Advanced Assay Systems for Radionuclide Contamination in Soils – 8360

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ABSTRACT

Through the support of the Department of Energy (DOE) Office of Environmental Management (EM) Technical Assistance Program, the Idaho National Laboratory (INL) has developed and deployed a suite of systems that rapidly scan, characterize, and analyze surface soil contamination. The INL systems integrate detector systems with data acquisition and synthesis software and with global positioning technology to provide a real-time, user-friendly field deployable turn-key system. INL real-time systems are designed to characterize surface soil contamination using methodologies set forth in the Multi-Agency Radiation Surveys and Site Investigation Manual (MARSSIM). MARSSIM provides guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose or risk-based regulation and provides real-time information that is immediately available to field technicians and project management personnel. This paper discusses the history of the development of these systems and describes some of the more recent examples and their applications.

INTRODUCTION

Through the support of the DOE Office of EM Technical Assistance Program, the INL has developed and deployed a suite of systems that rapidly scan, characterize, and analyze surface soil contamination. The INL systems integrate sensor systems with data acquisition and synthesis software, global positioning to provide a real-time, user friendly field deployable turn-key system. INL real-time systems are designed characterize surface soil contamination using methodologies set forth through MARSSIM. MARSSIM provides guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose or risk-based regulation and provides real-time information that is immediately available to field technicians and project management personnel. This paper discusses the history of the development of these systems and describes some of the more recent examples and their applications.

CORE APPROACH

The INL Environment Engineering and Technology department and the Modeling and Simulations group collaborate to provide the technical expertise for development of real-time measurement systems. The core approach used produces systems that are developed and tested with commercially available off-the-shelf components, and combines them with custom integration and system control software.

While the concept of real-time measurements is not new, the INL has created flexible systems that are applied to unique conditions. INL systems are usually a product of practical need by cleanup contractors to increase operational efficiency while meeting stakeholder expectations and regulatory cleanup requirements. The INL has provided real-time system support and conducted numerous working field demonstrations, primarily for DOE Cold War legacy sites such as the Fernald Closure Project (FCP) near Cincinnati Ohio and the Miamisburg Closure Project (MCP) near Dayton Ohio, and more recently, the Idaho Cleanup Project (ICP) near Idaho Falls, Idaho. Technology development benefited from early working technology demonstrations conducted at the Mound Ohio facility and at United Kingdom

Atomic Energy Authority (UKAEA) sites in 1998 in Harwell, England and Dounreay, Scotland (Figure 1).


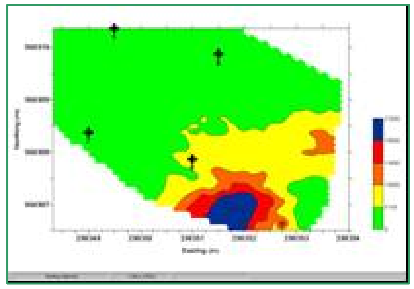

Figure 1. INL remote real-time scanning system and on-screen data output during field demonstration at Dounreay, Scotland in December 1998.

This experience has been leveraged into continuous improvements and useful adaptations to the original system approach.

EVOLVING REGULATORY GUIDANCE

Regulatory evolution of guidance on Environmental Protection Agency (EPA) oversight and remedial designs under evolving regulatory guidance from the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) increasingly allow a “learn as you go” approach through a project’s implementation period. The EPA supports a more streamlined approach to sampling, analysis, and data management activities conducted during site assessment, characterization, and cleanup [2] by embracing a *Triad* approach. The EPA Triad approach integrates Systematic Planning, Dynamic Work Plans, and On-site Measurement Technologies functions. The aim is to accelerate site characterization by using technologies that provide better decision-making tools. The INL has used “lessons-learned” experience from previous soil-remediation projects at the FCP, MCP, and others that can be applied to future projects.

SYSTEMS AND APPLICATIONS

New versions of basic INL real-time systems are discussed in this paper such as the All Terrain Vehicle (ATV)-based Gator, Excavation Monitoring System (EMS), the Actinide X-Ray in-Situ Scanning System (AXISS) and the Backpack Sodium Iodide System (BaSIS). Rapid development of these systems was possible because the basic system architecture they share was designed to adapt to variations in the systems as well as variation between different site conditions.

The mobile Sodium Iodide (NaI) concept was initially developed by the FCP to provide pre-screening analyses for its soils contaminated with radionuclides such as uranium, thorium, and radium. Other systems such as AXISS and a strontium-90 characterization system currently under development are new applications that also utilize the basic system architecture

MOBILE REAL-TIME SYSTEM EVOLUTION

Mobile real-time systems deployed and/or supported by INL-supported projects share a common operating system that can be configured for multiple applications. INL-supported projects included the Fernald and Mound Closure Projects in Ohio and the INL’s ICP, where true real-time software systems providing instantaneous information for site management were implemented. Real-time characterization data collection minimizes operational downtime and maximizes cost containment by avoiding sampling costs associated with physical sampling and laboratory analysis. The INL has developed a real-time operating system that incorporates real-time functions for acquiring spectral data and position information, processing spectra to obtain counts per second within specific regions of interest, computation of radiological activity, and correction of the computed activity for soil moisture content.

Early FCP systems acquired data that needed several days of post-processing and analyses to estimate field coverage and activity levels associated with radiological soil contamination. The original FCP acquisition system possessed little in the way of real-time visual feedback to the system platform operator. Data were gathered in a "batch" environment and then post-processed to compute the radiological activity of the surveyed area. Typically, this process occurred over a two- to four-day period.

The INL provided integrated engineering computer hardware and software support to greatly streamline the data acquisition and analysis process to the point where activity and coverage maps were available to the field technicians in near real time. The characterization system developed for the FCP was designed to operate from multiple platforms. The original platform used as the FCP was deployed from a large tractor-based vehicle called the Radiation Tracking System (RTRAK). The RTRAK provided the delivery or deployment system, but the acquisition and analysis hardware and software were designed and implemented by the INL. This acquisition and analysis system was deployed from five additional vehicles, which included four hand-pushed deployments dubbed the Radiation Scanning System (RSS) and an ATV-based system called the Gator, shown in Figure 2. The RTRAK was eventually retired towards the end of the FCP closure activities. Functionally, the RTRAK, RSS, and Gator platforms were identical and simply represented three different methods for mobile-deployment of the detectors and the real-time software analysis system.

Figure 2. The Gator real-time system.

EXCAVATION MONITORING SYSTEM

The Excavation Monitoring System (EMS) was developed for the FCP as a method to characterize excavations resulting from cleanup activities (ditches, foundation removal, etc.), and is a self-contained detection system that uses a standard excavator as the deployment platform. The EMS includes a self-righting vertical detector arm, which attaches to a detector mount and detector and to the vertical and lateral range finders. The detector arm is suspended from a horizontal platform that is coupled to the arm on the excavator and holds an on-board computer, a Global Positioning System (GPS) receiver and antenna, an antenna for a laser-based position tracker, and an excavator coupler. Other major components of the system include excavator cab and support van computers, software, and displays.

The EMS is typically applied to nonstandard survey situations that cannot be handled with conventional platforms. These situations include surveys of pits, trenches, mounds, vertical surfaces, soft or wet ground, and other conditions that are unsafe for human entry. The EMS protects workers and reduces their potential exposure thereby advancing the “as low as reasonably achievable” (ALARA) objectives and worker health and safety. The EMS is capable of deploying a variety of detectors and is currently configured to deploy NaI and High Purity Germanium (HPGe) gamma-spectrometry systems at FCP (See Figure 3.).

Real-time gamma measurements can be made in several modes including stationary measurements at a prescribed detector height or offset, and mobile scanning measurements can be made with either detector at a prescribed detector height and scanning speed. Either gross activity or spectrometric measurements can be collected in any of these modes. All stationary or mobile measurements are tagged with the detector location. The movement of the EMS-mounted detector over the survey area is tracked using either GPS or a laser-based tracking system that traces detector location on display screens in the excavator cab and in the support van.

Figure 3. EMS NaI platform is used to survey trenches.

ACTINIDE X-RAY IN SITU SCANNING SYSTEM

Over the last 2-1/2 years, the INL has provided soil and building characterization technologies to delineate radioactive contamination in support of soil remedial actions at the MCP. Part of the project focused on development of an actinide scanning system, possessing capability to quantify Plutonium-238 in real-time scan mode. Performance testing in FY 2002 and FY 2003 achieved detection limits exceeding the cleanup and hot-spot criteria activity levels for Plutonium-238. The AXISS Large Area Proportional Counter (LAPC) was referenced in a paper written and presented by Dr. Kevin H. Miller from the Environmental Measurements Laboratory in New York, New York at an American Nuclear Society conference in New Orleans [2]. This information formed the basis leading to a working AXISS in the field as demonstrated at the Building-38 excavation in March 2004 (see Figure 4). The AXISS was used regularly to survey roadbeds and other areas where soil haulers operate until the Plutonium-238 phase of the project was completed.

Figure 4. AXISS performing survey and a contour plot of Building-38 survey performed by the AXISS at the MCP in 2004.

The AXISS was used at the MCP to quantify Plutonium-238 concentrations in the field. These in situ measurements are used to establish that cleanup and hot-spot levels for Plutonium-238 have been achieved (i.e., 55 pCi/g and 165 pCi/g, respectively, at MCP). The AXISS provides the ability to rapidly cover 100% of the desired survey area. Collected information is instantly available via the system's real-time data system, and display of field data is available for remedial decision-making. The AXISS possesses protocols for routine system operation that include source checks, energy calibration, efficiency calibration, and background measurements. Automated Quality Assurance/Quality Control (QA/QC) measures are integrated into the control software [3] to provide nearly error-free QA/QC and to provide automatic documentation that is used to validate decisions made to achieve cleanup goals. Automated features on the AXISS dramatically reduce labor requirements as well as errors due to factors associated with human nature, such as fatigue and repetitive activity.

The AXISS is designed to serve multi-role applications. The system could be used for first response to dirty bomb attacks to rapidly determine identity, physical extent, activity level, and concentration of contaminants. The system can also be used for a multitude of preventive applications such as pre-event sweeps of public gatherings and venues.

BACKPACK SODIUM IODIDE SYSTEM

Real-time characterization during remediation at the ICP is being accomplished through the use of the BaSIS. This system includes a 3-in. by 5-in. sodium iodide (NaI) detector, GPS capability, and a portable computer integrated into a lightweight backpack. The system is controlled with specialized software that allows the operator and/or remediation field manager to view data as it is collected. Upon completion of the planned excavation stages, the area is surveyed for residual radiological contamination. After data collection is complete, data are available to the remediation field manager as a contour map showing the area(s) that require further excavation. Rapid BaSIS data turn-around supports the EPA Triad approach. Project cleanup decisions are made based on real-time information and used to guide the remediation process.

The DOE, in conjunction with the State of Idaho and the EPA signed the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (FFA/CO) [4] in 1991, provided the roadmap to closure for CERCLA activities at the INL for the past 15 years. Site investigation, risk assessment and remedial actions at the INL have followed the traditional CERCLA process, which adherence to EPA guidance.

Recent EPA guidance for site cleanup closely parallels the Triad approach. The ICP negotiated with the appropriate CERCLA regulatory agencies (EPA, Idaho Department of Environmental Quality, and DOE Idaho Operations Office) to allow the use of real-time instrumentation instead of laboratory based analytical methods. By using the BaSIS in such a manner, the INL demonstrated compliance of its results by achieving the regulatory objectives during remediation efforts that are presently underway.

The dynamic work strategy developed for the soil removal at the Test Area North (TAN) site located within the INL was based on the use of real-time field measurements. Previous investigations at the TAN site have shown that if the Cesium-137 concentrations are below the 23 pCi/g remedial action goal, other contaminants of concern (COC's) (i.e., volatile and semi volatile organic compounds) are also below their respective remedial action goals. As such, the concentration of Cesium-137 in the soil, as measured with field instrumentation, can be used during the remediation activities by field personnel and project managers to determine when the remediation process is complete.

The BaSIS is configured to collect data in two modes; 1) Scan and 2) Point-and-Shoot. The scan mode was designed to allow scanning, or moving measurements to be made over relatively large areas. While in scan mode, the BaSIS system software collects 10-second spectra from the NaI detector, calculates the Cesium-137 concentration, and provides a GPS coordinate for each location. The position assigned to each measurement corresponds to the midpoint between the locations at which the measurement started and where the measurement ended.

REAL-TIME CONFIGURATION AND CONTROL

The real-time instrumentation developed by the INL and used at the ICP includes radiation measurement equipment tailored to report Cesium-137 concentrations in soil. The system is comprised of a NaI gamma-ray spectrometer; GPS; field-rugged system control computer; and field deployment platform (backpack). The hardware is configured for deployment using a field backpack to allow for optimum portability and ease of deployment in areas inaccessible to vehicle-based platforms. Due to its portability, the noted advantages using the BaSIS at the ICP include the ability to provide a mobile survey of selected areas in a fraction of the time required to perform the surveys using an in situ HPGe detector.

The field-rugged computer and real-time software package process and integrate the signals from the NaI gamma-ray spectrometer and the DGPS. The real-time software provides a simple graphical user interface and push-button control of all system functions for ease of operation. Similar to the HPGe systems currently used, BaSIS provides 100% coverage of the excavated area(s) of concern, with a 3.7m diameter, detector field-of-view. Use of the BaSIS follows a dynamic work plan approach. The BaSIS provides a higher density of discreet measurements, thus increasing the spatial resolution of the survey four-fold over conventional measurements with an HPGe system. Additionally, the real-time software used in the BaSIS system eliminates the need for time consuming post-processing of the data. Detailed contour maps are produced from the data and made available to project personnel within minutes of completing the survey.

Key features of the BaSIS include:

- 100% coverage during characterization
- Identification and quantification (pCi/g) of Cesium-137, with a minimum detectable concentration of 1.5-pCi/g for a 10-second count.
- Real-time display of position and radionuclide concentrations during survey
- Continuous data collection (Scan Mode), or stationary measurements (Point & Shoot Mode)
- User-selectable threshold alarms that alert the operator to activity exceeding selected limits

- Lightweight backpack system can be deployed almost anywhere
- Detector field of view
- Real-time data management software provides:

    - Automated data collection
    - Automated QA/QC functions for system and data
    - Automated mapping function
    - Automated data archiving.

SUMMARY

INL mobile real-time systems have been successfully used as pre-certification devices for contaminated soils under specific conditions, and accepted by regulators as an approved method to replace or significantly reduce physical sampling and laboratory analysis. These systems coupled with advanced data collection and analysis software developed at the INL to perform production pre-screening soil surveys are also used to determine final analytical sample locations for final validation of sites. The success of the real-time soil characterization program at DOE-Ohio field office sites at Mound and Fernald provided the driver for use of some of these systems at the current INL ICP. Additionally, the use of INL real-time advanced assay systems at Fernald resulted in overall cost savings to the soil remediation project totaling $34M by the end of the project in 2006[5].
Although the genesis of these systems occurred in the DOE Environmental Management program, other agencies have examined the use of real-time mobile spectrometry in cross-cutting applications such as National Homeland Security; where modified versions of these systems could be applied to monitoring, and surveillance of facilities and events as well as event-response to terrorist attacks using radioactive materials.

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