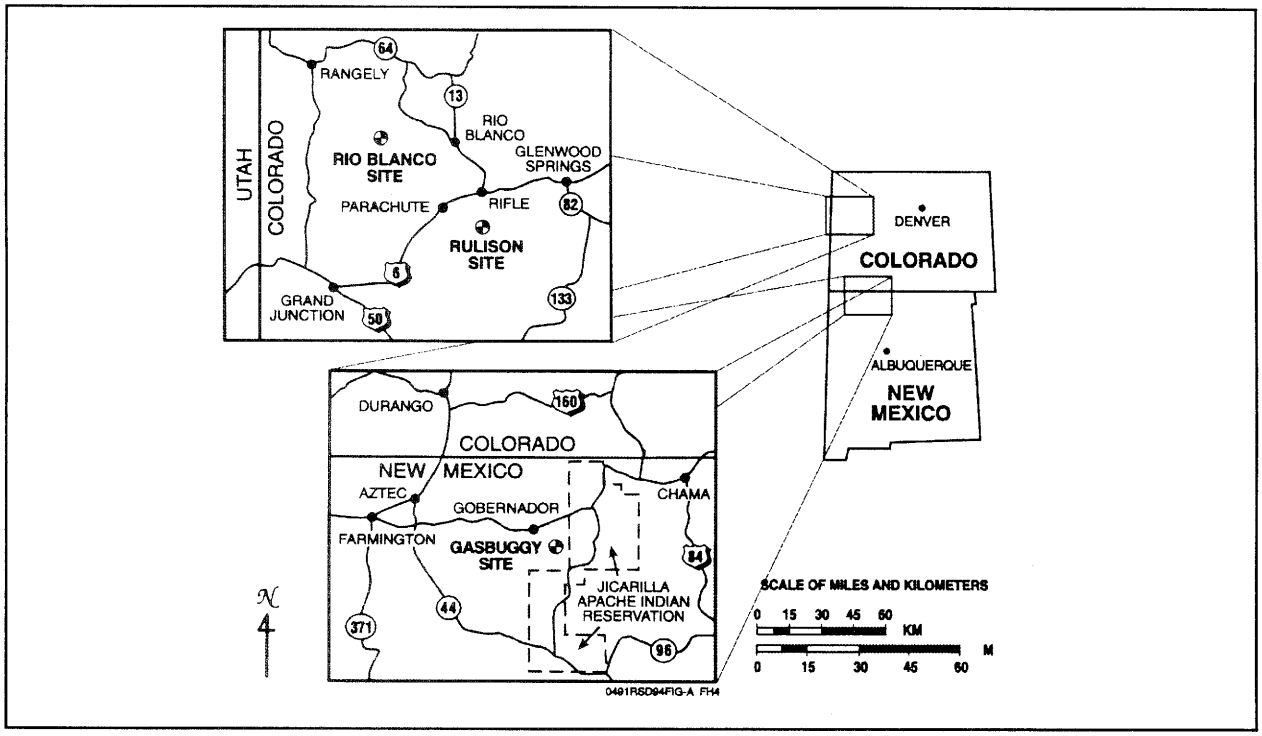

Figure 1. Locations of the Gasbuggy, Rulison and Rio Blanco gas stimulation sites.

METHOD

Gamma-ray spectra were obtained in the field with a high-purity germanium (HpGe) diode detector. The relative collection efficiency of the device was about 30%. Power was supplied by a portable battery pack system that also functioned as an amplifier, analog-to-digital converter, and multichannel analyzer. All spectra were recorded on miniature diskette for later analysis. The total gamma-ray flux was measured with a portable pressurized ion chamber (PIC) system for comparison with the in-situ spectrometry results. Typical data collection times were 30 min at a single location. Calibrations of the equipment were made using radioactive sources traceable to the National Institute of Standards and Technology. Exposure rate due to cosmic radiation was deduced from the barometric pressure at each location.

The method of obtaining surface activities and dose rates has been described in Helfer and Miller (1988), and Miller and Schebell (1993). Conversion factors applied to the observed gamma-ray peaks were calculated for the detector taking into account the detector response at various angles and source energies.

RESULTS

Tabulations of exposure rate contributions from radionuclides in the environment and from cosmic-ray flux are given in the following tables with PIC measurements made at the same times and locations. A comparison of the sums of the deduced contributions to the results of the PIC can be used as a measure of the accuracy of the in-situ method. Uncertainties in the HpGe and PIC measurements have been discussed in Hefler and Miller (1988) and Faller (1992). Exposure rate contributions from ^{40}K, and the ^{232}Th and ^{238}U series were calculated assuming a uniform distribution in the ground. No reduction in rate due to the de-emanation of radon gas was assumed. Also, the rate from ^{137}Cs was calculated using a depth distribution parameter, α/ρ, of 0.05, as no core samples were taken in this study. This distribution is extended and was selected because it represents a general upper limit of the exposure rate contribution.

GASBUGGY

The Project Gasbuggy Site is located in Rio Arriba County, New Mexico, approximately 55 mi (89 km) east of Farmington. The site lies on the eastern side of the San Juan Basin structure of the Colorado Plateau Province of northwestern New Mexico and southwestern Colorado. The surface elevation is about 7,100 ft (2,200 m) above sea level, and the surrounding area is hilly and forested. Average annual site precipitation is approximately 49 in (122 cm) (U.S. DOE 1986).

The Gasbuggy test, which was conducted on December 10, 1967, was the first gas stimulation experiment conducted in the United States. A nuclear device with a 29 kiloton yield was detonated at a depth of 4,240 ft (1,290 m) at the interface of the underlying Lewis Shale and Pictured Cliffs Sandstone formations. The explosion opened a cavity calculated to have a radius of 78 ft (24 m), which immediately collapsed to form a rubble filled chimney (Duff 1971). Re-entry drilling was performed in 1968, and a series of gas tests were performed until 1976. Site restoration took place from August to September of 1978 (U.S. DOE 1983).

A map of the Gasbuggy site showing the locations of the only operating well (10-36) and several plugged wells, is shown in Figure 2. Eight survey locations on and near the site are also shown. Results of all surveys are given in Table 1. The area surrounding the wellheads (survey locations 1-5, and 8) is level and grass cover. Survey locations 6 and 7 were taken in a forested area with extensive pine litter cover. Survey location 9 was in a rocky area near an arroyo with sparse ground cover.

RULISON

The Project Rulison Site is located in Garfield County, Colorado, about 40 mi (65 km) northeast of the city of Grand Junction. The site surface elevation is approximately 8,200 feet (2,500 m) above sea level, and is situated on the steep northern slope of Battlement Mesa at the upper reaches of Battlement Creek. The site receives an average annual precipitation of 20 in (50 cm) (U.S. DOE 1984).

The Project Rulison explosive was a 43 kiloton device detonated on September 10, 1969, at a depth of 8,426 ft (2,560 m) within the Mesa Verde sandstone formation. The explosion created a rubble-filled chimney approximately 270 ft (82 m) in height and 70 feet (21 m) in radius. Re-entry drilling to the cavity began in April of 1970, and production testing of liberated gas took place from October to April of 1971. Site cleanup activities were conducted in July of 1972 (U.S. AEC 1973).

Wells and survey locations at the Rulison site are shown in Figure 3. Results of the measurements are given in Table 2. The area surrounding plugged wells R-E and R-EX is sparsely covered with vegetation and gravel, and appears to be subject to frequent runoff. Survey location 3 (not shown) lies in a grass covered field 0.5 miles (0.8 km) west of the Rulison surface ground zero, adjacent to a pond that was used for the disposal of effluents during the project operations. Location 4 (not shown) was a graveled, sparsely vegetated field.

RIO BLANCO

The Rio Blanco Site is located in Rio Blanco County, Colorado, approximately 50 mi (80 km) north of Grand Junction. The site elevation is 6,600 ft (2,000 m) above sea level, and lies in an alluvial drainage area adjacent to Piceance Creek. The surrounding area is semi-arid with sagebrush cover, and consists of low, rolling hills and creek washes. The annual precipitation is about 13 in (33 cm) (U.S. AEC 1972).

The Rio Blanco nuclear test consisted of a simultaneous detonation of three 30 kiloton devices placed at depths of 5,840, 6,230, and 6,690 ft (1,780, 1,890, and 2,040 m). The test took place on May 17, 1973, and created three separate nuclear chimneys. A re-entry well to the top chimney was completed in late 1973, and a well to the bottom chimney in 1974. All stack testing was performed before the end of 1974, and site clean up operations were conducted from July to November of 1976 (Eberline 1978).

A map of the project Rio Blanco area is shown in Figure 4, with plugged and operating wells, and three survey site locations. Survey location 5 was in an arid wooded area uphill from the site. Results of the surveys are given in Table 3.

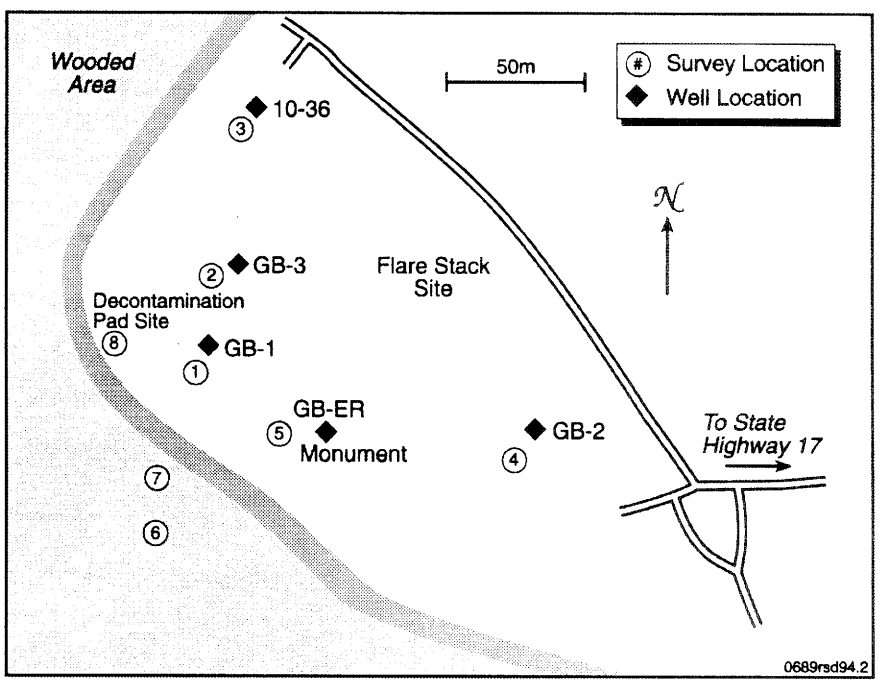

Figure 2. Project Gasbuggy Surface Ground Zero Site.

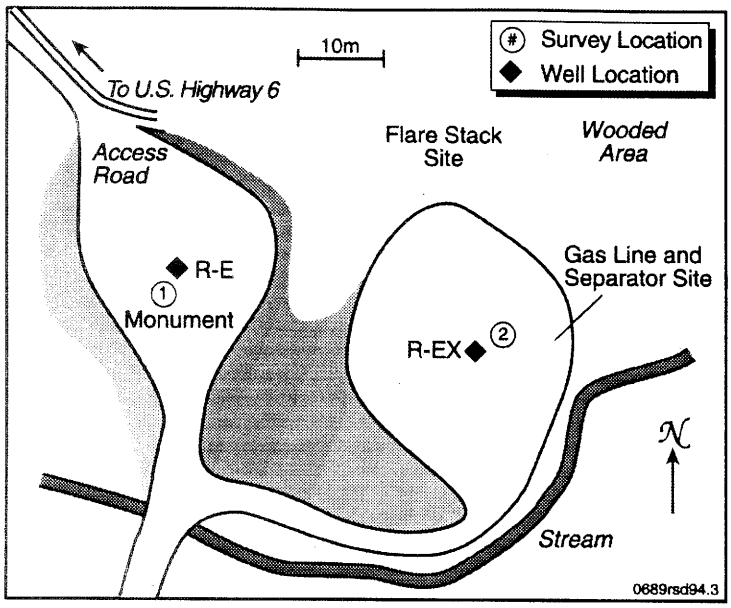

Figure 3. Project Rulison Surface Ground Zero Site.

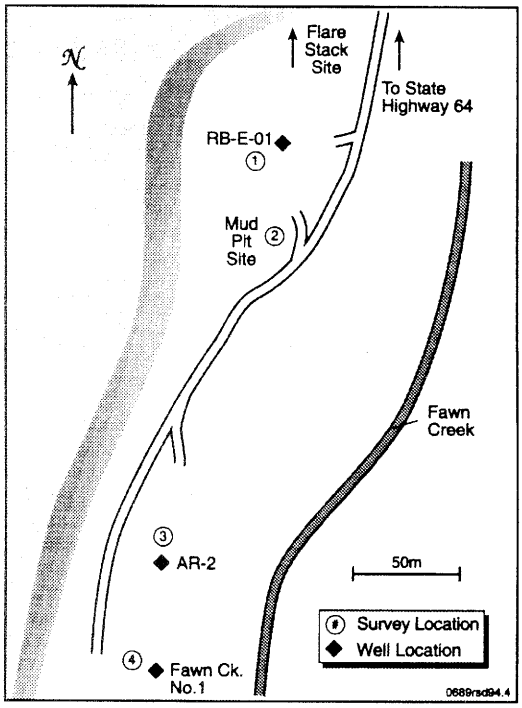

Figure 4. Project Rio Blanco Surface Ground Zero.

Table 1. Exposure rate inventories at Gasbuggy survey locations

	Exposure Rate (μR/h)[a]						
Location	Cosmic	^{40}K	^{232}Th[b]	^{238}U[b]	^{137}Cs[c]	Sum γ	PIC
1. Well GB-1 (reentry hole)	8.2	3.8	2.4	2.1	0.04	16.5	18.0
2. Well GB-3	8.2	1.8	3.1	2.7	0.03	15.8	17.5
3. Well 10-36 (monitoring hole)	8.2	3.9	2.9	1.9	0.06	16.9	17.5
4. Well GB-2	8.2	3.7	3.3	2.2	0.02	17.6	17.5
5. Well GB-ER (emplacement hole)	8.2	3.5	2.2	2.0	0.03	16.1	15.0
6. 50m South of Well GB-1	8.2	3.4	2.4	2.0	0.3	19.0	16.9
7. 40m south of Well GB-1	8.2	3.6	2.1	1.7	0.3	18.4	17.0
8. Decontamination Pad	8.2	3.9	4.0	3.4	0.02	19.6	20.0
9. Gobernador, N.M. 16 km northeast of Gasbuggy SGZ	7.3	4.4	4.7	3.8	0.08	20.2	19.0

[a] *1.0 μR/h = 9.1 nGy/h dose rate in air.*
[b] *Contribution from series.*
[c] *Assuming α/ρ = 0.05 (extended distribution).*

Table 2. Exposure rate inventories at Rulison survey locations

	Exposure Rate (μR/h)[a]						
Location	Cosmic	^{40}K	^{232}Th[b]	^{238}U[b]	^{137}Cs[c]	Sum γ	PIC
1. Well R-E (emplacement hole)	9.7	3.3	3.3	2.3	0.07	18.6	17.0
2. Well R-EX (reentry hole)	9.7	3.9	3.0	2.0	0.05	18.6	17.5
3. Effluent Pond	9.3	4.5	3.6	2.0	0.18	19.7	17.5
4. 32 km north of Rulison SGZ	8.6	2.9	2.7	1.7	0.04	16.0	15.7

[a] *1.0 μR/h = 9.1 nGy/h dose rate in air.*
[b] *Contribution from series.*
[c] *Assuming α/ρ = 0.05 (extended distribution).*

Table 3. Exposure rate inventories at Rio Blanco survey locations

	Exposure Rate (μR/h)[a]						
Location	Cosmic	^{40}K	^{232}Th[b]	^{238}U[b]	^{137}Cs[c]	Sum γ	PIC
1. Well RB-E-01 (EW) (reentry hole)	7.5	4.0	3.6	2.7	0.07	17.8	17.5
2. Well AR-2 (reentry hole)	7.5	4.0	3.7	2.5	0.07	17.8	16.5
3. Mud Pit Site	7.5	4.0	3.2	2.6	0.05	17.4	16.5
4. Well Fawn Creek #1 (disposal well)	7.5	3.6	3.6	2.6	0.05	17.3	18.0
5. 1.6 km northwest of Rio Blanco SGZ	7.5	5.9	1.7	2.3	0.2	17.6	17.3

[a] *1.0 μR/h = 9.1 nGy/h dose rate in air.*
[b] *Contribution from series.*
[c] *Assuming α/ρ = 0.05 (extended distribution).*

CONCLUSION

The sums of the deduced exposure rates and the total rates measured with the PIC are within the uncertainties expected of the analytical methods. The surveys taken at on-site locations in all cases are similar to those taken off-site. The only man-made radioactive isotope observed was ^{137}Cs, and was highest at off-site locations 6 and 7 at Gasbuggy, and location 5 at Rio Blanco. All three locations had extensive forest liter, which is known to accumulate fallout radiocesium (Witkamp and Barzansky 1968), and do not lie in areas of extensive drainage. The assumption of an extended depth distribution at these locations probably contributes to the calculated high rates, because the ^{137}Cs tends to reside primarily near the surface. An assumption of a purely surficial distribution ($\alpha/\rho=\infty$) reduces the deduced rates somewhat and corresponds to surface concentrations of 2.6, 2.5, and 1.2 pCi/cm^2 (0.97, 0.91, and 0.44 kBq/m^2), respectively. These activities are consistent with those observed at other locations in the United States with similar amounts of precipitation (Arnalds et al. 1989, Cox and Frankhauser 1984).

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