

Appendix C
Detection Limits

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ENVIRONMENTAL SURVEILLANCE PROGRAM GAMMA SPECTROMETRY ANALYSES DETECTION LIMITS

Tables C-1 and C-2 give absolute detection limits in the right-hand column for each sample type. The absolute detection limits are the total activities that may be present in the sample aliquot taken for analyses. These activities should be detected under the counting conditions described and calculated according to the definition of L. A. Currie. This definition is as follows:

$$\text{Detection limit} = \frac{2.71 + 4.66 B^{1/2}}{t \times E \times P \times 2.22}$$

where

- B = Total correction in counts (Compton, background, blanks, etc., for the same counting time)
- t = Counting time in minutes
- E = Counting efficiency as a fraction
- P = Gamma-ray emission probability for the particular gamma ray being measured
- 2.22 = dpm/pCi.

The figures in the left-hand column of each sample type give the same detection limits expressed in terms of pCi/unit weight or volume for the average sample sizes expected to be analyzed. The absolute detection limits must remain constant for a given counting time and efficiency; therefore, the detection limits in terms of concentrations become higher or lower as the sample size actually used in the analyses becomes smaller or larger. Table C-3 presents descriptions of environmental monitoring samples for gamma spectrometry analyses and counting conditions for stated detection limits.

ENVIRONMENTAL SURVEILLANCE PROGRAM RADIOCHEMICAL ANALYSES DETECTION LIMITS

Tables C-1 and C-3 list approximate detection limits of present methods used to analyze the samples discussed in this report. These limits are based on sample sizes and forms as described in this report. Actual detection limits may vary depending upon background, yield, counting time, and sample volume.

The detection limits given in Table C-3 in terms of activity per unit weight or volume are derived from the total activities in microcuries (μCi) that must be present in the sample aliquot. The detection limits are calculated under the following conditions:

- A counting time of 1,000 minutes

- A counting efficiency of about 25%
- A chemical yield of about 80%
- Clean detector and reagent blanks that give not more than about 5 counts in 1,000 minutes in any given energy interval
- The calculation performed according to the definition of detection limits given by L. A. Currie as follows:

$$Detection\ limit = \frac{2.71 + 4.66 B^{1/2}}{t \times E \times Y \times 2.22E + 6} \mu Ci$$

where

B = Total background and blank correction

t = Counting time in minutes

E = Counting efficiency as a fraction

Y = Chemical yield as a fraction

$2.22E+6$ = dpm/ μ Ci.

These absolute detection limits, in terms of total microcuries per sample, are approximately 3E-6 for strontium-90 and approximately 3E-8 for all alpha-emitting nuclides. To determine the detection limits as activity concentration, the absolute detection limits must be divided by the sample size taken for analyses. On samples, the activity found is divided by the actual sample size analyzed or reported in terms of total activity per sample.

Table C-1. Absolute detection limits for waste management surveillances of air, water, and soil samples for gamma spectrometry.

Radionuclides	Air Filters		Water Filtrate		Water Insoluble		Soils	
	E-9 pCi/mL	Total pCi	E-2 pCi/mL	Total pCi	E-4 pCi/mL	Total pCi	pCi/g	Total pCi
Sc-46	1	6	0.2	8	5	2	0.19	120
Cr-51	5	3	1.1	44	20	8	0.5	300
Mn-54	0.5	3	0.5	20	3	1.2	0.1	60
Co-58	0.5	3	0.09	3.6	4	1.6	0.1	60
Fe-59	0.9	5.4	1.5	60	7	2.8	0.11	60
Co-60	0.8	4.8	0.8	32	6	2.4	0.2	120
Zn-65	1	6	0.5	20	15	6	0.2	120
Nb-94	0.5	3	0.15	6	4	1.6	0.1	60
Nb-95	0.5	3	0.11	4.4	80	32	0.1	60
Zr-95	0.8	4.8	0.3	8	7	2.8	0.11	60
Ru-103	0.7	4.2	0.16	6.4	4	1.6	0.1	60
Ru-106	5	30	0.12	4.8	40	1.6	0.5	300
Ag-110m	0.5	3	0.15	6	5	20	0.1	60
Sb-124	0.5	3	0.13	5.2	5	2	0.1	60
Sb-125	1.5	9	0.3	12	15	6	0.2	120
Cs-134	0.6	3.6	0.09	3.6	4	1.6	0.1	60
Cs-137	0.8	4.8	0.3	12	20	8	0.1	60
Ce-141	0.9	5.4	0.3	12	6	2.4	0.1	60
Ce-144	5	30	1.0	40	20	8	0.4	240
Eu-152	2	12	0.5	20	15	6	0.2	120
Eu-154	2	12	0.3	12	15	6	0.3	180
Eu-155	2	12	0.8	32	10	4	0.3	180

Table C-1. (continued).

Radionuclides	Air Filters		Water Filtrate		Water Insoluble		Soils	
	E-9 pCi/mL	Total pCi	E-2 pCi/mL	Total pCi	E-4 pCi/mL	Total pCi	pCi/g	Total pCi
Hf-181	0.6	3.6	0.12	4.8	6	2.4	0.1	60
Ta-182	2	12	0.5	20	20	8	0.4	240
Hg-203	0.5	3	0.15	6	2	0.8	0.1	60
Am-241	4	24	1.5	60	40	16	1.2	700
Gross beta	9.5	NA	NA	NA	NA	NA	NA	NA
Gross alpha	3.3	NA	NA	NA	NA	NA	NA	NA

Table C-2. Absolute detection limits for waste management surveillance of biotic samples for gamma spectrometry.^a

Radionuclide	Small Mammals		Vegetation	
	pCi/g	Total pCi	pCi/g	Total pCi
Sc-46	0.2	12	0.07	12
Cr-51	1.4	84	0.4	67
Mn-54	0.18	11	0.05	8.4
Co-58	0.3	18	0.05	8.4
Fe-59	0.6	36	0.08	14
Co-60	1	60	0.1	17
Zn-65	0.7	42	0.13	22
Nb-94	0.2	12	0.05	8.4
Nb-95	0.2	12	0.04	6.7
Zr-95	0.3	18	0.07	12
Ru-103	0.2	120	0.04	6.7
Ru-106	2	12	0.5	84
Ag-110m	0.2	12	0.05	8.4
Sb-124	0.2	12	0.04	6.7
Sb-125	0.7	42	0.11	18
Cs-134	0.3	18	0.04	6.7
Cs-137	1.3	78	0.13	22
Ce-141	0.2	12	0.05	8.4
Ce-144	1.1	66	0.16	27
Eu-152	0.6	36	0.1	17
Eu-154	0.7	42	0.15	25
Eu-155	0.6	36	0.1	17
Hf-181	0.2	12	0.04	6.7
Ta-182	1.1	66	0.3	50
Hg-203	0.16	96	0.05	8.4
Am-241	2	120	0.3	50

a. No biota samples collected in 2000.

Table C-3. Detection limits for environmental surveillance samples for radiochemical analyses.

Nuclide	Detection Limits			
	Air ($\mu\text{Ci/cc}$)	Water ($\mu\text{Ci/mL}$)	Soil ($\mu\text{Ci/g}$)	Veg. ($\mu\text{Ci/g}$)
Am-241, Pu-238, Pu-239, Pu-240	8 E-18	2 E-11	3 E-9	6 E-10
Sr-90	1 E-16	3 E-10	6 E-8	1.2 E-8
U-234	6 E-18	6 E-11	3 E-9	2 E-9
U-235 and U-238	4 E-18	4 E-11	6 E-9	1 E-9
H-3	1 E-11	—	—	—