COLORADO DEPARTMENT OF HEALTH

Review and Comments

Draft Compendium of In-Situ Radiological Methods and Applications at Rocky Flats Plant April 2, 1993

GENERAL COMMENTS:

Scope of the Report

The objective of this report is to present an overview of the methods available for in-situ characterization of radionuclides for site investigations in a manner that is useful to project managers and regulators. Much useful information regarding the physics and operating principles of the HPGe detector is presented; however, the report falls short of meeting its main objective. As stated in the Introduction to this report, "A comparison of these methods and applications is needed so that the project manager or regulator can compare the pros, cons, and limitations of each of the methods to ensure that the chosen method meets the data quality objectives of the project." Such a comparison of methods should be a major focus of this report. The pros, cons and limitations of all available in-situ radiological detectors should be identified and compared, including FIDLER, NaI and HPGe.

The report should list available methods and make recommendations on appropriate methods for common situations encountered at Rocky Flats. At a minimum, the pros, cons, and limitations of available methods should be presented for characterizing each of the four main types of releases using the five considerations identified in the Introduction.

The report does not adequately provide a quantitative application of the information presented to any proposed uses for in-situ measurements. In most cases, a single measurement would not be performed; in a large area survey, the measurements may be used to generate contours, whereas in a small area survey, each measurement may be individually analyzed. The compendium does not provide insight into these specific applications.

Another question that should be addressed in this report is the availability of similar information from other DOE Complex Facilities. Are the in-situ devices reported in this document used at other DOE sites for In-Situ characterization? Are other devices available but not used at Rocky Flats? Are there any studies/reports similar to this one from other DOE facilities? Have other sites published papers on in-situ radionuclide characterization techniques?

Report Organization

The overall organization of the report is cumbersome and difficult to follow, thereby limiting its usefulness as a reference. The report should be reorganized so that each major topic is discussed in a separate section or chapter. For example, the section of the report on basic radiation is, in general, well prepared and of appropriate technical level; however, it is difficult to discern when the background information concludes and the discussion of in-situ detectors begins.

One possible rough shell for organizing the report in to Chapters might be as follows:

I. Introduction
   - Objectives of Report
   - Summary of Recommendations/Conclusions
II. Basic Radiation Principles
III. Review of Radiation Detection Instruments
   - Gas Filled
   - Scintillation
   - Semiconductor
IV. Comparison of In-Situ Radionuclide Detection Methods/Applications

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Grammatical and Typographical Errors

There are numerous spelling, grammatical, and punctuation errors and inconsistencies throughout this draft document. The Division has not specifically commented on all of these errors but expects that the final document will be reviewed and grammatical/typographical errors minimized.

HPGe Detector Issues

One of the issues which prompted this report was the proposed use of HPGe detectors to characterize radionuclide contamination below asphalt. This issue appears to have been avoided in this report. It is critical to the proper application of the HPGe detector that the project manager as well as the regulators understand HPGe's usefulness as well as its limitations. In this regard, potential application of the HPGe detector over asphalt (with potential surface and/or below asphalt contamination) or next to potentially "hot" buildings, should be critically reviewed and the HPGe detector's uses and limitations specifically identified. Any site specific information necessary to evaluate the applicability of the HPGe detector should also be discussed.

- Issues concerning use of the HPGe detector over or near obstructions such as pavement or buildings are of extreme concern to CDH. It was expected that this issue would be addressed in this report. The report briefly presents a limited look at the effects of standing water on theoretical gamma flux. This issue needs to be further explored in this report and a consensus reached on when HPGe is appropriate and what is actually being measured.

- Questions such as how environmental variables (wind, ground cover, vegetation, temperature) or specific geometry of detector placement (level or parallel to terrain) impact survey readings. If further studies need to be conducted to quantify or verify the impact of these variables, they should be proposed. Operating constraints, such as fair, dry weather during seasons when the ground is relatively dry, should be explicitly stated.

- When HPGe detector data is analyzed, factors are applied to account for obstructions to the field of view of the instrument, such as buildings, the instrument truck, and surface water. Adjustments to the source distribution model to account for these obstructions and possible impacts on the survey results and DQO should be included in this report.

- What data is actually collected in the field from the HPGe detector and how is the data analyzed and interpreted (graphical, statistical routine, numeric methods, etc.)? What data is reported to the project manager as results of the survey? What impact does the field technician have on the results? What assumptions are made and how do they impact the results? How is the data validated? How should the project manager interpret results of the survey (variation across adjacent locations, variation among natural and/or man-made isotopes, isolated hot or cold spots)?

- The analytical software for the HPGe detector should not be treated as a "black box" in this report.. The report should at a minimum outline the computational methods, critical assumptions, input variables and results generated.

- There is no discussion of the specific detection limit for ^{241}Am, or the concentration of ^{239}Pu that will be inferred from the ^{241}Am measurements.

- The Lecture Notes attached to this report as Appendix II mention a choice of two types of HPGe crystals (P type and N type). This report should discuss this issue, including differences between the two types of crystals, which type is used at the Rocky Flats Plant, and why.

Specific Comments:

Page 1: Introduction - The introduction to the report raises several valid issues regarding in-situ radiological surveys that are vital to characterizing radiological contamination (DQO, relation to soil sampling, statistical modeling of results, spatial variability, field of view). The section that states "sampling on a grid basis becomes prohibitively expensive" should specify what type of sampling is being referred to. If a specific issue is raised in the introduction it must be addressed in the report. Discussions of each issue raised in the introduction should be added and/or emphasized in the appropriate sections of this report.

Page 1, Middle - To define the radiological character of an area... These steps should begin by measuring gross radionuclide activity against natural background -- and then identify and measure the radionuclides that are present in excess of background. In addition to the spatial extent of the radionuclides, what about temporal extent?

Page 4: Reference Citations - All detailed reference citations should appear in the reference section of the report with consistent reference notations in the text. Any general references, not specifically cited in the report, should be clearly distinguished in the reference section of the report.

The selection of Dr. Knoll's book for basic physics information was an excellent choice for this report.

Page 7: Radiation and Radioactivity - In the next to last sentence of the first paragraph in this section, 'For example, U-238 and U-239 have different atomic masses because of the different number of protons in their nuclei.' Substitute "neutrons" for "protons" in this sentence.

There are five types of radiation of concern at the RFP. X-rays are also of concern; this document defers that topic to page 9.

Figure 4: Far right arrows - for readability, it is suggested that the emission be identified there rather than on the arrows pointing to the left, for consistency.

Electrons (and beta particles) are not found in the nucleus of an atom. The mass difference and charge (equal to an electron) is ejected as a beta particle.

The source of x- and gamma rays are different. X-ray energies can and do exceed those of gamma rays. X-ray energies originating from radioactive materials are typically lower energies than the associated gammas from the same material.

Page 10: Radiation Quantities and Units - This discussion should be expanded to include other radiation units. Of the units used to describe radioactivity, the two most frequently encountered at RFP are the Curie (e.g. low-level waste is defined as < 100 nCi/g) and the REM (usually used for personal protective dose equivalence allowances). This would be a perfect opportunity to correlate the two - it would be very helpful to understand how an activity level (or potential ARAR) expressed in pCi/g, or units such as counts per minute (cpm) and disintegrations per minute (dpm) often found in RFI/RI reports, compare to ALARA exposure limits, usually expressed in mrem/year. This could be accomplished in a simple table format and, where possible, conversion factors.

This section defines the Curie as a common unit to express radiative activity as both total activity and specific activity. It would be helpful to define the terms total activity and specific activity in this section.

Page 10: Radiation Detection Instruments - Pictures and/or simple schematic diagrams of each of the radiation detection instruments should be included in this section for each major type of detector that is discussed.

Page 12, Subtitle Gamma - This subtitle should properly be changed to "Gamma and X - Rays".

Page 13: Neutrons (second paragraph) - It would be helpful to define the term 'criticality incident' as used in this discussion.

Page 16: Gas-Filled Detector Characteristic Curve - The text reports this curve as natural log of the number of ion pairs collected; however, the figure does not indicate that the y-axis has a ln scale.

Page 17-19: Detector Characteristic Curve - In reference to statements that, "No detectors at the RFP operate in this region", it is suggested that for consistency a statement regarding each region be made. Where instruments at RFP do use that region, make a statement that a discussion will follow identifying the application.

Page 18: Detector Characteristic Curve - The text states that the detectors in the proportional region are more sensitive than those in the ionization region and can measure lower radiation intensities. Yet, it is stated that a potential disadvantage is that proportional region detectors are not as accurate as ionization chamber region detectors. The GM region is reported as the most sensitive region, but can not distinguish between types of radiation. What is the difference between sensitive and accurate in this discussion? Definitions of accuracy, precision, and sensitivity may be helpful.

Page 20: Proportional Counters - The Ludlum Model 12-1A is reported to be used to survey areas for alpha contamination. Are these types of detectors used in field screening or characterization surveys?

Page 22: Scintillation Detectors - The NaI sensor and the FIDLER instrument are important examples of scintillation detectors used at RFP, yet this section of the report only mentions NaI sensors once (example comparing sensor density, page 22). Descriptions and background discussions on the NaI sensor and FIDLER instrument should be added to this section of the report. The NaI Detector and the FIDLER instrument should be added to the examples of detectors used at RFP.

Page 26: Semiconductor Detectors - The major disadvantage of semiconductor detectors, that they are sensitive to thermal excitation, should be expanded to include relevant information such as what temperature range is generally used, how temperature impacts detection results, how are the detectors are cooled, what are the sources of heat (radiation, applied voltage, etc.), and whether there are any ambient temperature operating limits.

The list of examples of semiconductor detectors used at RFP should include a short description of where the HPGe is used, similar to earlier example lists for other types of detectors.

This would be a logical place for a division in the report (end of generic detector description and beginning of specific applications at RFP). It would also be helpful to summarize in tabular form the basic detector technologies and what they may be used for:

Detector Type	Able to detect:
1. Gas filled	
- ionization chamber	gamma
- proportional	alpha
- Geiger-Müller	beta, gamma
2. Scintillation	
- sodium iodide	gamma, neutron
3. Semiconductor	
- germanium	gamma

Pages 27/28: Comparison of NaI and HPGe Sensors - "Health physics instrumentation, in general, does not have that capability" (to identify and quantify all radionuclides that may be present). "This includes the ... sodium iodide (crystalline scintillator) coupled to a scalar commonly referred to as the FIDLER." Several of the IA OU Workplans specify the use of NaI detectors for radiation surveys. Is this appropriate when quantification is necessary? Or are these NaI detectors the multichannel variety that can identify radionuclides?

The report states that the MDA of the FIDLER for Americium-241 should be on the order of 15 pCi/g for a distributed source and 50 mCi for a point source. How are these numbers projected? If the MDA should (non-committal) be on this order, is this a typical MDA for a FIDLER or some type of minimum operating standard? What would cause the MDA to be different? How do FIDLER MDA compare to MDA for NaI or HPGe surveys?

There needs to be a statement made as to what is being measured and why, specifically regarding RFP weapons grade Pu (Am-241) and the 'assumed' relationship basis.

It would be helpful to list minimum detectable activity (MDA) for both NaI and HPGe detectors for each of the radionuclides of concern at RFP. Again, a tabular format with sensitivity and detection limits would suffice. In order to minimize potential confusion these numbers should be reported in consistent units.

To compare the background sensitivity of the FIDLER, NaI and HPGe detectors the plots in Figures 11, 12 and 13 should have the same scale range (maximum y axis).

The units for reporting photopeak resolution, keV FWHM, needs to be defined. The Division is not familiar with the term "FWHM". The units cps and gam should also be defined in the report before they are used.

Page 29: In-Situ Detector Characterization - This section sounds like a characterization report for an HPGe Detector. It should summarize the theory and methodology used to characterize in-situ detectors in language that the project manager can easily understand. The characterization of NaI and FIDLER detectors should be added to the discussion in this section. Information on who performed this test on HPGe sensors for EG&G does not appear to be relevant to this discussion and should be deleted.

Several additional issues regarding the characterization of detectors need to be added or clarified in this section. For example, how does detector characterization differ from calibration (the attached Lecture Notes use the term calibration)? How often are detectors characterized? How often are they calibrated? What characterization parameters are critical to determining appropriateness for an application?

A number of important variables are identified at the bottom of page 32. A statement should be added to this section addressing individual site situation characteristics and which parameters must be adjusted in the analysis.

A schematic of the calibration equipment with the model geometry should be included in this discussion to clarify how the model relates to the physical system. For example, it is not clear from the text how the detector Effective Area plots (3-D Surface) relate to the polar orientation (north, south, east, west) of the source around the detector.

Page 30: Equation 2 - The report does not define A or theta O as used in equation 2. They should both be specifically defined for use in the equation similar to R(O). Units used in the definition of equations should be in standard abbreviation or complete words.

Page 33, 34, 35: Detector Response Plots-
(1) The text states that the source was moved from 0 to 90 degrees, yet the series of plots appears to be limited to a maximum of 80 degrees. This discrepancy must be corrected or explained in the report.

(2) The use of dark shading in the plots for what appears to be the 50 to 100 cm2cps/gam/s range hides the Energy/Angle grid lines and makes it very difficult to interpret. If practical, this shading should be adjusted.

(3) Notes should be added to the plots or the captions/titles expanded to define the physical detector configuration, (number of detectors in array, detector IDs, mounting geometry) and which detector is reported. While this information is available in the text, with a series of multiple plots having the information on the plots is very helpful.

(4) The angle plotted should be defined or referenced to the text or a diagram and any non-standard abbreviations used in the plots should be noted and defined, for example the unit 'gam'.

If the In-Situ theory is needed to understand calibration curves than the section on the model should be presented before the calibration is discussed.

Page 44: The Theory of In-Situ Measurement - The intended audience for this report is not mathematicians. The formulas are extremely complex and unless the reader has a background in higher mathematics, they would be very difficult to get through. This section must be presented in a manner that is reasonably understandable by the project manager. Also, all of the terms and variables used must be defined, with appropriate units.

It appears from the attached reference papers that the selection of an appropriate flux model is critical to the analysis of in-situ detector data. The factors influencing the choice of the flux model for analyzing RFP data, and the models strengths and weaknesses, should be discussed in this section of the report. It is not sufficient to simple rewrite on of the flux equations from the attached references. It should be clear what model is used and how it should be interpreted.

The presentation of the equations on pages 44 and 47 approach absurdity. The mathematical theory in this section (pp. 44-48) seems out of place and could perhaps be moved to an appendix or simply replaced by a reference pointing interested readers to the attached papers.

What models are used to interpret FIDLER and NaI results? How do these instruments modeling assumptions compare to the HPGe?

Page 48: Measurements - The last section of the report is not an appropriate place to raise new issues (topographic effects, shielding field of view, count times) that are not fully addressed in the report. Blanket statements such as, "If there is material between the area to be characterized and the detector such as water...then the measurement becomes more complex" are not adequate. These issues need to be discussed in detail within the report and conclusions or recommendations presented so that the project manager has the information necessary to properly interpret characterization results.

The statement "Simply stated, as shown by the theory, the measurement takes place...over a period of time" is too much hand-waving. The impact of count time on the results of measurements is never discussed in the report. Sufficient counting time appears to be critical to properly conducting the characterization. This and all other critical parameters should be quantified, where possible, in this section.

It is stated that hillsides can be approximated by tipping the horizontal plane model. How is the model 'tipped'? Why would it not affect the characterization results? Does RFP 'tip' the model for hillsides? How can a sampling strategy be developed to minimize topographic effects?

Why not model a generic radiological survey relating detector height above the surface to diameter of area surveyed and to counting times needed to achieve adequate counting statistics? The model would enable time/cost tradeoffs against areas to be measured.