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ENVIRONMENTAL RESTORATION PROJECT

A Department of Energy Environmental Cleanup Program

Washington Group International Environmental Restoration Project Standard Operating Procedure

for:

Use of Gamma Scintillation Detectors for Soil Screening

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Rev 0, 07/18/01	Rick Haaker	New Procedure	All
Rev 1, 06/23/03	Andrew Crowder	Change to non-site specific use	All

Use of Gamma Scintillation Detectors for Soil Screening

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Procedure for use of gamma scintillation detectors to estimate radionuclide concentrations in soil samples

NOTE: ER Project personnel may produce paper copies of this procedure printed from the controlled-document electronic file located at http://erinternal.lanl.gov/documents/Procedures/qps.htm. However, it is their responsibility to ensure that they are trained to and utilizing the current version of this procedure. The author may be contacted if text is unclear.

1.0 PURPOSE

This procedure describes the use of gamma scintillation detectors and the single channel analysis method to estimate and record concentrations of radionuclides in soil samples. The intended audience for this procedure includes health physicists, radiological engineers and instrument technologists.

2.0 SCOPE

2.1 This SOP is a mandatory document and shall be implemented by all ER Project participants when they perform soil gamma screening for americium-241 and cesium-137 for the ER Project.

2.2 Subcontractors who perform work under the ER Project's quality program shall follow this SOP for soil gamma screening for americium-241 and cesium-137 or use their own procedure, as long as the substitute meets the requirements prescribed by the ER Project Quality Management Plan and is approved by the ER Project's Quality Program Project Leader (QPPL) before starting the designated activities.

3.0 TRAINING

3.1 All users of this SOP are trained by reading the procedure in addition to hands on training, and the training is documented in accordance with QAP-2.1.

3.2 The **Field Team Leader** (FTL) shall monitor the proper implementation of this procedure and ensures that relevant team members have completed all applicable training assignments in accordance with QAP-2.1.

4.0 DEFINITIONS

NOTE: A glossary of definitions can be located on the ER Project internal homepage *http://erinternal.lanl.gov.*

4.1 Threshold Setting – The pulse height threshold in millivolts. In order to be counted, a photon must produce a voltage spike in the detector circuit that is greater than the threshold setting but less than the threshold setting plus window setting.

4.2 Window In - A configuration on a single channel analyzer that causes the scaler to only count photons that deposit a specific range of energy within the detector.

4.3 Window Setting - The width in millivolts of the window that determines how broad of an energy range of pulses can be counted by the scaler.

5.0 BACKGROUND AND PRECAUTIONS

Note: This SOP is to be used in conjunction with an approved SSHASP. Also, consult the SSHASP for information on and use of all PPE.

Note: This SOP is to be used only on characterized sites such as TA21-011(k) where the radiological contaminants are known and thus the potential interferences are understood. The response factors (GeoFac) provided in Tables A.1 and A.3 are appropriate for Los Alamos soils in the geometry specified. The GeoFac values that are provided should overestimate soil concentrations by about 30 per cent in most instances. The GeoFac values may need to be re-determined if any changes are made to the sample, detector, counting geometry, media to be screened or the isotopes of interest.

6.0 RESPONSIBLE PERSONNEL

The following personnel are responsible for activities identified in this procedure:

- Author
- Field Team Leader
- Quality Program Project Leader

7.0 EQUIPMENT

7.1 Suggested equipment and supplies needed to implement this procedure are:

- Ludlum 2221 Single Channel Analzyer, or equivalent;
- Gamma Scintillation Detector;
- Rubbermaid 14 oz low-form container (round shape);
- Saran wrap (or similar plastic cling wrapping material);
- Calibrated radiation source(s); and

- Calibrated scale.

7.2 The recommended detectors and energy ranges for cesium-137 and americium-241 are:

Isotope	Recommended Detector	Energy Range of Interest
Americium-241 photopeak	Eberline PG-2 or equivalent	45 to 75 KeV
Cesium-137 photopeak plus continuim	Ludlum 44-10 or equivalent	200 to 800 KeV

8.0 PROCEDURE

Note: Deviations from SOPs are made in accordance with QAP-5.1, Procedure Development and documented in accordance with QAP-5.4, Control of Field Notebooks.

Note: The following procedure contains a response factor that is a function of density, composition and geometry. The basis for the response factor must be documented in a memo to the project file.

8.1 The detector and sample geometry indicated in Figure 1 is mandatory. The low-form containers may be re-used without decontamination provided that they are lined with a thin layer of Saran Wrap (or equivalent) that is replaced each time a new sample is counted.

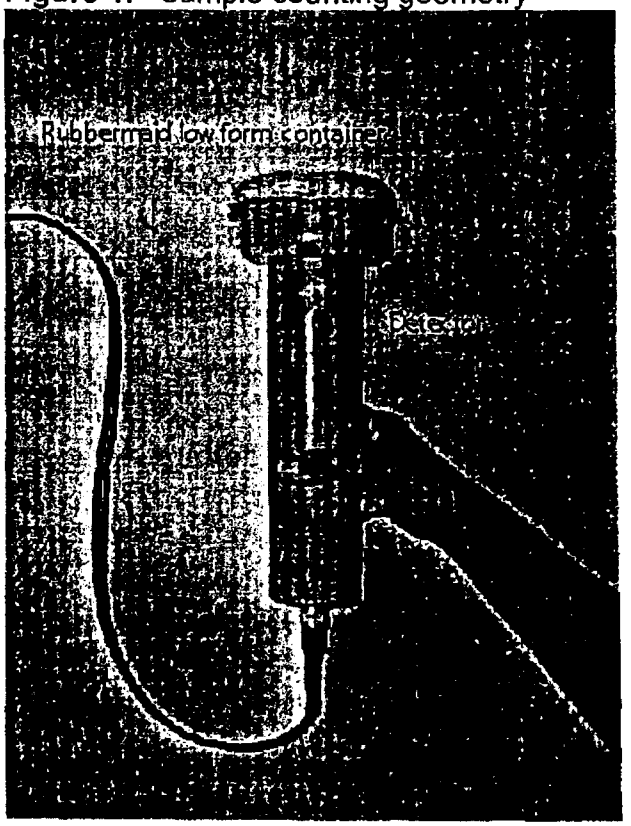
8.2 Preliminary Detector Setup. The following steps are involved in setting up the voltage, window and threshold. Setup for the americum-241 photopeak involves only a one-point calibration. Setup of the cesium-137 region of interest is slightly more complicated since it is based on a two point energy calibration.

8.2.1 Am-241 photopeak: Set up the ratemeter/scaler and PG-2 detector with the window "In" and the unit turned on. Adjust the high voltage reading to a low value (~400 volts) then adjust the threshold to 55 millivolts and the window to 10 millivolts. Place the Am-241 source directly beneath the detector. Roughly set the voltage by eye to give the maximum count rate. As you turn up the voltage, the count rate will gradually increase to a maximum value and then drop off again. Now, precisely set the voltage by performing a series of integrated counts at HV intervals of about 3 volts. Once the voltage giving the maximum count rate is obtained, set the instrument to that voltage. If a more intense Am-241 source is needed, any commercially manufactured

Am-241 source may be used to set the operating voltage. Once the voltage has been set adjust the threshold to 45.0 millivolts and the window to 30.0 millivolts to give a photon energy region of interest of 45 to 75 KeV.

8.2.2 Cesium –137 photopeak: Set up the ratemeter/scaler and Ludlum 44-10 detector with the window "In" and the unit turned on.

Figure 1. Sample counting geometry



Adjust the high voltage reading to a low value (~400 volts) then adjust the threshold to 63.1 millivolts and the window to 6 millivolts. Place the Cs-137 source directly beneath the detector. Roughly set the voltage by eye to give the maximum count rate. As you turn up the voltage, the count rate will gradually increase to a maximum value and then drop off again. Now, precisely set the voltage by performing a series of integrated counts at HV intervals of about 3 volts about the rough maximum voltage. Once the voltage giving the maximum count rate is obtained, set the instrument to that voltage.

8.2.3 Cesium-137 region of interest: Step 8.2.2 has been completed on the ratemeter/scaler and Ludlum 44-10.

8.2.3.1 Replace the cesium-137 source with an americium-241 source and then set the window to 2 millivolts. Gradually turn down the threshold and observe the count rate. The count rate should reach increase to a maximum at a threshold of around 5 mV. If a more intense Am-241 source is needed, any commercially manufactured Am-241 source may be used to determine the threshold setting. Record the threshold and window values for the maximum count rate in the field logbook.

8.2.3.2 Now solve the linear equation for KeV gamma energy versus millivolts: (1) step 8.2.2 produced results 661 KeV and 66.1 mV, and (2) step 8.2.3.1 produced results "60 KeV" and "THRESHOLD + 1 mV".

8.2.3.3 Calculate the mV setting that correspond to 200KeV and set the threshold to that value.

8.2.3.4 Calculate the mV setting that corresponds to 800 KeV. Set the window so that the window and threshold mV values sum to this mV value.

8.3 Response Factor. If media other than soil or crushed tuff will be counted, estimate a preliminary response factor for each type of detector used, if possible. The response factors may be modeled using MCNP or other appropriate software. The basis of the response factor shall be described in a memo to the project file. Once analytical data is obtained from a fixed laboratory, the response factor may be adjusted. The equations given in the Attachment assume that the response factor has the following units:

$$(\text{Counts / Photon Emitted})_{\text{volume source}} / (\text{Counts / Photon Emitted})_{\text{disk source.}}$$

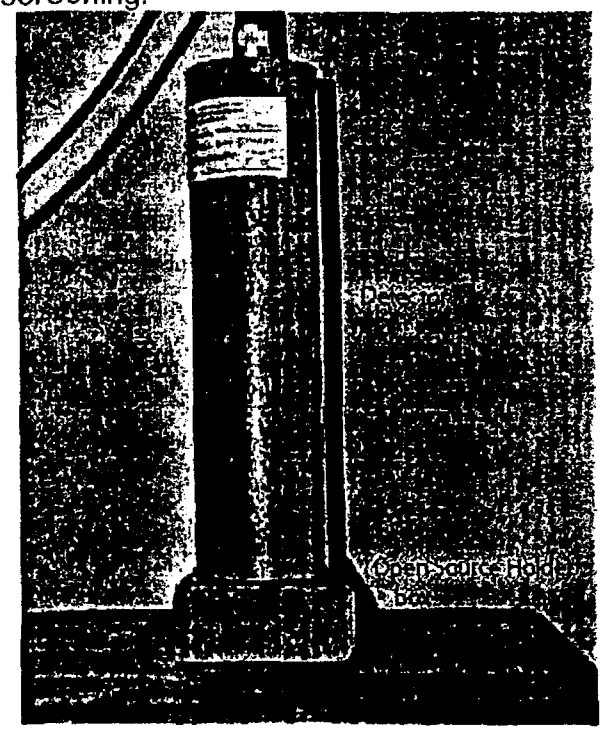
8.4 Daily Operability checks. Perform the following checks before the first use of the day:

8.4.1 <u>In the WGI office,</u> verify operability of the ratemeter/scaler detector. Check battery reading. Verify current calibration date and settings for High Voltage, Window and Threshold. Record the readings in your field logbook.

8.4.2 <u>In the WGI office,</u> perform a response check. Count the cailbrated source and background for 120 seconds. Use a calibrated source in the configuration shown in Figure 2 for the PG-2 (Am-241 source). Use a calibrated source and the configuration shown in Figure 3 for Cs-137. For the Ludlum-44-10, both the 16.8 cm distance between the Cs-137 source and the detector and the orientation are mandatory. Record the readings.

8.4.3 At the fixed counting location, set up the instrument on-site in the configuration shown in Figure 1.

Figure 2: Am-241 Source Check Configuration. The detector shown is a Ludlum 44-10. Normally an Eberline PG-2 would be used for Am-241 soil screening.



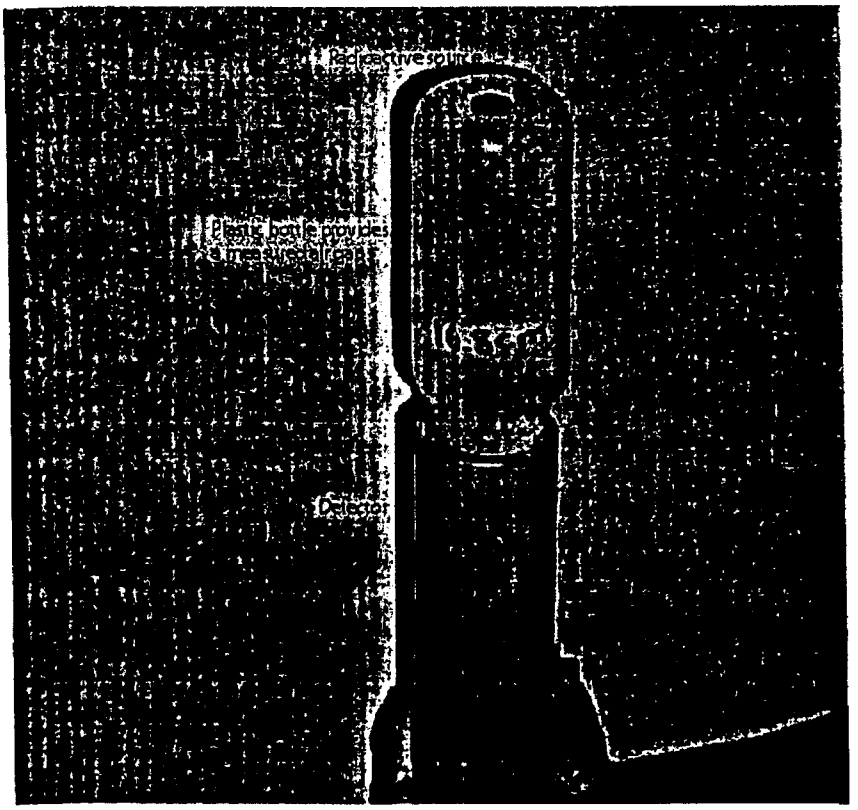
8.4.4 Measure the number of counts in the count interval on a "reference" soil sample collected from an area in the vicinity of the site that is free of radiological contamination. Record the count result (counts) and count duration (seconds or minutes).

8.4.5 Weigh the calibration masses alone and in combination to obtain a scale response for the 400, 700, and 1200 gm masses. The balance performance is acceptable for site gamma screening if all of the measured weights of the calibration masses are within 5 g of the expected values.

8.4.6 Determine the tare weight on an empty Rubbermaid container with lid.

8.4.7 Record all information in a logbook.

Figure 3. Cs-137 source check configuration



8.5 Counting samples. Once the equipment has been response checked for the day, you may proceed to counting the samples.

8.5.1 Determine the gross weight of the sample, including the container cover.

8.5.2 Measure the number of counts in the count interval on the soil sample and note the duration of the count (seconds or minutes).

8.5.3 Enter all data in a field notebook.

8.5.4 Review the data and results.

8.5.5 If a lower detection limit is desired, count the background "reference" (step 8.4.4) and samples (step 8.5.2) for a longer time period. 60-second counts on the reference and samples are expected to give a minimum detectable activity of roughly 10 pCi/g.

8.6 Calculations. The sample problem given in the Attachment provides all equations used in the estimation of concentrations and MDAs.

8.7 Daily Software Checks. Run the test problem to verify that the software calculates the same result for the test problems once rounding error is taken into account.

8.8 Data Management. Record all data in a field logbook or on forms. Suitable forms can be printed out for almost all data from the Microsoft Access database for the counting data.

9.0 REFERENCES

The following documents have been cited/used within this procedure:

- WGII Contractor's Quality Management Plan for the ERPDP
- WGII QAP2.1, Indoctrination and Training
- WGII QAP 4.1, Site Document Control
- WGII QAP 4.2, Site Records Management
- WGII QAP 5.1, Procedure Development
- WGII QAP 5.4, Control of Field Notebooks

10.0 RECORDS

The **FTL** is responsible for submitting the following records (processed in accordance with QAP-4.2, Site Records Management) to the Records Processing Facility.

- Field Notebook
- Sample Collection Logs
- Chain of Custody Forms
- Microsoft Access counting database file

11.0 ATTACHMENTS

11.1 Attachment A: Calculations and Test Problem

Calculations and Test Problem

The pertinent equations used for both Cs-137 and Am-241 estimates are:

Net Weight (NetWt):

NetWt = GrossWt – TareWt

Efficiency (cpm/pCi) (Eff):

Eff = [(SourceCt / SourceS) - (BkgdCt / BkgdS)] * 60 * 2.22 / SA

Net CPM (NetCPM):

NetCPM = [(SampleCt / SampleS) - (SoilBkgdCt / SoilBkgdS)] * 60

Estimated Activity (pCi/g) (EstAct):

EstAct = NetCPM / (Eff * GeoFac * NetWt)

Estimated Minimum Detectable Count Rate (MDCPM):

MDCPM = (3 + 3.29 * ([SoilBkgdct / SoilBkgdS] * SampleS *

(1 + [SampleS / SoilBkgdS])) $^{0.5}$) * 60 / SampleS

Estimated Minimum Detectable Activity (pCi/g) (EstMDA):

EstMDA = MDCPM / (Eff * GeoFac * NetWt)

Am-241 test problem

Table A.1 Test Input Data for Am-241 Test Problem.

Description	Name	Value
Sample Count Result	SampleCt	20000
Gross Weight of the sample with lid	GrossWt	600
Calibrated Source Count Result	SourceCt	3000
Background Count Result	BkgdCt	500
Reference Soil Count Result	SoilBkgdCt	550
Source Count Duration, Seconds	SourceS	60
Sample count Duration, Seconds	SampleS	120
Background count duration, seconds	BkgdS	180
Reference Soil Count, Seconds	SoilBkgdS	240

Source Activity, dpm	SA	15400
Container Tare Weight with Lid	TareWt	30
Response factor	GeoFac	*

The Am-241 test calculations shall produce the results provided in Table A.2 once round-off is taken into account. If this result cannot be reproduced, contact the author of this procedure.

Table A.2. Am-241 Test Problem Results.

Description	Name	Value
Net Weight	NetWt	570
Efficiency	Eff	0.4084415584
Net CPM	NetCPM	9862.5
Estimated Activity (pCi/g)	EstAct	270.3879
Estimated Minimum Detectable Count Rate	MDCPM	34.91010794
Estimateed Minimum Detectable Activity (pCi/g)	EstMDA	0.9570870

Cs-137 test problem *

Table A.3. Test Problem Data for the Cs-137 Test Problem

Description	Name	Value
Sample Count Result	SampleCt	70000
Gross Weight of the sample with lid	GrossWt	600
Calibrated Source Count Result	SourceCt	100998
Background Count Result	BkgdCt	18234
Reference Soil Count Result	SoilBkgdCt	37000
Source Count Duration, Seconds	SourceS	360

* For Am-241 only, GeoFac = 0.093756 + 4.2955 E-5 (Tare Wt – Gross Wt)

Sample count Duration, Seconds	SampleS	380
Background count duration, seconds	BkgdS	320
Reference Soil Count, Seconds	SoilBkgdS	300
Source Activity, dpm	SA	5994000
Container Tare Weight with Lid	TareWt	30
Response factor	GeoFac	7.6038

The Cs-137 test calculations shall produce the results provided in Table A.4 once round-off is taken into account. If not, contact the author of this procedure.

Table A.4. Cs-137 Test Problem Results.

Description	**Name**	**Value**
Net Weight	NetWt	570
Efficiency, cpm/pCi	Eff	0.004961944
Net CPM	NetCPM	3652.631579
Estimated Activity (pCi/g)	EstAct	28.08187
Estimated Minimum Detectable Count Rate	MDCPM	169.7863368
Estimateed Minimum Detectable Activity (pCi/g)	EstMDA	1.305338