Real-Time Soil Characterization and Analysis Systems Used at US Department of Energy Closure Sites in Ohio

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ABSTRACT

The Idaho National Engineering and Environmental Laboratory (INEEL) and the Fernald Environmental Management Project (FEMP) have jointly developed a field-deployed analytical system to rapidly scan, characterize, and analyze surface soil contamination. The basic system consists of a sodium iodide (NaI) spectrometer and global positioning system (GPS) hardware. This hardware can be deployed from any of four different platforms depending on the scope of the survey at hand. These platforms range from a large tractor-based unit (the RTRAK) used to survey large, relatively flat areas to a hand-pushed unit where maneuverability is important, to an excavator mounted system used to scan pits and trenches. The mobile sodium iodide concept was initially developed by the FEMP to provide pre-screening analyses for soils contaminated with uranium, thorium, and radium. The initial study is documented in the RTRAK Applicability Study and provides analyses supporting the field usage of the concept. The RTRAK system produced data that required several days of post-processing and analyses to generate an estimation of field coverage and activity levels. The INEEL has provided integrated engineering, computer hardware and software support to greatly streamline the data acquisition and analysis process to the point where real-time activity and coverage maps are available to the field technicians. On-line analyses have been added to automatically convert GPS data to Ohio State-Plane coordinates, examine and correct collected spectra for energy calibration drifts common to NaI spectrometers, and strip spectra in regions of interest to provide moisture corrected activity levels for total uranium, thorium-232, and radium-226. Additionally, the software provides a number of checks and alarms to alert operators that a hand-examination of spectral data in a particular area may be required. The FEMP has estimated that this technology has produced projected site savings in excess of $34M through FY 2006. Additionally, the INEEL has applied this real-time concept to develop an *in-situ* platform to detect plutonium-238 in contaminated soils to the 50 pCi/g level. The heart of this system is a large-area proportional counter that collects spectra in the x-ray region. A prototype system was demonstrated at the Mound Environmental Management Project (MEMP) in October of 2002.

INTRODUCTION

The Idaho National Engineering and Environmental Laboratory (INEEL) has developed real-time analysis software for a series of related mobile soil characterization systems used to quantify radionuclide contamination at several Department of Energy-Ohio closure sites. These systems have operated in a production environment at the Fernald Environmental Management Project (FEMP) located in Ross, Ohio, and have also been used to identify soil contamination at the Ashtabula Environmental Management Project (AEMP) located in Ashtabula, Ohio. Additionally, the INEEL has developed a mobile *in-situ* system to quantitatively determine plutonium soil contamination. This system has been demonstrated at the Mound Environmental Management Project (MEMP) located in Miamisburg, Ohio.

The Radiation Tracking System (RTRAK) (1) is predecessor to these systems. It was originally developed at the Fernald Environmental Management Project (FEMP) and consisted of a Sodium Iodide (NaI) spectrometer and a global position system (GPS) deployed from a large John Deere farm tractor. The RTRAK was typically used to survey several acres per day. Position-stamped spectral data were collected at regular intervals and stored on disk. The data were analyzed and quality checked in a process that often took 4-5 working days. The final product was a database that was used to overlay contamination data onto site maps of the area.

In concert with FEMP personnel, the INEEL began streamlining and improving the RTRAK process from the data collection phase through the analysis and reporting phase in 1999. On-line analyses of the spectra were added which mimicked analyses previously done in a post-process fashion. Real-time data displays were created that allowed the RTRAK operator to view sensor coverage and indicate "hot-spots" of uranium, radium, thorium, and overall activity using a color-coded square indicative of the location and activity. Individual spectra are stored in an industry standard format and a summary "log file" is generated that contains collection parameters (i.e. position, moisture content, etc.) and data analysis of each spectrum collected. The net effect of this streamlining activity was to reduce the data turnaround from one week to one hour. Additionally, on-line data quality checks were incorporated into the process reducing false starts or re-runs of land surveys essentially to zero. A version of the RTRAK software and hardware was deployed at the AEMP during October of 2002 to determine the feasibility of using the system at the AEMP.

At the MEMP, the INEEL has applied an RTRAK-type concept to develop an *in-situ* soils characterization tool for plutonium-238. Here, the NaI spectrometer was replaced by a Large Area Proportional Counter (LAPC) that is sensitive to photons ranging from 10 to 100 keV. This work is in the pre-demonstration phase and positive results have been obtained in the initial tests of the system.

IN-SITU GAMMA SPECTROSCOPY DEVELOPMENTS AT THE FEMP

The RTRAK system was borne out of a series of *in-situ* gamma spectrometry validation studies conducted by FEMP, Argonne National Laboratory (ANL), and Environmental Measurements Laboratory (EML) personnel in 1997. These studies addressed precision, accuracy, detection limits, robustness, data quality, and comparability with laboratory analytical data. As a result of these studies, the US Environmental Protection Agency (USEPA) and the Ohio Environmental Protection Agency have approved the use of gamma spectrometry for soil characterization during all phases of remediation except for the final certification phase at the FEMP. Therefore, the base system, which consisted of strictly a data acquisition platform, had regulatory approval at the FEMP prior to the INEEL involvement. While use of the base system provided time and cost savings when compared to the alternative laboratory analysis methods, turn-around time and quality assurance of the massive amount of data collected was less than optimal.

While the RTRAK worked well in large, open, flat areas, it was cumbersome to use on gentle hillsides and small areas. The FEMP developed the Radiation Scanning System (RSS) and the Gator system to address different deployment scenarios and provide redundant capabilities. The RSS and Gator systems are identical to the RTRAK except that they are deployed differently. The RSS is fitted onto a modified baby carriage and is operated from a laptop computer. It is a hand-pushed vehicle but contains all the scanning capabilities of the RTRAK machine. The Gator is fitted onto a John Deere Gator six-wheeled utility vehicle and is designed to operate in tighter quarters than the RTRAK. It can also handle uneven terrain more gracefully than the RTRAK. The electronics and sensor packages are identical between the FEMP systems. The same software package operates all platforms. Only the calibration constants for the detectors are unique. Additionally, the INEEL has adapted this analysis and hardware package such that it is mounted to the end of an excavator arm. The Excavation Monitoring System (EMS) can remotely survey pits and trenches where personnel safety is an issue.

A photograph of the Gator vehicle is shown in figure 1. The NaI detector is mounted to the front of the vehicle and encased in a 20.3-cm diameter PVC tube for weather and dust protection. A GPS antenna is mounted onto the top of the Gator. A compact industrial computer performs all data collection and management functions.

Fig. 1. FEMP's Gator vehicle.

NaI System Use and Description

The NaI systems used at the FEMP are designed to provide rapid, 100% coverage of large areas to support pre-design investigations, excavation control, and pre-certification activities in the soils remediation process. Precision and detection limits are sufficient to determine the general patterns of contamination within a given area with respect to total uranium, thorium-232, radium-226 and gross activity. Data from the NaI systems are suitable for mapping and spatial averaging, and provides an ideal front-end survey tool to guide the use of high purity Germanium (HPGe) detectors as required in the FEMP pre-certification process. Specific applications for the NaI systems include:

- Complete coverage of areas to assess the spatial patterns of contaminant distribution in pre-design investigations;

- Rapid identification of areas potentially exceeding Waste Acceptance Criteria (WAC) during soil excavation activities;
- Complete coverage and rapid identification of areas potentially exceeding final remediation levels (FRLs), hot spot criteria, and WAC exceedances in pre-certification activities;
- Rapid collection and analysis of data allowing HPGe measurements or physical samples to be focused on specific areas; and
- Support of the site as-low-as-reasonably-achievable (ALARA) goals.

The limitations and usage of the NaI system at the FEMP are described in the user guidelines and measurement strategies document (2).

The heart of each FEMP NaI system is a single 10-cm x 10-cm x 40.6-cm Sodium Iodide crystal and supporting electronics (i.e., photo-multiplier tube, pre-amplifier, and multi-channel analyzer). Every vehicle is equipped with a real-time differential correcting GPS package. These hardware pieces are connected to an industrial mini-computer that provides a menu-driven user interface, real-time analysis, and information display to the operator. The user interface provides a number of alarms and gauges that allow the operator to stay within the usage guidelines prescribed in references 1 and 2. These include the path followed, speed of the vehicle, and the degree of overlap between adjacent passes.

The FEMP NaI systems typically operate in a mobile scanning mode. Spectral data are collected at a nominal vehicle speed of one mile per hour. Spectra are collected on a continuous basis and stored individually. Normally, individual spectra are collected in four-second (real time) blocks. Spectra are analyzed individually and together in two spectra "sliding windows" where two spectra are added to form a longer count time "virtual spectrum". The purpose of the sliding window concept is to increase the count times thereby increasing detection sensitivities and decreasing uncertainties associated with the analysis functions.

On-Line Analysis Capabilities

The INEEL has developed a sophisticated "operating system" (OS) for the FEMP NaI *in-situ* gamma ray spectrometers that acquires data, creates an electronic record of all conditions important to the data collection process, and incorporates nearly all of the analysis options used by the FEMP into a single, cohesive, real-time software package. In addition, the NaI OS provides an intuitive visual display of the analyzed data that allows the operator to adjust survey parameters in the field. While the INEEL has implemented and been the integrator for all software activities, this has been a joint effort involving FEMP, ANL, EML, and R.T. Reiman who is an independent consultant to the FEMP.

The NaI OS incorporates several features that insure the analyses results are of the highest possible quality over the course of a survey within the limitations of the instrument. In general, the NaI systems are designed to cover many acres often requiring several hours to complete. The NaI OS incorporates an automated energy calibration algorithm (3) to compensate for the energy calibration shifting (due to temperature and counting rates) that is common to NaI spectrometers. The NaI software keys on the 1460.8 keV K-40 and 2614.8 keV Tl-208 gamma ray lines (which are dominant in the Fernald background) for energy calibration during field operations. The energy calibration is adjusted approximately once a minute by summing sixteen consecutive spectra and examining the location of the potassium and thallium peaks. Multiple spectra are added to increase counting statistics; thereby increasing the accuracy of the peak location algorithm.

Spectra are analyzed singularly and by adding together consecutive spectra to form a temporally longer spectrum. The NaI OS extracts the gross count rates from the uranium, potassium, radium, thorium and background regions in the spectrum. These regions are adjusted to accommodate any energy calibration shifts before the gross count rates and normalized background count rates are extracted. The net count rate for each of these regions can be calculated by subtracting the normalized background count rate from the gross signal count rate. Nominal activities, uncertainties, and minimum detectable concentrations are calculated in real-time from the gross, net, and background count rates as described below.

Nominal concentration values for uranium, thorium, radium and potassium are computed using the results from multi-variable regression analyses (1) that are in the general form of equation 1. Coefficients are determined by careful measurements on a controlled calibration pad at the FEMP. The dominant coefficient is always the coefficient paired with the analyte of interest and the potassium coefficient is zero in all instances except where potassium activity is calculated. The relative values of the regression coefficients are proportional to the interference noted between the various energy windows during the RTRAK calibration studies.

$$N = a_1 * Th_{NCPS} + a_2 * Ra_{NCPS} + a_3 U_{NCPS} + a_4 * K_{NCPS} \qquad \text{(Eq. 1)}$$

where,

N = analyte activity in pCi/g (i.e. Th, Ra, U, or K)
a_i = coefficients from the multiple linear regression analysis (four sets of four coefficients)
Th_{NCPS} = thorium window net counts per second
Ra_{NCPS} = radium window net counts per second
U_{NCPS} = uranium window net counts per second
K_{NCPS} = potassium window net counts per second.

The nominal value for Ra-226 is corrected for radon loss from the soil as defined in Appendix F of Reference 4 and shown in equation 2. All analyte values are corrected for moisture content as shown in equation 3. For Ra-226, the radon loss correction must be done prior to the moisture correction calculation.

$$Ra_{radon} = 0.771 * Ra_{nom} + 0.477 * Ra_{nom}^2 \qquad \text{(Eq. 2)}$$

where,

Ra_{radon} = Ra_{226} corrected for effect of radon loss from the soil
Ra_{nom} = Nominal value of Ra_{266} from equation 1.

$$N_{MC} = N_{nom} * (1 + M_{txm}) \qquad \text{(Eq. 3)}$$

where,

N_{MC} = Analyte activity corrected for moisture content
N_{nom} = Analyte activity nominal value (including radon loss correction for Ra_{226})
M_{txm} = Moisture content on a dry weight basis (grams of moisture per gram of soil).

The 95% uncertainty bounds and minimum detectable concentrations are also computed in real-time for uranium, thorium, radium and potassium analytes. For measurements involving soil concentrations of U-238, Ra-226 and Th-232 near their final remediation levels (FRL), the major source of uncertainty is counting error in the signal and background windows (4). Assuming other contributors are negligible (i.e. error in count time, etc.), the variance in net count rate for a particular isotope is shown in equation 4, which in turn can be used to compute the 95% uncertainty bound.

$$\mu^2(N) = \frac{GC + \left[\frac{n_s}{n_b}\right]^2 * BC}{T^2} \qquad \text{(Eq. 4)}$$

where,

$\mu^2(N)$ = Variance of the isotope net count rate
GC = Gross counts in the signal window
n_s = Number of channels in the signal window
n_b = Number of channels in the background windows
BC = Gross counts in the background windows
T = Spectrum live time.

Field minimum detectable concentration (MDC) levels are also computed and reported as described in reference 5. The MDC of the system (under calibration conditions) is an *a-priori* estimate of the minimum net activity that can be measured reliably by a particular system or technique under a given set of conditions. MARSSIM (2000) (6) defines it as the net activity level that detected 95% of the time. The static MDC results for the FEMP systems on the FEMP calibration pad are provided in table I (5).

Table I. MDC of FEMP NaI Systems.

Quantity	RTRAK	RSS1	RSS2
		Uranium (ppm)	
4sec MDC	337	345	306
8sec MDC	234	239	207
3xFRL*	246	246	246
		Ra-226 (pCi/g)	
4sec MDC	18.4	22.2	17.1
8sec MDC	9.8	12.1	9.5
3xFRL	5.1	5.1	5.1
		Th-232 (pCi/g)	
4sec MDC	1.6	1.5	1.6
8sec MDC	1.1	1.0	1.1
3xFRL	4.5	4.5	4.5

*A 3xFRL activity is defined as a hot spot requiring further analysis.

NaI Software User Interface

The NaI OS is designed as a menu-driven, point-and-click user interface that guides users through the process of setting up and initiating a soil survey. The software features an electronic worksheet that prompts the user for important data acquisition parameters and serves as a documentation trail for the survey. The main data acquisition screen provides real-time updates of surface activity for uranium, thorium, radium and total gross activity, the spectrum from which activities were calculated, and several alarms.

An example of the main data acquisition display is provided in figure 2. The main X-Y maps show the path of the vehicle in local Ohio State Plane coordinates. The colors of the dots that form the vehicle path represent the activity level computed from the spectrum. Each map can be toggled to display uranium, thorium, radium or gross activity. Total uranium is displayed in parts per million, thorium and radium in pCi/g, and gross activity in counts per second (CPS). After computing the isotopic activities from a spectral measurement, the software places a dot on a map showing the measurement location. The dot is color-coded to represent the measured activity level. The ranges of activity, each represented by a different color, may be selected for each isotope by the operator. In the example below, the data plotted on the total CPS map are green in color when the activity is less than 5000 CPS, yellow when between 5000 and 18000 CPS, and red when above 18000 CPS. A nominal total uranium plot has levels less than 164 ppm, between 164 and 721 ppm, and greater than 721 ppm. Nominal thorium plots are green when less than 1.5 pCi/g, yellow between 1.5 and 4.5 pCi/g, and red when above 4.5 pCi/g. Nominal radium divisions occur at 1.7 and 5.1 pCi/g. These divisions correspond to FRL, three times FRL, waste acceptance criteria (WAC), and three times WAC levels for the FEMP site and are relevant to the administrative cleanup levels at Fernald.

In addition to the color-coded area maps provided to the NaI operator, alarms are provided to insure that the operator is aware when the GPS is not working properly and when calculated activities exceed three times the WAC (uranium) and FRL (thorium and radium) levels. Alarm levels are configurable by the operator. Output from the NaI OS includes a summary log file and error log file. The log file contains all information associated with the survey such as GPS coordinates, spectra file names, computed activities, uncertainties, minimum detectable concentrations, and alarm conditions. The error log file duplicates much of the information in the log file for records that showed an alarm. Alarms conditions can be generated from GPS errors or high activity readings.

The data undergo a final quality control check where the data are inspected against the error log alarms prior to release to the FEMP database. Alarm investigation outcomes may range from an "OK" stamp onto the data in question, to requiring that a HPGe spectrum be collected to verify the alarm condition. The final product of the FEMP process is a released posting of the data on site drawings that may show contours, fences, roads, and buildings. An example of this is shown in figure 3. In this case, the posted data may contain several days of fieldwork and is designed to provide a comprehensive picture of a designated work area.

Estimated Cost savings at the FEMP

This work was funded by the US Department of Energy Accelerated Site Technology Deployment (ASTD) program. The project was entitled, "An Integrated Technology Suite for Cost Effectively Delineating Contamination in Soils in Support of Soil Remedial Actions". The ASTD funded portion of this work was completed in April of 2001. The Subsurface Contaminants Focus Area supported the project, which successfully deployed both mobile and stationary *in-situ* gamma ray spectrometers to delineate radionuclide contamination in site soils during remediation. These systems have become an integral part of the soil remedial-action effort at Fernald. The program estimates the savings in characterization costs due to the elimination of the collection and analysis of physical samples alone will exceed $34M by Fiscal Year 2006. Savings through December 2000 are estimated at about $16M (7).

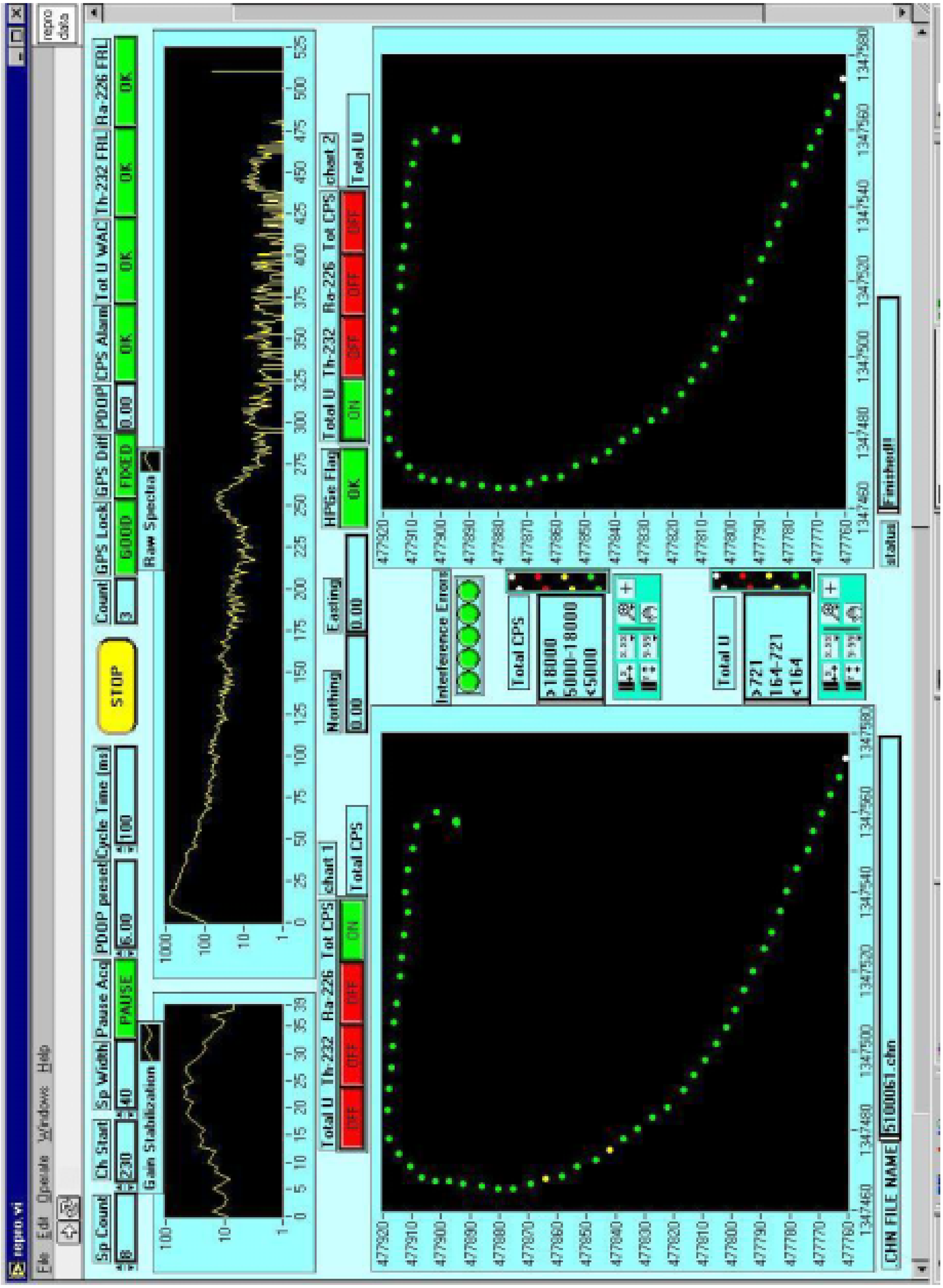

Fig. 2. Example NaI data acquisition interface.

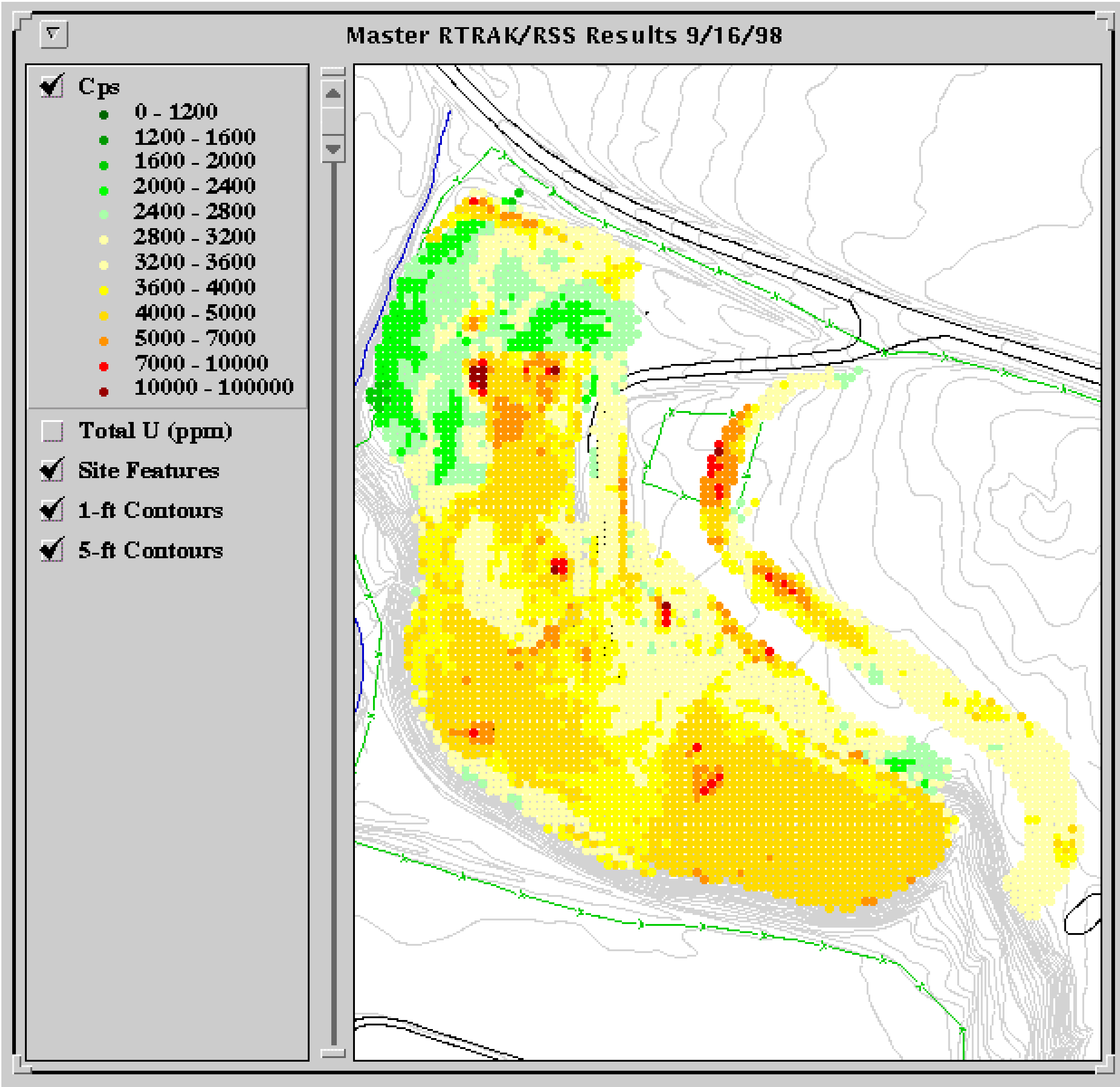

Fig. 3. Example Final NaI Data Posting at Fernald.

IN-SITU SOILS CHARACTERIZATION AT MEMP

During the summer of 2002, the INEEL began development of a system to detect *in-situ* near-surface soil contamination from plutonium-238. Initial laboratory measurements and calibration were done with a Large Area Proportional Counter (LAPC) x-ray detector obtained from the Environmental Measurements Laboratory (EML) (8, 9). The LAPC has dimensions of 16.5 cm x 70.5 cm x 5.9 cm (L x W x H) and is filled with a mixture of 90% xenon and 10% methane at a pressure of 0.15 MPa. The detector has a thin (0.025-cm) beryllium window and aluminum support grid with an effective area of 850 cm^2. The output of the detector is connected to a charge sensitive pre-amplifier, which, in-turn is connected to an amplifier and 1,024 channel multi-channel analyzer.

Plutonium-238 detection is based on measuring the L x-ray triplet emitted during in the decay of Pu-238 at energies of 13.6, 17.13, and 20.29 keV. The LAPC and associated electronics were mounted on a hand-pushed vehicle similar in design to the RSS system used at the FEMP. The system incorporates a GPS and operating system to perform real-time surveying and mapping of potentially contaminated land areas. The system was calibrated at the INEEL using surrogate amercium-241 sources to determine detector efficiency across the energies of interest.

The system was taken to the MEMP in Miamisburg, Ohio for a pre-field demonstration during October 2002. The purpose of the demonstration was to test the INEEL system using plutonium-238 spiked MEMP soil samples to gather system performance and operational data prior to a full-scale field test. The testing was performed indoors over a 1.2-m x 1.2-m plywood box. The test box was populated with 16 30.5 cm x 30.5 cm sample trays containing concentrations of 0, 50, and 500 pCi/g plutonium-238.

Sample Preparation

Approximately 80 kg of MEMP site background soil was screened using gamma spectroscopy to determine natural isotopic content. The soil was placed in milling cans and dried to less than 1% moisture. The soil was milled and sieved to 1mm particle size using Zirconia media. "Blank" (uncontaminated) 1.5-kg samples were added to sample trays and reconstituted to 18% moisture. Final soil depth in the sample trays was approximately 1.75 cm. Spiked soils were prepared by adding a plutonium-238 aqueous reference standard to individual 1.5-kg soil samples in the milling cans. The spiking methodology was validated by laboratory analyses using anion exchange separation and alpha spectroscopy. The average concentration of each spiked batch was within 5% of the target concentrations. After analytical confirmation, the spiked soils were added to sample trays, reconstituted to 18% moisture, and labeled in a code know only to MEMP personnel. All samples were covered with a cellophane wrap to preserve moisture content.

Experimental Description

MEMP personnel (10) orchestrated blind tests of the INEEL system. This was done by placing sample trays of varying concentrations in specific areas of the plywood test box according to a pre-determined MEMP test plan. Initially, INEEL personnel were unaware of contents of the sample trays. A total of twenty-one tests representing differing configurations of sample trays were tested during a four-day period. The tests represented different arrangements of blank (0), 50, and 500 pCi/g trays.

Preliminary Analysis and Test Results

The INEEL system is designed to collect mobile spectra; however, all tests done at the MEMP facility were done indoors in a stationary setting. The INEEL software package developed for the plutonium scanner was patterned after the Fernald NaI OS, and designed to provide plutonium-238 activity and uncertainties in real-time. However, the emphasis of these tests was to establish a baseline detection capability and uncertainty. It should be noted that these data are preliminary and likely require more analysis to fully comprehend the capability of the system.

Figure 4 shows an example spectrum collected with the INEEL plutonium-238 system during the MEMP pre-demonstration test. Four 500 pCi/g Sample trays were arranged directly underneath the LAPC with 50 pCi/g trays comprising the rest of the sample trays as indicated in table II. This spectrum has a 20-min count time and is presented primarily to illustrate that the plutonium-238 triplet located between 10 and 20 keV is clearly visible at this concentration.

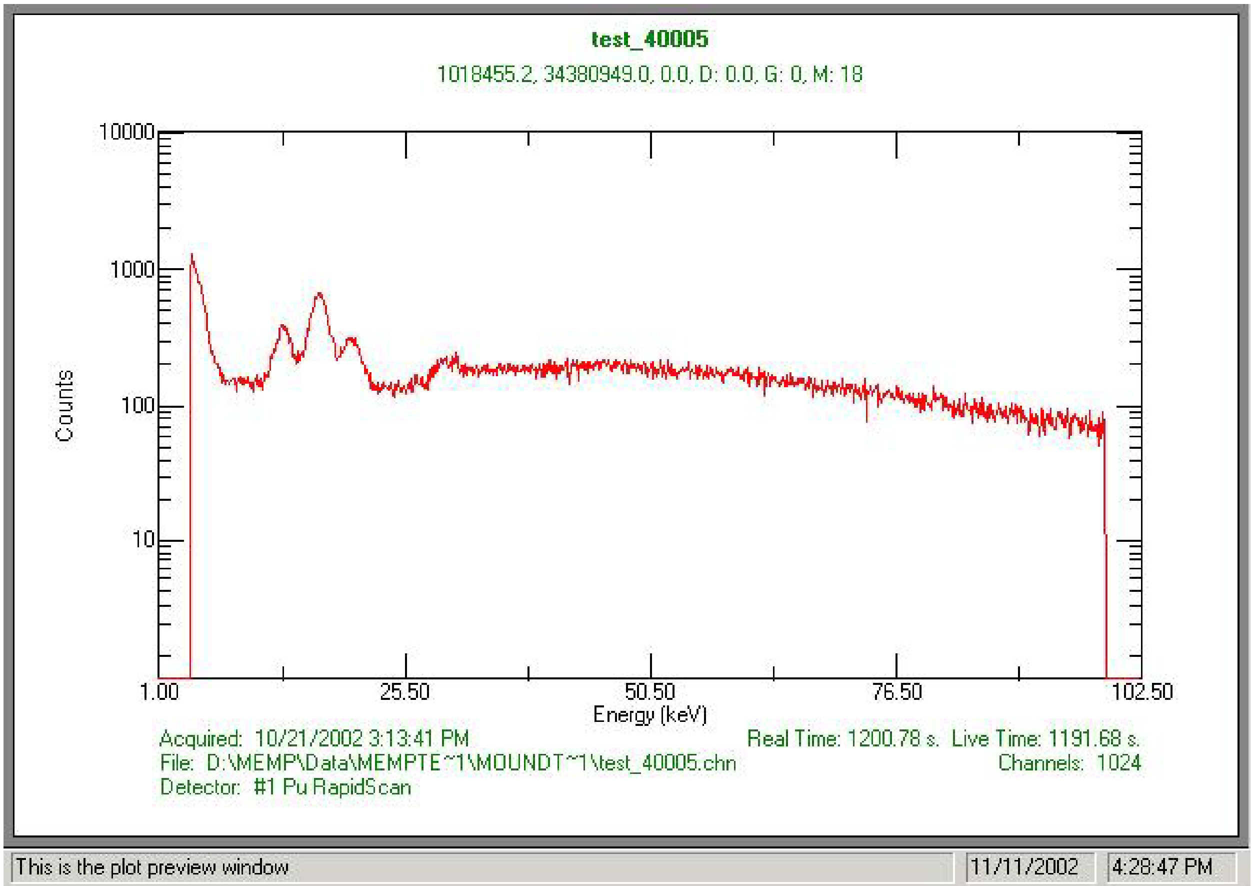

Fig. 4. Test 4 spectrum.

Table II. Sample location matrix for test 4

Tray A 50 pCi/g	Tray B 50 pCi/g	Tray C 50 pCi/g	Tray D 50 pCi/g
Tray E 50 pCi/g	Tray F 500 pCi/g	Tray G 500 pCi/g	Tray H 50 pCi/g
Tray I 50 pCi/g	Tray J 500 pCi/g	Tray K 500 pCi/g	Tray L 50 pCi/g
Tray M 50 pCi/g	Tray N 50 pCi/g	Tray O 50 pCi/g	Tray P 50 pCi/g

Twenty-one tests were conducted during the four-day testing period. Some of the tests were repeat configurations. In general, the pre-demonstration tests were designed to run for 60 minutes with intermediate data collected at 60 sec, 120 sec, 300 sec, 10 min, 20 min, 30 min, and 45 min. An abbreviated test matrix of the tests done at Mound is shown in table III. Blank trays (i.e. no measurable Pu-238) were used where a tray activity was not specified.

Table III. Summary of soil tests done at Mound.

Tray Layout	**Estimated Average Activity Over the 1.2 m x 1.2 m Box**	**Test Number**
All blank trays.	0 pCi/g	7
All 16 trays at 50 pCi/g	50 pCi/g	14
Trays F, G, J, K at 500 pCi/g All other trays blank.	125 pCi/g	2
Trays B, C, N, O at 500 pCi/g All other trays blank	125 pCi/g	6
Trays E, I, H, L at 500 pCi/g All other trays blank.	125 pCi/g	8
Trays A, D, M, P at 500 pCi/g All other trays blank.	125 pCi/g	1

Preliminary test results from specific tests performed with the INEEL plutonium-238 system are summarized in table IV. Table IV consists of spectra analyzed at different count times during a given acquisition. For example in test 14, intermediate spectra were written to disk and analyzed at six intervals from 60 seconds to 30 minutes. The true time column in table IV indicates the actual clock time taken to collect the spectra. The live time column is the time the detector is actively collecting pulses from a source. Detector true time is always less than true time because there is "dead time" between pulses where the detector electronics are processing information and unavailable during active data acquisition. Dead time is normally small in low activity areas, but can be significant as activity increases. At the concentration levels used for these tests, there was very little dead time.

Only two of the test configurations contained uniform activity levels across the test fixture. Test 7 essentially provided a background test without contamination, and test 14 provided a uniform contamination level of 50 pCi/g. Test number 7 consisted of blank trays (no measurable Pu-238 contamination) and the INEEL system essentially verified this by reporting a dry weight concentration of 7.4 pCi/g with a one-sigma error band of 5.2 pCi/g. Note that this was attained after a one-hour count time. Test number 14 consisted of uniform 50 pCi/g trays which was confirmed by the INEEL system which reported a nominal concentration of 49 pCi/g with a one-sigma uncertainty of 3.3 pCi/g after 30 minutes of counting. This test configuration was repeated four times with nominal concentrations ranging from 40 to 50 pCi/g with uncertainties less than 5 pCi/g.

The bulk of the test configurations consisted of placing the 500 pCi/g trays in various positions about the test box. This was done to examine the field-of-view of the LAPC. The INEEL system measured a Pu-238 concentration of approximately 350 pCi/g when four trays were placed directly underneath the detector. This is contrasted with a measurement of 28 pCi/g Pu-238 concentration when four trays were placed in the far corners of the test box. This indicates that the field-of-view of the LAPC is somewhat smaller than the 1.2 m x 1.2-m test box. Adding the results of tests 2, 6, 8, and 11 can simulate a virtual test that contains 500 pCi/g sample trays in all locations. Doing so equates to a nominal concentration of 532 pCi/g which is very close to the reported 5% variation from expected concentration values during sample preparation. Note that during tests involving 500 pCi/g sample trays, acceptable uncertainties are attained with much shorter count times.

Table IV. Preliminary test results from specific tests at Mound.

			Net Area Count Rate (CPS)		Concentration (pCi/g)	
Spectrum	**Live Time (seconds)**	**True Time (seconds)**	**Triplet Sum**	**one-sigma uncertainty**	**Dry weight**	**one-sigma uncertainty**
TEST 7 – All Blank Trays						
70001.chn	3576.3	3600.0	0.32	0.22	7.4	5.2
TEST 14 – All Trays at 50 pCi/g						
140001.chn	60.7	61.1	3.77	0.76	87.7	17.7
140002.chn	119.6	120.4	3.64	0.54	84.7	12.5
140003.chn	299.4	301.3	2.58	0.35	60.0	8.1
140004.chn	598.7	602.5	2.02	0.24	47.1	5.6
140005.chn	1195.0	1202.7	2.71	0.18	62.9	4.1
140006.chn	1791.6	1803.2	2.11	0.14	49.1	3.3
Test 2 – Trays F, G, H, K at 500 pCi/g. All other trays blank.						
20001.chn	60.0	60.4	20.37	1.06	473.9	24.6
20002.chn	120.1	121.0	15.73	0.65	366.0	15.0
20003.chn	297.8	299.9	16.26	0.46	378.4	10.7
20004.chn	596.7	601.2	14.79	0.32	344.2	7.5
20005.chn	1192.4	1201.1	14.97	0.23	348.4	5.3
Test 6 – Trays B, C, N, O at 500 pCi/g. All other trays blank.						
60001.chn	60.9	61.3	5.53	0.8	128.7	18.4
60002.chn	120.4	121.2	5.36	0.6	124.8	14.6
60003.chn	298.3	300.3	5.35	0.4	124.6	8.7
60004.chn	597.0	601.0	8.35	0.3	194.2	6.1
60005.chn	1193.6	1201.5	4.98	0.2	115.9	4.4
60006.chn	1788.9	1800.8	5.15	0.2	119.8	3.6
Test 8 – Trays E, I, H, L at 500 pCi/g. All other trays blank.						
80001.chn	60.7	61.1	4.51	0.7	105.0	16.8
80002.chn	120.6	121.4	3.28	0.5	76.2	12.4
80003.chn	299.2	301.2	2.91	0.3	67.7	7.9
80004.chn	596.6	600.5	3.06	0.2	71.2	5.3
80005.chn	1193.2	1201.0	1.69	0.2	39.4	4.0
80006.chn	1789.7	1801.5	1.57	0.1	36.6	3.4
80007.chn	2684.0	2701.7	1.48	0.1	34.5	2.8
80008.chn	3576.1	3600.0	1.56	0.1	36.2	2.4
Test 1 – Trays A, D, M, P at 500 pCi/g. All other trays blank.						
10001.chn	59.4	60.1	2.43	0.68	56.5	15.84
10002.chn	120.2	121.9	2.71	0.96	63.2	22.33
10003.chn	296.6	300.5	1.44	0.32	33.4	7.54
10004.chn	593.0	600.6	1.25	0.23	29.0	5.25
10005.chn	1185.3	1200.2	1.26	0.16	29.3	3.70
10006.chn	1778.4	1800.7	1.22	0.13	28.3	3.00
10007.chn	2667.2	2700.5	1.20	0.11	28.0	2.46
10008.chn	3556.1	3600.0	1.20	0.09	28.0	2.14

CONCLUSIONS AND RECOMMEDATIONS

Mobile Sodium Iodide systems can be used as a pre-certification device for contaminated soils under specific conditions, and has been accepted by regulators as an approved method in the state of Ohio. These systems coupled with advanced data collection and analysis software developed at the INEEL are routinely used at the Fernald Environmental Management Project to perform production pre-screening soil surveys. The results of these NaI surveys are used to direct follow-up surveys that may require more sophisticated high-resolution spectrometers, and to select analytical sample locations. The FEMP has estimated that overall site cost savings will exceed $34M by FY 2006.

The success of this program has prompted the DOE-Ohio field office and the state of Ohio to explore use of these systems at the other Ohio DOE sites. This process has begun at the Ashtabula Environmental Management Project. The success of this program should prompt other DOE sites to examine the use of mobile spectrometry where the contamination and conditions match the detection capability of the system.

The INEEL has shown that quantitative *in-situ* analysis of Pu-238 contamination at levels below 100 pCi/g is possible with reasonable count times by using a large area proportional counter to examine x-rays between 10 and 20 keV. This system has been demonstrated at the Mound Environmental Management Project using plutonium soil samples spiked between background and 500 pCi/g. The next step in this process is to establish the capabilities of the system in a mobile scanning mode. A number of parametric studies are planned where count time, scan speed, detection limits, and uncertainties will be examined. The trials and tribulations of the RTRAK system promoted by the FEMP serves as an excellent model by which this system can be deployed and accepted as a viable field instrument for screening activities in plutonium soil cleanup.

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