

Detection of Depleted Uranium in Soil Using Portable Hand-Held Instruments

IAEA-SM-359/P-5

Robert L. Coleman and Michael E. Murray
Oak Ridge National Laboratory¹

Abstract^{3/4} The Measurement Applications and Development Group at the Oak Ridge National Laboratory (ORNL) has collected and analyzed data with the purpose of evaluating the in-situ detection capabilities of common hand-held detectors for depleted uranium (²³⁸U) in soil. Measurements were collected with one each of the following detectors: a FIDLER operated in a gross (full spectrum) mode, a FIDLER operated in a spectrum specific (windowed) mode, a 1.25" x 1.5" cylindrical NaI detector operated with a gross count rate system, and both open and closed-window pancake-type detectors. Representative samples were then collected at the same location and later analyzed at an ORNL laboratory. This report presents a correlation between the measurements and the soil concentration results and should be helpful to anyone interested in estimating measurement sensitivities for depleted uranium in soil.

1. INTRODUCTION

Radiological investigations performed in support of decommissioning tasks will typically consider direct measurements as well as sampling requirements. As such, the quantification of detection ability is a key issue to consider when selecting instrumentation for radiological investigations either prior to or following remedial actions. The Measurement Applications and Development Group at the Oak Ridge National Laboratory (ORNL) has collected and analyzed data with the purpose of evaluating the in-situ detection capabilities of common hand-held detectors for depleted uranium in soil. This information will be useful to anyone involved with remedial investigations associated with sites contaminated with depleted or natural uranium.

Measurements were collected at a contaminated site with one each of the following detectors: (a) a large, thin NaI detector (FIDLER) operated in a full spectrum mode; (b) a FIDLER operated in a spectrum specific (windowed) mode; (c) a 1.25" x 1.5" cylindrical NaI operated with a gross count rate system; and (d) both an open and closed-window pancake detector. Representative samples were then collected at the same location and later analyzed for uranium and radium content at ORNL. This brief report presents the results of the field measurements and the laboratory results and forms a correlation between the two. The information will be helpful to anyone who must estimate scan or measurement sensitivity for these types of detectors when evaluating residual, depleted uranium in soil.

2. METHODS

Data was collected specifically for the evaluation of the in-situ detection capabilities for depleted uranium in soil using a FIDLER, a 1.25"x1.5" NaI and a pancake detector using the following detector configurations:

¹Oak Ridge National Laboratory, Life Sciences Research Division: P.O. Box 2008; Oak Ridge, TN 37849-6379

- a FIDLER NaI detector connected to a portable multi-channel analyzer (MCA) and operated in a full spectrum mode,
- a FIDLER operated with a spectral window set from about 40 keV up to around 150 keV— also connected to a portable MCA,
- a 1.25"x1.5" NaI detector operated in full spectrum mode,
- a Geiger-Mueller (GM) “pancake” without a beta shield, and
- a GM “pancake” with a beta shield.

After performing typical survey scans at the contaminated property, locations were chosen for this study such that a range of possible contamination levels would be included. Each detector was placed at contact with the top of the soil prior to any surface disturbance and a measurement, in counts per minute (cpm), was collected. Following the measurement, a sample was collected from the top two inches of the soil at the same point and prepared for transport to the laboratory. A second measurement was then collected at the bottom of the two-inch depth with each detector. A second sample was collected over the subsequent two inches of soil, e.g. a two to four inch sample, and packaged for transport. All samples were analyzed at an ORNL laboratory for gamma-emitting uranium, thorium, and radium isotopes using solid-state gamma spectrometry.

3. RESULTS

Review of the sample data indicated that the only isotope of appreciable activity (above background) in the collected samples was uranium depleted of ^{235}U —i.e., the mass ratio of ^{238}U to ^{235}U was appreciably less than 0.7%. The vertical distribution of uranium within the top 4 inches of soil varied among measurement locations so, for analysis purposes, the data set was broken into two distinct groups:

- *exponential profile*— locations where the activity in the top two-inches of soil was greater than twice the activity in the bottom two-inches of soil, and
- *uniform profile*— locations where the activity was relatively uniform throughout the entire four inches of surface soil.

Field measurement data for each of the two groups of sample locations were then correlated to the uranium activity concentration in the collected soil samples. To normalize the measurement data for charting purposes, all detector data was divided by typical detector background count rates. Background data was selected by choosing measurement locations where laboratory assay results indicated natural levels of radioisotopes in the soil. The ratios are referred to here as *relative responses*, carry a unit-less dimension and are similar in concept to signal-to-noise ratios.

The relative response of the detectors as a function of ^{238}U activity concentrations are shown graphically in Figures 1 and 2. The windowed FIDLER response tracked almost identical to the full spectrum FIDLER and, as would be expected, the closed window pancake data showed very poor response at such low uranium concentrations. These data sets were therefore excluded from the plots. A linear fit was performed for the remaining data sets and have been superimposed on Figures 1 and 2.

4. CONCLUSION

For the case where residual uranium was found primarily in the top two-inches of soil the results indicated that the detection sensitivity was best for the open-window pancake detector— although there was poor consistency in the results. The FIDLER NaI detection system showed a second-best sensitivity response while the 1.25” x 1.5” NaI system ranked third. Unlike the pancake data, both NaI detectors indicated a reasonably predictable pattern of response as a function of uranium soil concentration— as would be expected considering the primary radiations being measured by each type of detector.

The detection sensitivity for a detector can be estimated using a number of means. Static measurement sensitivities are typically estimated by considering statistical parameters associated with nuclear counting [see side-bar]. For scanning, a typical approach for estimating sensitivity is to define a target source configuration— such as a 1 m² soil area— and to then set a detection threshold that could be adopted during survey scans. The detection threshold (cpm), sometimes referred to as an *action level*, can then be directly related to detection efficiency (cpm Bq⁻¹ g) information to formulate an expected measurement sensitivity (Bq g⁻¹).

The specification of detection sensitivity values is a process that leads to varied results— depending on the needs and wants of whomever is evaluating the data. As such, no attempt is made in this brief paper to derive specific estimates of measurement sensitivities. Ultimately, the selection of measurement and sensitivity criteria must be made by those directly involved with a specific site. To that end, the data presented here is a critical parameter that should be considered when evaluating detector responses for measuring depleted uranium in soil.

SIDE BAR: MORE ABOUT MEASUREMENT SENSITIVITY

Static Measurements

Standard methods for calculating *minimum detectable concentrations* (MDCs) are available for estimating sensitivities of static measurements with pulse-counting types of radiation detectors. While these approaches are reasonable for laboratory conditions where detector backgrounds are relatively constant, i.e. predictable, the application of similar methods to field measurements can lead to overly optimistic predictors of detection ability. The natural background of most detectors will vary significantly across a region of investigation when collecting measurements on soil. As such, the background response will be represented as a distribution and may or may not follow a Gaussian profile. If one has enough information about the distribution, then probabilistic intervals can be postulated for estimating detection sensitivities which are very similar to those used in standard MDC formulae. A more practical approach is to simply select a background value at the upper end

of what will be expected during a survey. This will insure that realistic estimates of detection ability are being used.

Scans

Scanning sensitivities are more typically estimated using less precise methods. Instrument-specific count rate *action levels* are selected which are believed to represent reasonable criteria for personnel to consider as *significantly greater than background*. The most common method for estimating action levels is to set a feel-good criteria that is believed to be a reasonable detection threshold for the detector in use. For a high count rate instrumentation such as NaI count-rate systems, this criteria will normally fall in the range of 50% to 100% above the detector background response. For low count rate instrumentation, such as GM pancakes, this value will typically be at least 100% above background.

Fig. 1 Graphical correlation of measurements when there was **uniform** uranium contamination in the top four inches of soil. All measurements were collected at contact with the soil surface.

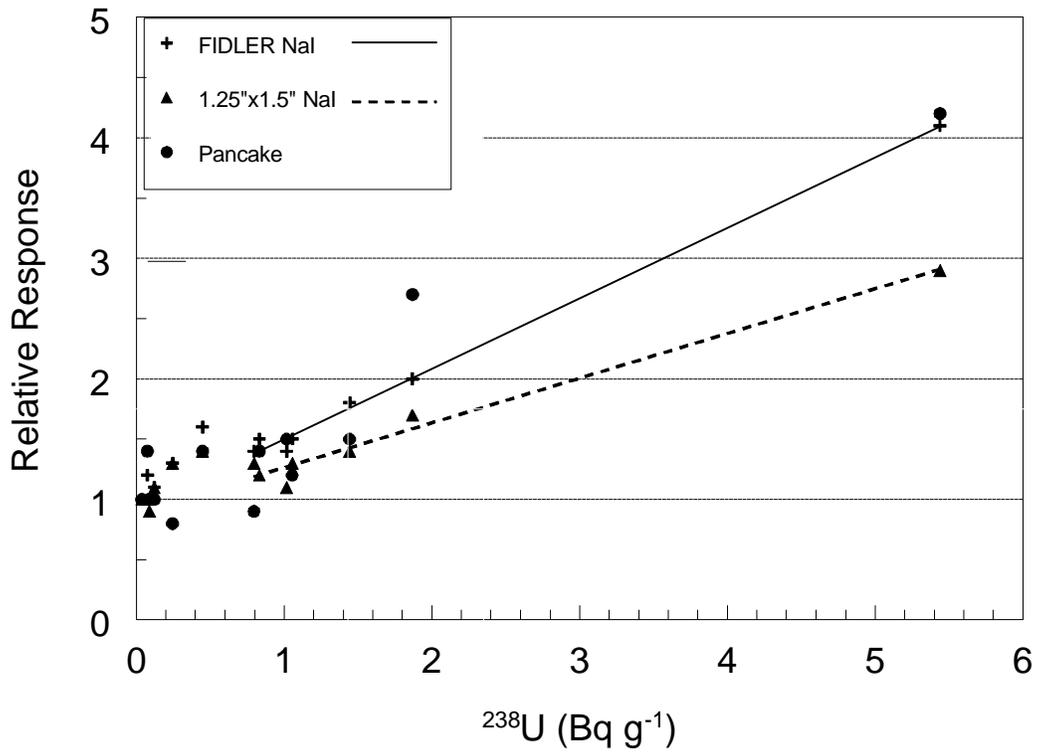


Fig. 2 Graphical correlation of measurements when there was non-uniform, or **exponential**, uranium contamination in the top four inches of soil. All measurements were collected at contact with the soil surface.

