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A Research Report for Westinghouse Hanford Company

Surface Gamma-Ray Survey of SX Tank Farm

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D. C. Stromswold
R. J. Arthur

August 1996

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
Operated for the U.S. Department of Energy
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**Surface Gamma-Ray Survey
of SX Tank Farm**

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Summary

Measurements made over the surface of the SX Tank Farm at Hanford, Washington, show ^{137}Cs to be the only significant gamma-ray-emitting contaminant. A high-purity germanium detector, mounted 1 m above ground on a tripod, collected the data in the surface survey. Most of the detected radiation originated from specific above-ground objects, such as pipes and vents. One area of increased radiation in the north section of the tank farm, between tanks SX-102 and SX-105, was apparently due to contamination of the soil by ^{137}Cs . An area of interest near tanks SX-108, SX-111, and SX-112, below which borehole logs had indicated deep ^{137}Cs contamination, also showed ^{137}Cs at the surface, but the signal originated mainly from surface objects rather than from contaminated soil.

A significant result of the surface survey is the understanding that surface objects with contamination can affect the signal observed by borehole logging tools as they reach the ground surface. The borehole data may indicate an apparent increase in contamination at the ground surface, e.g., from a surface spill of radioactive liquid. However, the entire increase in signal might actually be due to radiation shine from nearby contaminated objects, such as pipes at or above the ground surface.

Surface surveys of all Hanford tank farms would provide data to aid interpretation of near-surface borehole data. The surface surveys would identify contaminated above-ground objects. The surveys would also provide a measure of the near-surface soil contamination if the detector is shielded to mainly view the ground when contaminated above-ground objects are present.

Acknowledgments

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Introduction

The SX Tank Farm has 15 buried, radioactive-waste tanks, each with a 4×10^6 liter (1×10^6 gallon) capacity. The tanks are 23 m (75 ft) in diameter, approximately 14 m (45 ft) tall with domed tops, and are covered by about 2 m (7 ft) of overburden. Extensive piping, some of which is on the surface, interconnects the tanks. Vents and access holes also extend to the surface. The ground surface above the tanks has various amounts of radioactive contamination resulting from past spills of radioactive liquid. The main gamma-rays measured at the ground surface are from ^{137}Cs .

The tank farm contains numerous boreholes around the tanks that are useful in monitoring subsurface contaminants that have leaked from the tanks or migrated down from the surface. Well logs obtained using high-purity germanium (HPGe) detectors show the presence of ^{137}Cs at many of these boreholes (DOE 1996). In particular, logs of some boreholes near tanks SX-109 and SX-112 indicate extensive ^{137}Cs at depths down to about 38 m (125 ft). Potential sources for the ^{137}Cs include tank leaks, pipeline leaks, and downward migration from surface spills.

In an attempt to determine the origin of the deep ^{137}Cs near tanks SX-109 and SX-112, new boreholes are being added in 1996. Before the ground was disturbed to make these boreholes, the SX-Tank Farm was surveyed for surface radiation to show the general surface contamination and identify any areas of high contamination. Areas of high contamination could indicate the location of prior surface spills that could subsequently move downward through the ground or along borehole casings. Pacific Northwest National Laboratory (Pacific Northwest) performed this surface survey for Westinghouse Hanford Company.

Equipment

A HPGe gamma-ray detector mounted on a tripod collects the surface gamma-ray data. The detector has an efficiency of 75%, relative to a 7.6×7.6 cm NaI detector. The detector is located 1 m above the ground and oriented downward, with its liquid nitrogen dewar on top. To maintain the same configuration used when the detector was calibrated, the detector has no side shielding.

Cables approximately 60 m (200 ft) long connect the detector to support electronics located in an air-conditioned trailer outside the tank farm. In this way, only the detector and cable are subjected to potential contamination. Figure 1 shows a diagram of the electronics, which use an Ortec data collection system. The analog to digital converter (ADC) uses 4096 channels to digitize each spectrum for energies up to about 3 MeV.

Figure 1. HPGe and Supporting Electronics for Data Collection

Calibration

The HPGe detector is calibrated for gamma-ray-emitting contaminants based on data collected at the U.S. Department of Energy's facility at Rocky Flats, Colorado. The calibration uses "point" sources of ^{60}Co , ^{137}Cs , ^{152}Eu , and ^{241}Am with intensities traceable to National Institute of Standards and Technology standards. These sources were mounted on a frame that rotated the sources around the detector to create radiation incident on the detector at various angles. The data were processed at Rocky Flats by R. T. Reiman to calculate the detector's sensitivity to a uniform distribution of gamma-ray-emitting sources in the ground (no published reference available). This method of calibration is similar to that of Helfer and Miller (1988). Although the individual spectra obtained during this calibration are no longer available, the calibration factors from prior processing of the data provide the necessary correlation between count rate and source concentration in the ground. The detection efficiency for the 662-keV gamma ray from ^{137}Cs , the main contaminant identified at the SX Tank Farm, is

Efficiency = 3.63 counts/second per picoCurie of ^{137}Cs per gram of earth material

In practice, however, at the SX Tank Farm, this calibration only calculates an "apparent" concentration of ^{137}Cs because the ^{137}Cs is mainly localized in surface objects rather than in the near-surface ground.

Figure 2 shows the approximate radial sensitivity for ^{137}Cs located in the ground at various distances from the detector positioned 1 m above the ground. As shown in the figure, the greatest signal fraction arises from the area directly below the detector and lesser contributions come from more distant rings. For a uniform source distribution with depth, most of the signal reaching the detector originates from the top 30 cm (1 ft) of the soil.

Figure 2. Approximate Radial Sensitivity for Detector 1 m above Ground Surface (Helfer and Miller 1988)

Data Collection

The detector was located at points on a grid that covered a rectangular area (91 x 152 m; 300 x 500 ft) above the tanks whose centers are 30 m (100 ft) apart. For most of the area, the grid lines were 15 m (50 ft) apart. In an area of particular interest near tanks SX-109 and SX-112, the grid lines were 7.6 m (25 ft) apart. Protrusions of surface piping and other equipment sometimes prevented placing the detector at the desired location. In these cases, the detector was offset with a notation of its actual position. Figure 3 shows the locations where data were collected.

Daily operation checks of the equipment consisted of collecting spectra from a small thorium source in a fixed position near the detector.

The counting time for most grid points was 300 s (real time before dead-time losses in the counting electronics). The high efficiency of the detector allowed short counting intervals, but in areas of highest surface contamination, the high efficiency produced very high count rates and dead times in excess of 50%.

In addition to the occasional problems from high count rates, some gain drifts were encountered. These were apparently due to the preamplifier being heated from the warm summer temperature, which sometimes exceeded 35°C (95°F). The relatively short data collection intervals helped to minimize problems from gain drifts.

Data Analysis

Peaks in the gamma-ray spectra allowed specific gamma-ray-emitting contaminants to be identified from the energy of the peaks. The only significant contaminant detected was ^{137}Cs , based on the 662-keV gamma ray. The number of counts in the peak at this energy provided the means for calculating the concentration of ^{137}Cs in the soil, using prior calibration. The computer program RAYGUN (Gunnink and Niday 1972; Gunnink and Ruhter 1980; Hensley et al. 1988) calculated the peak areas. This program is used routinely at Pacific Northwest to analyze gamma-ray spectra from waste disposal barrels and boxes. RAYGUN was used rather than the Rocky Flats spectrum analysis program previously used during calibration because RAYGUN located and calculated the counts in small peaks better. The original calibration was transferred to RAYGUN-analyzed peaks by processing some of the field data with both programs to establish the correlation between peak areas obtained from each program. Peak areas were then converted to concentrations using the detector's calibration and known gamma-ray emission intensities from radionuclides.

At the locations where excessive count rates were encountered, additional corrections to the count rates were made based on the observed peak for ^{40}K , a naturally radioactive nuclide found in nature. For these locations, the data collection live times calculated by the electronics were obviously incorrect because unrealistic values of ^{40}K resulted. Consequently, the times were adjusted to produce results consistent with other locations under the assumption that ^{40}K is fairly uniform, a reasonable assumption. The same adjusted times were then used to calculate count rates of the other gamma rays in the spectra. The dead time corrections using ^{40}K were necessary because dead-time corrections beyond those provided by the data acquisition electronics were not available. In the future, a separate dead time correction would be desirable, as well as using a less efficient HPGe detector if count rates remain high.

The computer program SURFER (Golden Software, Inc., Golden, Colorado) produced contours of the calculated concentrations using as input the detector location and calculated radionuclide concentration for each point on the grid that covered the SX Tank Farm. Data were entered in a standard spreadsheet format which was then used by the SURFER program as data input. Several gridding methods were available within the SURFER program for interpolating from the irregularly

Figure 3. Data Collection Locations (Indicated x-y grid intervals in units of "feet.")

spaced input values to produce a regularly spaced array of concentrations at a given grid density. The available gridding methods in the SURFER program fundamentally differ from each other in the way that weighted averages are computed and applied to the measured data values. The preferred gridding method is kriging because it is the most flexible method available. The option chosen for data representation in this application was kriging with no smoothing and with no anisotropic effects; a linear variogram model was selected to determine the way that localized observations were used and weighted when interpolating grid points.

Results

Figures 4 and 5 show the contour and 3-dimensional plots, respectively, of the calculated ^{137}Cs concentration, which is given in units of picoCuries of ^{137}Cs per gram of earth material (pCi/g). Table 1 contains the data used by the program SURFER to produce these figures. As shown in the figures, areas of distinct increases in calculated concentration are apparent. However, above-surface pipes, vents, and other structures at the SX tank farm complicate data interpretation. For example, the calculated high concentration shown on figure 4 at point "A" [grid location (X,Y) = (125,225)] southwest of tank SX-108 apparently arises from ^{137}Cs in an above-ground pipeline that bends downward and enters the tank. The increased radiation at this location may be due to the shine of radiation from the tank through the pipe opening. Some of these pipes entering the ground are wrapped with lead wool to reduce the gamma-ray transmission. In this case, the full-energy gamma-ray peak originating from a source inside the pipe is reduced, but a broad band of low-energy gamma rays results from scattering in the lead shielding.

Figure 6, which shows the location of the tanks and some surface objects, is useful in identifying possible surface objects that may be the origin of the observed radioactivity. Figure 6 is also included as a transparency at the back cover of this report. The transparency is useful for overlaying the contour plot of Figure 4.

Most other high-radiation anomalies for ^{137}Cs in Figures 4 and 5 also appear to arise from radiation emitted from surface objects, such as vents or pipes. These anomalies are seen at locations B (50,350), C (25,175), D (125,175), E (0,100), F (150,50), and G (250,50). As shown on Figure 6, these locations have surface objects noted by symbols. The objects above the centers of the tanks where increased radioactivity was observed (e.g., location B at tank SX-106 and location F at tank SX-114) are pump pits used during transfers of radioactive liquid. The elevated radiation near the edges of tanks SX-111 and SX-112 (locations D and C) originates from the condenser pits at those positions. The elevated ^{137}Cs at location E apparently comes from a surface pipe or building on the west side of the tank farm.

The high radiation from these surface objects overwhelms any variations in signal from the nearby surface soils, making useful calculations of soil contamination impossible at these locations. The calculated concentrations (pCi/g) are not those of the contamination in the ground. Instead they are "apparent" concentrations resulting from a mixture of radiation from the ground (for which the detector is calibrated) and from contaminated above-ground objects (for which the detector is not calibrated). Using a detector shielded around its sides would reduce the sensitivity to above-surface objects and focus the measurement on the ground below the detector. However, such a configuration would require many more data collection locations to cover the entire surface area of the tank farm.

Figure 4. Contour of Calculated ^{137}Cs Concentration (pCi/g)

Figure 5. 3-Dimensional Plot of Calculated ^{137}Cs Concentration (pCi/g)

Table 1. Calculated Concentrations from Surface Survey Data

Run No.	X (ft.)	Y (ft.)	Cs-137 (pCi/g)	Run No.	X (ft.)	Y (ft.)	Cs-137 (pCi/g)
96072213	0	0	6.9	96072210	150	0	12.5
96072202	0	50	51.9	96072206	150	50	522.1
96071905	0	100	340.5	96071816	150	100	44.7
96071906	0	150	25.8	96071811	143	157	58.4
96071907	0	200	12.4	96071813	150	175	47.5
96071908	0	250	21.6	96071815	145	200	59.9
96071909	0	300	41.3	96071814	150	225	171.8
96071913	0	350	55.7	96071806	147	250	138.8
96072416	0	400	40.1	96071912	150	300	36.4
96072417	0	450	101.2	96072407	150	350	24.2
96072418	0	500	101.2	96072405	150	400	424.2
96071820	25	150	57.7	96072406	150	450	133.0
96071612	25	175	453.1	96072403	150	500	27.6
96071613	25	200	15.5	96072209	200	0	11.0
96071614	25	225	19.2	96072207	200	50	38.3
96071615	25	250	27.2	96072306	200	100	33.2
96072212	50	0	16.2	96072307	200	150	37.8
96072203	50	50	24.4	96072313	200	200	30.7
96071903	50	100	73.3	96072314	200	250	35.3
96071819	35	150	54.8	96072315	200	300	18.2
96071601	50	175	27.7	96072322	200	350	44.3
96071602	50	200	19.4	96072323	200	400	30.5
96071603	50	225	31.6	96072328	200	450	38.6
96071801	60	245	53.4	96072402	200	500	181.7
96071910	50	300	35.8	96072301	250	0	9.3
96071914	50	350	404.8	96072208	250	50	131.5
96072415	50	400	40.9	96072305	250	100	54.8
96072413	50	450	49.7	96072312	250	150	34.6
96072412	50	500	71.5	96072311	250	200	28.1
96071818	75	150	98.7	96072317	250	250	29.0
96071610	75	175	21.3	96072316	250	300	37.4
96071608	75	200	24.8	96072321	250	350	8.1
96071605	75	225	42.5	96072324	250	400	110.3
96071802	75	250	108.6	96072327	250	450	39.3
96072211	100	0	10.2	96072330	250	500	57.5
96072205	100	50	20.8	96072302	300	0	6.8
96071902	100	100	57.7	96072303	300	50	21.2
96071817	100	150	48.8	96072304	300	100	23.8
96071611	100	175	27.2	96072309	300	150	49.4
96071607	100	200	52.9	96072310	300	200	27.4
96071606	100	225	210.4	96072318	300	250	19.6
96071804	100	250	98.6	96072319	300	300	31.6
96071911	100	300	34.5	96072320	300	350	33.4
96072408	100	350	28.0	96072325	300	400	28.9
96072409	100	400	38.6	96072326	300	450	30.3
96072410	100	450	13.3	96072329	300	500	36.1
96072411	100	500	79.7				
96071810	125	150	44.1				
96071809	125	175	405.1				
96071808	125	200	82.6				
96071807	125	225	1646.7				
96071805	125	250	122.7

Figure 6. Location of Buried Tanks and Surface Objects

The high radiation from surface objects would also be expected to produce increased count rates in gamma-ray logging logs as they reach the ground surface. This increased count rate would then appear to be the result of increased contamination at the ground surface. As shown in Figure 4, the effects of contaminated objects at or above ground level can extend to distances of at least 15 m (50 ft) through the air.

Only the ^{137}Cs anomaly at location H (150,400) between tanks SX-102 and SX-105 appears to be due to contamination in the soil, although a buried pipeline is nearby. If the increased ^{137}Cs signal were coming from the pipeline, an elongated response along the east-west direction of the pipe would be expected. The ^{137}Cs at this location may be due to a prior spill of radioactive liquid.

Only three spectra showed ^{60}Co . The highest concentration of ^{60}Co occurred at grid location (0,350) where 0.05 pCi/g was calculated. However, as with ^{137}Cs , the calculated concentration assumes uniform distribution of the source in the soil, whereas for the SX Tanks Farm, the source is probably located in a pipe or other object. Hence the calculated concentration is an "apparent" concentration that would produce the same gamma-ray signal.

Conclusions

The spectral gamma-ray measurements collected over the surface of the SX Tank Farm showed that surface objects such as pipes and vents were the main sources of the observed gamma-ray signal. Radiation from these surface objects would also reach detectors placed in nearby boreholes when the detectors reach the ground surface. Consequently, borehole logs that indicate increased contaminants at the ground surface likely result from the detector's sensitivity to above-ground contaminated objects, such as pipes or vents.

Surface surveys of all Hanford tank farms could provide valuable data for understanding the near-surface contamination and the effect of above-surface contaminated objects on borehole measurements made at the ground surface. In the absence of strong signals from contaminated objects (or if the surface detector is shielded on its sides) the data could indicate actual ground contamination, including areas of increased gamma-ray-emitting contaminants from spills at the ground surface.

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