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MAR 2001
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March 6, 2001

Ms. Eliza Frank
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Reference: Work Assignment No. Y513, 06082.500; State of New Mexico Environment Department, Santa Fe, New Mexico; General Permit Support Contract; Los Alamos National Laboratories (LANL)-1B; Draft Mesa-Top Material Disposal Area; Summary of Field and Laboratory Screening Methods for Radiological Contamination; Task 01 Deliverable

Dear Ms. Frank:

Enclosed please find the deliverable for the above-referenced work assignment. This deliverable consists of a summary document which briefly discusses common practices associated with conducting radiological field screening and laboratory analysis of field samples. In addition, a table entitled "U.S. EPA Drinking Water Methods for Radionuclide Parameters" has been included in the document for easy reference.

If you have any questions, please feel free to contact Ms. Phebe Davol at (254) 793-3419 or Ms. Paige Walton at (801) 582-9329.

Sincerely,

June K Dreith

June K. Dreith
Project Manager

32371

Enclosure

cc: Mr. John Kieling, NMED
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TASK O1 DELIVERABLE

SUMMARY OF FIELD AND LABORATORY SCREENING METHODS FOR RADIOLOGICAL CONTAMINATION

Los Alamos National Laboratories (LANL)-1B;
Draft Mesa-Top Material Disposal Area

Submitted by:

TechLaw, Inc.
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Submitted to:

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In response to:

Work Assignment No. Y513, 06082.500

March 2001

Summary of Field and Laboratory Screening Methods for Radiological Contamination

The following text summarizes some common practices in conducting radiological field screening and laboratory analysis of field samples. The discussion is based upon professional judgment and only the most applicable and widely used, cost effective, and accepted methodologies and instruments are discussed. More detailed information was provided for tritium and other select isotopes (Sr-90, Cs-137, Pu-239 and U-238). Summary tables are provided for each section of text.

Survey Preparations

Prior to conducting any radiological surveying, it is important to have an idea of the radioisotopes and the type of radiation (alpha, beta and/or gamma) each isotope emits. Once the instrument or instruments for use have been chosen, it is important that the instruments are properly calibrated by a qualified laboratory. Often the instruments will require calibration to a specific isotope, thus prior knowledge of the contaminants that may be present is helpful. When possible, the instruments should be calibrated using a National Institute of Standards and Technology (NIST) traceable source, which is a fairly standard practice. Each day prior to using a survey meter, the batteries and high voltage should be checked. If using a gas-dependent probe, the gas should have been fully purged from the probe. At least once daily, the probes should be source-checked to ensure proper working order. Typically three one-minute readings are taken. There should not be more than a 20% variance by day in the source readings. To help maintain consistency of readings, the probes should be checked in the same area each day and that area should be free of radiological contamination. A daily log of the instrument, serial number, probe, probe number, battery check, maintenance performed, and source check (source identification and reading) should be maintained.

Once the instruments have been checked, background radiation levels should be determined. Background readings are important if gross radiation readings are to be taken. Since all background materials contain naturally occurring radionuclides (NORM), it is essential to know how much of the field reading is due to NORM and how much is contributable to site contamination. Background should also be taken if radionuclide-specific measurements are to taken, for the same reason for gross readings. Selection of a proper background is very important. The background should be non-contaminated and should be of a similar geological makeup as the area to be surveyed. If concrete or another type of material is to be surveyed, a similar type of material of similar age should be used as background. Often more than one background is required. Proximity to the survey area is not important. At a minimum, three one-minute background readings should be taken for survey meter/probe to be used. This data should be recorded in the log. The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575, provides a good discussion on selection of background reference areas.

Summary of Field Preparations

1. Identify potential radionuclides of concern.
2. Determine type of radiation each radionuclide emits (alpha, beta, and/or gamma).
3. Identify medium to be surveyed (soil, soil core, concrete, swipe, etc.).
4. Select most appropriate instrument system (survey meter and probe).
5. Obtain the instruments and ensure they have been properly calibrated.
6. Each day, conduct a source check of the instruments to be used. Record.
7. Select the appropriate background area or areas.
8. Obtain at least three one-minute counts in each background area. Record.

Field Techniques for Tritium (H-3)

Tritium is a very low-energy beta emitter, with a half-life of 12.3 years. Due to the low energy emissions, some of the more typical field survey instruments used to detect beta radiation are not appropriate. For example, the low energy betas from tritium cannot penetrate the Mylar window on a Geiger-Meuller pancake detector. The other beta detector is a gas-flow proportional counter, but this is used primarily on flat surfaces. The best field screening methods for detection of tritium for soil, vapor, liquids, and swipes are summarized in the following table and are discussed in the text below. While other methods may be available, the methods discussed below are based upon professional judgment obtained through years of field experience.

Summary of Field-Screening Techniques for Tritium

Matrix	Method	Result
Soils/Solids	1. Electret Ion Chamber 2. Liquid Scintillation Counter (LSC)	1. Gross beta 2. Concentration
Vapor (Air)	Silica gel tube and LSC	Concentration
Water	LSC	Concentration
Swipe (loose contamination)	1. LSC – unprepared 2. LSC - prepared	1. Gross beta 2. Concentration

Soils (Solids)

There are two primary field-screening methods used to detect tritium in soils or other solids (e.g., tuff). The first option, the electret chamber, can be used to scan a core to determine gross beta levels. The liquid scintillation counter can be used to determine a more definitive concentration.

1. Electret Ion Chamber

An electret ion chamber is used to detect low energy beta, alpha gamma and/or radon. The chamber is opened to the surface and placed directly on the area to be measured to allow the tritium beta particles to enter the chamber. The charge before and after deployment is measured. The rate of change of the charge is proportional to the beta activity. Background corrections for all gamma radiation and radon must be made. Background is determined by deploying a separate electret run in parallel with the electret used to determine the field reading. For determining gamma radiation, the window to the chamber is not opened, but left closed.

The lower limit of detection is dependent on the exposure time and the volume of the chamber used. The longer the deployment time, the lower the level of detection. Typically for beta radiation, due to tritium, the detection limits are 6,000 dpm/cm^2 at one hour and 300 dpm/cm^2 at 24 hours (MARSSIM, 2000).

2. Liquid Scintillation Counter (LSC)

The LSC can be used in both the field and the laboratory and is primarily used to detect alpha and beta radiation. A tritium standard is run through the LSC first, and then the results of the sample runs are compared to the spectrum of the standard, resulting in an approximation of the concentration of tritium.

Samples are placed into a vial with an LSC cocktail solution. This solution, provided by a laboratory, is a combination of a solvent, an emulsifier and a fluorescent solute. Raw samples can color or cloud the LSC cocktail solution, causing the sample to adsorb the radiation before it reaches the LSC cocktail. This process, called quenching or pulse quenching, will result in an underestimation of the activity. Thus, to prevent quenching, a small amount of sample is typically oxidized with a field oxidizer prior to placing in the vial with the LSC cocktail solution. The field oxidizer typically has tungsten coils, which will burn the sample. A vial is attached to the oxidizer, and the fumes from the oxidation process are caught within the vial with the cocktail solution. The vial is then put into the LSC. A website that provides an excellent discussion on the LSC and LSC cocktails is:
http://laxmi.nuc.ucla.edu:8248/M248_98/autorad/Scint/scint1.html.

The accuracy of the results from an LSC is dependent upon the calibration of the instrument and sample preparation. The LSCs are calibrated and certified as calibrated by the provider of the instrument, either the company or laboratory.

Vapor (Air)

Vapor (air) concentrations of tritium are typically measured using a silica gel cartridge. The cartridge is connected to a pump, similar to that used for a continuous air sampler. The end of the cartridge is opened to the ground. Often a shield will be placed over the cartridge so that only emissions from the ground are captured. Once the sample has been obtained, the vial is sealed. A sample of the silica gel is put into a vial with an LSC cocktail solution and counted.

A tritium standard is run through the LSC first, and then the results of the sample runs are compared to the spectrum of the standard, resulting in an approximation of the concentration of tritium. The accuracy of the results from an LSC is dependent upon the calibration of the instrument and sample preparation. The LSCs are calibrated and certified as calibrated by the provider of the instrument, either the company or laboratory.

Water

Once a water sample has been taken, some of the sample is placed into a vial with the LSC cocktail solution. The sample is then counted.

A tritium standard is run through the LSC first, and then the results of the sample runs are compared to the spectrum of the standard, resulting in an approximation of the concentration of tritium. The accuracy of the results from a LSC is dependent upon the calibration of the instrument and sample preparation. The LSCs are calibrated and certified as calibrated by the provider of the instrument, either the company or laboratory.

Swipes

Frequently a physical sample of a solid is not warranted, but the sampler may still want to know if any loose (versus fixed) surface contamination is present. In these cases, a swipe sample may be taken. For preliminary results, the swipe may be placed into a vial with LSC cocktail solution and analyzed. However, for more detailed results, the sample should be prepared, similar to a soil sample, through ashing.

A tritium standard is run through the LSC first, and then the results of the sample runs are compared to the spectrum of the standard, resulting in an approximation of the concentration of tritium. The accuracy of the results from an LSC is dependent upon the calibration of the instrument and sample preparation. The LSCs are calibrated and certified as calibrated by the provider of the instrument, either the company or laboratory.

General Field Screening Instrumentation

The proper survey detector to be employed during a field survey depends upon the radionuclides of concern and the type of material to be surveyed (soil versus a flat surface). Frequently, it is too difficult to survey for the primary isotope of concern (it may be an alpha emitter) in a certain medium (soil), therefore, detection may rely on detection of the radionuclide's progeny. Thus, it is important to know what type of radiation the radioisotopes of concern emit.

Most field radiation detection systems detect a gross radiation reading (gross alpha, beta or gamma). Therefore, it is important to know what your background radiation levels are. The difference between the field measurements at the area of concern and background levels represents the net radiation. It is very important that the background selected is representative of the area of concern (e.g., similar geology) in order to most accurately define the radiological conditions attributable to site activities.

The following field detectors are recommended based upon professional experience. The discussed list does not cover all possible detectors available and/or necessarily applicable. The below table summarizes detectors by medium and radiation. A more detailed discussion of information provided within the table is in the following text.

Summary of Commonly Used Field Instruments

Type of Radiation	Field Equipment (Detector)	Comments
Alpha	ZnS(Ag) Scintillation Gas-flow proportional counter, alpha mode	- Not recommended for soils. Only use on smooth, flat surfaces. - Not recommended for soils. Only use on smooth, flat surfaces. Note: For soils, usually rely on beta or gamma radiation from progeny.
Beta	Gas-flow proportional counter, beta mode GM pancake	- Use on flat surfaces for greatest efficiency, gross beta results. - Versatile, use for soils (cores), swipes. Use on uneven surfaces, gross beta results.
Gamma	NaI scintillation FIDLER	- General probe for gross gamma of soils, use for U-238 only if high concentrations. -Use for low-energy gammas, Pu-239 and U-238, either gross gamma or nuclide-specific, can use on soils.

	MCA (Multi-Channel Analyzer)	- Estimates radionuclide-specific concentrations for soil, water or air samples.
Recommendations for screening for specific radionuclides in cores samples and soils: Sr-90: GM pancake Cs-137: GM pancake Pu-239: FIDLER, MCA U-238: FIDLER, MCA		

Alpha Emitters

Alpha radiation is difficult to detect, due to their low ability to penetrate and the shortness of range in air. Alpha radiation is most easily measured when the surface being surveyed is a smooth, flat surface. For this, a silver activated zinc sulfide, ZnS(Ag), alpha scintillation meter or a gas-flow proportional counter in alpha mode may be used. If swipes are taken, an alpha scintillation meter can be used to read the swipes.

However, in the field, especially when dealing with a porous medium such as soil, alpha detection is very difficult. There are detection systems that can be used, however, most surveys are conducted relying on the detection of either beta or gamma emissions from the progeny of the primary radioisotope of concern. For example, U-238 and Pu-239 primarily emit alpha radiation, however, detection of U-238 is usually through detection of the beta and gamma energy from its progeny and Pu-239 is detected through the low-energy gamma emissions.

Beta Emitters

There are two primary detectors used in the field to detect beta radiation: a gas-flow proportional counter and a Geiger-Mueller (GM) meter with a beta pancake probe (pancake).

The gas-flow proportional counter can be used to measure gross beta contamination present on relatively flat surfaces (e.g., a concrete slab). The detector must be held as close to the surface as possible to maximize efficiency. Therefore, the less surface contact the detector has, the less efficient the measurements. The detectors are charged using a P-10 gas (10% methane and 90% argon), but the detector may be disconnected and used in the field typically for three to four hours before requiring to be recharged. The detector operating voltage is set for sensitivity to beta radiation. Some low energy gamma may be detected, but the efficiency is very low. This system would be applicable for Sr-90 and Cs-137, if the surface of contamination is relatively flat.

The GM pancake probe is easy to use and useful for detection of higher energy beta and gamma radiation. Since the detector is relatively small (approximately two-inches in diameter), the detector can be used on more irregular surfaces. The GM pancake is a

very useful screening probe, and could be used to screen for the presence of beta energy from Sr-90 and Cs-137. The pancake may be used on soils and to analyze swipes.

Gamma Emitters

There are several types of gamma detectors that are used in the field. The selection of which is best is dependent on the energy of the gamma radiation and whether a gross gamma or semi-quantitative result is desired. The sodium iodide scintillation detector and the FIDLER probe are used to detect gross gamma contamination. A field portable Multi-Channel Analyzer (MCA) is used to determine more specific concentrations of specific radioisotopes.

The sodium iodide (NaI) scintillation meter is probably the most commonly used probe for detection of gamma radiation. The probes typically have either a one- two- or three-inch NaI crystals. The selection of the size of the crystal needed is dependent upon the required sensitivity (the larger the crystal the better the sensitivity), size of area to be surveyed and costs. For scanning of cores, a one-inch NaI is typically sufficient. While a NaI detector may be used to detect U-238, it is not common. This is because the detection of U-238 with a NaI detector is relying on the detection of the gamma radiations from the daughter products. If the concentration of U-238 is very low or close to background levels, a NaI does not have the efficiency required to detect the U-238. Therefore, a pancake, a gas-flow proportional counter or even a FIDLER (see below) is more appropriate. For isotopes such as Pu-239, which emit a very low energy gamma (13.6 keV), NaI detectors are not the most efficient and a FIDLER is often used.

For the low energy gamma emitters such as Pu-239 (13.6 keV), a FIDLER (Field Instrument for the Detection of Low Energy Radiation) probe is the most widely used instrument. A FIDLER uses either a three- or five-inch NaI or a cesium crystal optimized to detect gamma energy below about 100 keV. If only one radionuclide is present, a FIDLER can be used to estimate a concentration of that radionuclide, however, is other radionuclides are present, the results can only be obtained for gross activity.

For field estimates of concentrations of Pu-239 or U-238, a portable germanium MCA may be used. For these low energy gamma emitters, a very thin beryllium window is used in conjunction with a planar crystal. The MCA can be used for soils, water and air filter samples.

Laboratory Analysis of Samples

For environmental samples there are basically a few standardized laboratory methods for obtaining specific radionuclide concentrations. Each of these methods is discussed below.

Alpha Spectroscopy

Alpha spectroscopy (alpha spec) is a very accurate means for identification and quantifying activity of alpha emitting radionuclides. The alpha spec is used in conjunction with a multi-channel analyzer, which will display the energy peaks used for identifying the specific isotopes. The alpha spec can be used for soil, water and air filter samples. The alpha spec is a good methodology for Pu-239 and U-238. However, since alpha spec analyses can be quite costly, U-238 is frequently measured using gamma spectroscopy (discussed below).

Liquid Scintillation Spectrometer

The liquid scintillation spectrometer or counter (LSC) is used for measuring specific alpha and beta emitting radionuclide concentrations in soil, water, and air filter samples. While the LSS can be used for gamma emitters, it is not often applied. LSC is typically used for low energy beta emitters, such as tritium, but can also be used for other strong beta emitters such as Sr-90.

Gamma Spectroscopy

A gamma spectroscopy (gamma spec) system uses a germanium detector in conjunction with an MCA to measure the activity of gamma emitting radionuclides in soil, water and air filters. Gamma spec is useful when more than one radionuclide is present and when cost is a concern. The laboratory will use different detectors depending on whether the sample contains strong- or low-energy gamma emitters. Since Cs-137 is the only radionuclide that emits a peak at 661.6 keV, gamma spec can be easily used for identification of Cs-137. For U-238, the primary identification is through the 63.3 keV peak of Th-234, and is verified with the 1001 keV peak of Pa-234m.

For drinking water, the Environmental Protection Agency has developed more specific guidelines for laboratory analytical methods. The EPA laboratory methods for drinking water are summarized in the following table. This table was copied from the EPA website: www.epa.gov/OGWDW/methods/eparads.html.

U.S.EPA Drinking Water Methods for Radionuclide Parameters

(from U.S. EPA Website)

Naturally Occurring Radionuclides				
Contaminant/ Method Focus	**Method**	**Title**	**Order Number**	**Source**
Gross Alpha and Beta by Evaporation (see NOTE #1 below)	EPA 900.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 1	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information
	00-01	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information
	Found on Page 1	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Gross Alpha by Co-precipitation (see NOTE #1 below)	00-02	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information
NOTE #1: *Natural uranium and thorium-230 are approved as gross alpha calibration standards for gross alpha with co-precipitation and evaporation methods; americium-241 is approved with co-precipitation methods.*				
Radium 226 using Radiochemical Methodology	EPA 903.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 13	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information
	Ra-03	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service
Radium 226 using Radon Emanation Technique	EPA 903.1	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service

	Found on Page 16	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
	Ra-04	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service
Radium 228 using Radiochemical Methodology	EPA 904.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 24	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
	Ra-05	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service
	Found on Page 19	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Uranium by Radiochemical Methodology (see NOTE #2 below)	EPA 908.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
Uranium using Fluorometric Methodology (see NOTE #2 below)	EPA 908.1	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
Uranium using Alpha Spectrometry (see NOTE #2 below)	00-07	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service
	Found on Page 33	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service

NOTE #2: *If uranium (U) is determined by mass, a 0.67 pCi/ug of uranium conversion factor must be used. This conservative factor is based on the 1:1 activity ratio of U-234 to U-238 that is characteristic of naturally occurring uranium.*

Man Made Radionuclides				
Radioactive Cesium by Radiochemical Methodology	EPA 901.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 4	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
Radioactive Cesium by Gamma Ray Spectrometry	EPA 901.1	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 92	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Radioactive Iodine using Radiochemical Methodology	EPA 902.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 6 and 9	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
Radioactive Iodine by Gamma Ray Spectrometry	EPA 901.1	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 92	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Radioactive Strontium 89 and 90 using Radiochemical Methodology	EPA 905.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 29	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
	Sr-04	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service

	Found on Page 65	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Tritium by Liquid Scintillation	EPA 906.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	Found on Page 34	Interim Radiochemical Methodology for Drinking Water (EPA 600/4-75-008) (revised) March 1976	PB 253258	National Technical Information Service
	H-02	Radiochemistry Procedures Manual (EPA 520/5-84-006) December 1987	PB 84-215581	National Technical Information Service
	Found on Page 87	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service
Gamma Emitting Radionuclides by Gamma Ray Spectrometry	EPA 901.1	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	EPA 902.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	National Technical Information Service
	EPA 901.0	Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA/600/4-80-032) August 1980.	PB 80-224744	EPA 901.0
	Found on Page 92	Radiochemical Analytical Procedures for Analysis of Environmental Samples, March 1979	EMSL LV 053917	National Technical Information Service

References

Most of the information provided in this paper is based upon experience. However, some references that may be helpful are listed below.

Survey Instruments

Ludlum, Inc., general survey meters and probes, (www.Ludlums.com)
Bichron Radiation Measurement Products, general survey meters and probes, (www.Bichron.com)
Rad Elec, tritium/electret meters, (www.radelec.com)
LND, Inc., general survey meters and probes, (www.lndinc.com)

Liquid Scintillation Information

UCLA (http://laxmi.nuc.edu:8248/M248_98/autorad/Scint/scint1.html)

Instrument Selection

"Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)", NUREG-1575 rev.1, August 2000 (see Appendix H)

"Measurement Methods for Radiological Surveys in Support of New Decommissioning Criteria", NUREG-1506, August 1995

"Minimum Detectable Concentration with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, NUREG-1507". June 1998

Background Selections

"Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)", NUREG-1575 rev.1, August 2000