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Radiological Monitoring Equipment for Real-Time Quantification of Area Contamination in Soils and Facility Decommissioning

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RADIOLOGICAL MONITORING EQUIPMENT FOR REAL-TIME QUANTIFICATION OF AREAL CONTAMINATION IN SOILS AND FACILITY DECOMMISSIONING

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ABSTRACT

The environmental restoration industry offers several systems that perform scan-type characterization of radiologically contaminated areas. The Idaho National Laboratory (INL) has developed and deployed a suite of field systems that rapidly scan, characterize, and analyse radiological contamination in surface soils. The base system consists of a detector, such as sodium iodide (NaI) spectrometers, a global positioning system (GPS), and an integrated user-friendly computer interface. This mobile concept was initially developed to provide precertification analyses of soils contaminated with uranium, thorium, and radium at the Fernald Closure Project, near Cincinnati, Ohio.

INL has expanded the functionality of this basic system to create a suite of integrated field-deployable analytical systems. Using its engineering and radiation measurement expertise, aided by computer hardware and software support, INL has streamlined the data acquisition and analysis process to provide real-time information presented on wireless screens and in the form of coverage maps immediately available to field technicians. In addition, custom software offers a user-friendly interface with user-selectable alarm levels and automated data quality monitoring functions that validate the data.

This system is deployed from various platforms, depending on the nature of the survey. The deployment platforms include a small all-terrain vehicle used to survey large, relatively flat areas, a hand-pushed unit for areas where manoeuvrability is important, an excavator-mounted system used to scan pits and trenches where personnel access is restricted, and backpack-mounted systems to survey rocky shoreline features and other physical settings that preclude vehicle-based deployment. Variants of the base system include sealed proportional counters for measuring actinides (i.e., plutonium-238 and americium-241) in building demolitions, soil areas, roadbeds, and process line routes at the Miamisburg Closure Project near Dayton, Ohio. In addition, INL supports decontamination operations at the Oak Ridge National Laboratory.

INTRODUCTION

INL began real-time technology support to Cold War legacy sites in the mid-1990s. The initial goal was to enhance environmental remediation characterization practices. After September 11, 2001, traditional cleanup technologies became companion to technologies that could serve the additional role of supporting U.S. National Homeland Security (NHS) objectives. INL has endeavored to constantly improve and adapt current systems and processes to embrace the new roles that serve NHS, but also to support new initiatives that serve space exploration and develop better technology to expedite environmental remediation challenges.

CORE APPROACH

The INL Environmental Engineering and Modeling and Measurements Departments, combined with the Modeling and Simulations Group, develop the real-time measurement system applications. The core approach is quite simple: a system is assembled and tested with commercially available, off-the-shelf components integrated with end-use-specific system control software. Mechanical and electrical engineering, custom fabrication, and materials science complete the physical system. Using existing component technologies is well suited for use in this application and benefit a project by absorbing individual component development costs that would typically be born by the project development phase.

While the concept of real-time measurements is not new, INL has created custom systems for unique conditions. INL systems are typically the product of a general effort by cleanup contractors to increase operational efficiency, while meeting stakeholder expectations and regulatory cleanup requirements. INL has provided real-time system support primarily at Department of Energy sites, such as the Fernald Closure Project (FCP) near Cincinnati, Ohio, the Miamisburg Closure Project (MCP) near Dayton Ohio, and the Idaho Cleanup Project (ICP) at INL. Working technology demonstrations of INL systems were also conducted in 1998 at United Kingdom Atomic Energy Authority (UKAEA) sites in Harwell, England and Dounreay, Scotland. This experience has been leveraged into continuous improvements and useful adaptations of the original system.

EVOLVING REGULATORY GUIDANCE

The evolution of regulatory guidance on remedial designs under CERCLA[1] increasingly allows a "learn as you go" approach during a project's implementation period. The U.S. Environmental Protection Agency (EPA) encourages a streamlined approach to sampling, analysis, and data management activities conducted during site assessment, characterization, and cleanup.[2] The EPA has an integrated "Triad" approach, specifically (1) systematic planning, (2) dynamic work plans, and (3) on-site measurement technologies. The aim is to accelerate site characterization by using technologies that have better decision-making tools. INL uses lessons-learned from previous soil remediation projects at the FCP, MCP, ICP and others that can be applied to future projects. Factors, such as homeland security needs and evolving EPA regulatory insistence on real-time systems, that support Triad, also drive design and function considerations for INL systems.

MOBILE REAL-TIME SYSTEM EVOLUTION

The mobile NaI concept was initially developed at FCP to provide prescreening analyses for soils contaminated with uranium, thorium, and radium. The software developed for these mobile or area survey applications was initially written in "C" and contained 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. However, due to evolving regulatory guidance and accelerated cleanup schedules, projects in Ohio, such as FCP and MCP, needed true real-time software systems, where instantaneous information would provide site management with rapid decision-making capabilities. Real-time characterization data collection was identified as a means to minimize operational downtime and maximize cost containment of costs associated with physical sampling and laboratory analysis.

INL 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 field technicians. The NaI operating system was rewritten in LabVIEW, which is an object-oriented graphically based software development environment (available from National Instruments, Inc.) that uses the virtual instrument concept, where a general-purpose computer can mimic the feel and functionality of a real instrument with dedicated controls and displays, and the added versatility of custom software. The LabVIEW environment provides a number of widgets (or tools) that allow software engineers to generate sophisticated displays, and communicate with hardware using all the common protocols (networking, serial lines, GPIB buses, etc.), timing functions, and file handling functions.

SYSTEMS AND APPLICATIONS

Mobile real-time systems deployed and supported by INL share a common operating system that can be configured for multiple applications. Similarly, the deployment platform is customized for specific applications. The deployment platforms include a small all-terrain vehicle used to survey large, relatively flat areas, a hand-pushed unit for areas where maneuverability is important, an excavator mounted system used to scan pits and trenches where personnel access is restricted, and backpack mounted systems to survey rocky shoreline features and other physical settings that preclude vehicle-based deployment. A global positioning system (GPS) provides platform position data to the control computer through a serial line. The radiation measurement hardware communicates with the control computer through either a parallel port or a universal serial bus (USB) connection. In addition, a typical MAP NaI computer can be linked to a field operations center (FOC) by way of a wireless Ethernet network. The FOC computer duplicates most of the information displayed to the NaI operator and allows a field supervisor to observe automated quality checks of the data as they are collected from a remote location.

All Terrain Vehicle Mobile Sodium Iodide System

Initial attempts to automate data acquisition and analysis for radiological contamination at the FCP site involved a mobile NaI gamma spectrometry system, called the RTRAK, which was deployed from a John Deere tractor. Contaminants of concern at FCP included radium-226, thorium-232, and uranium-238. The RTRAK development and attempts to automate data acquisition and quality parameters necessary to implement a real-time program are described in the RTRAK[3] Applicability Study.[4] Guidelines for use of the real-time characterization systems and measurement strategies are published by the Department of Energy.[5] Subsequent to

[1] Comprehensive Environmental Response, Compensation and Liability Act
[2] USEPA Office of Solid Waste and Emergency Response: EPA 542-F-01-03a, April 2001.

[3] Radiation Tracking System.
[4] U.S. Department of Energy, *RTRAK Applicability Study*, 20701-RP-0003, Rev. 2, DOE, Fernald Environmental Management Project, Cincinnati, Ohio, January 1999.
[5] *User Guidelines, Measurement Strategies, and Operational Factors for Deployment of In-situ Gamma Spectrometry at the Fernald Site,* 20701-RP-0006, Revision A, DOE, Fernald Environmental Management Project, Cincinnati, Ohio, July 1998.

RTRAK, INL was tasked to design and implement an advanced NaI-based data acquisition and management system. This system became known as the *Gator.* The Gator is a gasoline-powered utility vehicle manufactured by John Deere. The ATV-based system consists of a 4- by 4- by 16-inch sodium iodide detector computer-based multichannel pulse height analyzer, global positioning system (GPS), and laptop computer integrated via INL real-time system software. The detector is suspended from the front of the vehicle at a height of 31 cm; the electronics are mounted on the vehicle bed, behind the driver.

Calibration Process

The GATOR is calibrated using the same data acquisition software and the same spectral regions as the other NaI systems discussed in this paper. The calibration process consists of taking HPGe[6] and GATOR readings at a series of locations, determining the net count rates for the isotopes of interest from the GATOR spectral data, and performing multiple linear regression analyses to determine a best-fit equation to represent each isotopic data set.

Figure 1. Gator ATV platform, used for large flat areas.

Excavation Monitoring System

The EMS is a self-contained detection system that uses a standard excavator as the deployment platform. The EMS includes a self-righting vertical detector arm that attaches to a detector mount, a detector, and vertical and lateral range finders. The detector arm is suspended from a horizontal platform coupled to the excavator, and holds an on-board computer, a GPS receiver and antenna, and an antenna for a laser-based position tracker. Other major components of the system include excavator cab and support van computers, displays, and real-time data management software. The EMS is capable of deploying a variety of detectors and is currently configured to deploy NaI and HPGe gamma spectrometry systems at FCP.

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

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 objectives of ALARA and worker health and safety.

Figure 2. EMS NaI platform, used to survey trenches.

BaSIS

The INL-developed BaSIS system is in use at the Miamisburg Closure Project and at the INL site to rapidly characterize areas that other real-time platforms cannot access (Figure 3). The backpack-based system offers 100% coverage in areas accessible to walking by field personnel.

The BaSIS shares the same basic data collection functionality as the other NaI systems described. The system was designed specifically to detect both low-energy photons and higher energy gamma rays using FIDLER and large NaI detectors, respectively. Utilizing a simple region-of-interest stripping routine, the system offers the user the ability to obtain real-time information, including radionuclide(s) identification, corrected radionuclide activities, and measurement location. This information is used to make maps and support on-site remedial action decision-making. The system is configured to store the collected data on the computer hard drive for permanent archiving. In addition, the system has wireless local area network cards that allow personnel to view the real-time data collection activities from a remote location.

[6] High Purity Germanium detector.

Figure 3. BaSIS survey in PRS 66 excavation at MCP.

Interior Characterization Scanning System (ICISS)

The ICISS was deployed at the Miamisburg Closure Project (MCP). ICISS is deployed from a simple rolling platform that positions a selected detector next to walls and ceiling surfaces, and other interior building fixtures (i.e., lights, ventilation ducts, etc.) to perform scan or point-and-shoot surveys (Figure 4). ICISS replaces hand surveys conducted during building characterization. Contaminants of concern at MCP are primarily alpha and gamma. The ICISS reduces worker physical stress and required survey time, and improves data collection quality. The system possesses a mechanical DC motorized lift to elevate the detector head to the desired height and position. The platform is rolled to the desired x, y position where it can be conveyed along the floor for scanning surveys. Two of the wheels at the base of the platform can be locked to anchor the platform during stationary point-and-shoot data collection.

The control software is based on the virtual instrument concept, wherein a general-purpose computer can mimic the feel and functionality of a real instrument, with dedicated controls and displays. ICISS data are a permanent and retrievable record used to locate the areas of contamination for further sampling or removal.

Figure 4. Interior Characterization Scanning System inside the SW/R Process Facility at MCP.

Actinide X-Ray In Situ Scanning System

INL has provided soil and building characterization technologies to delineate radioactive contamination in support of soil remedial actions at MCP. Part of the project focused on developing an actinide scanning system, with the capability to quantify Pu-238 in a real-time scan mode.

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 for remedial decision-making. AXISS possesses protocol for routine system operation including daily source checks, energy calibration, efficiency calibration, and background measurements. Automated Quality Assurance/Quality Control measures are integrated into the operational process. AXISS is an ideal tool for first response to accidents and improvised explosive device (IED) events to rapidly determine the identity, physical extent, activity level, and concentration of contaminants.

Figure 5a. AXISS performing survey at the MCP Building-38 excavated footings.

The AXISS Large Area Proportional Counter (LAPC) is described in a paper written and presented at an American Nuclear Society conference in New Orleans by Dr. Kevin H. Miller of Environmental Measurements Laboratory. This information formed the basis leading to a working AXISS in the field, as demonstrated at the Building-38 excavation in March 2004, and has since been regularly used to survey roadbeds and other areas where soil haulers operate.

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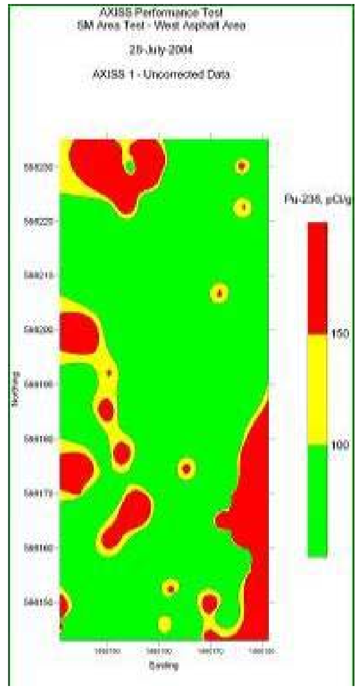

Figure 5b. Contour plot of the Building-38 survey performed by AXISS.