High-Resolution Gamma Spectroscopy Logging System

Problem Summary

In recent years, studies in radioactive waste management have become important issues at both commercial and government sites across the country as well as internationally. Effluent streams from commercial nuclear power plants contain low levels of radioisotopes. Additionally, waste material at the various disposal sites across the country is composed of low-level (LLW), high-level (HLW), and transuranic (TRU) waste in various physical forms. The waste is generally packaged in wooden, plastic, or metal containers and stored above ground or in shallow burial pits. Due to the nature of the waste disposal and storage environments, radioactive contamination leaches into the ground forming contaminant plumes. Due to infiltration of surface moisture, these contaminant plumes can move through the vadose zone and enter the groundwater system where it poses a potential threat to public and environmental health. However, before the plumes may be remediated, proper site characterization must be in place. Included in this site specific characterization is the need for accurate contaminant fate and transport monitoring in the vadose and saturated zones.

In order to monitor the radioactive materials, monitoring wells must be installed for the collection of soil and water samples. The vertical migration of radioisotopes has been characterized by the installation of monitoring wells; however, to determine contaminant migration through the vadose zone with time, new wells must be constructed at extremely high costs. Additionally, current groundwater monitoring practices involve the collection of samples from installed monitoring wells. In general these water samples must be preserved with nitric acid (or some other chemical), packaged and shipped to an environmental monitoring laboratory. In turn, the slow-turn around times from laboratory analyses delay the characterization process and add substantial monetary costs to the monitoring program for the shipping and analysis. Recently, however, it has been possible to take the lab to the sample through the development and use of portable gamma spectroscopy logging systems.

Solution/System Description

A new environmental monitoring technique has been developed and optimized over the past five years to aid in routine monitoring and site characterization processes. The technique is based on high-resolution gamma spectroscopy with high-purity germanium (HPGe) detectors. One such system is in operation at the Idaho National Engineering Laboratory (INEL) and is identified as the Gamma Spectroscopy Logging System (GSLS). This system is composed of an HPGe cryostat and LN_2 dewar housed in a watertight, stainless steel casing coupled to NIM-BIN and 486 personal computer. This tool has an outer diameter of 3.65 inches and is capable of logging any well or borehole with a 4.0 inch inner diameter casing or larger. The system is equipped with a sufficient length of cable to log to a depth of approximately 760 feet below ground surface. The cable consists of the electronic wiring required to send the spectral data signals, a vent hose for nitrogen and a kevlar shield which is used to support the weight of the cable and logging tool. Software developed specifically for the logging system controls the movement of the tool, and data acquisition and analysis. The software and hardware are configured to allow almost complete system automation.

The data acquisition system is comprised of the detector, multi-channel buffer, and the interface module that feeds the data into the computer. The computer then displays the information as a spectrum on the computer screen. The system is setup with 8,192 channels that provide the desired resolution.

All equipment is mounted in a one-ton, four-wheel drive Ford van. The power requirements for the system are all produced using the Ford 7.3 liter diesel engine. A power-take-off (PTO) unit is connected to the vehicle transmission which provides the hydraulic pressures needed to operate the cable hoisting system. A

120 Volt generator operates in place of the engine alternator and provides the power for all the computer and electronic equipment. The generator also provides power to a separate DC generator/regulator system that provides the DC current required for the data acquisition system, the top mounted crane, in addition to the DC requirements of the vehicle. The system is completely self-contained, and does not require external power.

This system is ideal for a variety of site characterization activities, and provides numerous benefits over conventional water and soil sampling methods including 1) real-time data acquisition which eliminates the need for sample shipping and relying on slow laboratory turn around, 2) decrease in the volume of waste generated during the sampling and analysis program, 3) provides the ability to routinely and repeatedly monitor contaminant movement in the unsaturated and saturated zones of a well without installing new wells, and 4) provides the ability to monitor multiple radionuclide concentrations at depth-discrete intervals ranging from land surface to approximately 760 feet bgs. There is no other system or method currently available that can provide all of this information as quickly as the GSLS. Another unique application of this system would be in the use of determining partitioning coefficients in contaminant fate and transport modeling.

A hypothetical scenario would be as follows: Collect a water sample with a disposable Teflon bailer at a discrete depth. This sample is then analyzed using the logging tool with the same sample/detector geometry present in the borehole environment. The logging tool is then lowered to the same depth, and allowed to collect data. This data would contain the amount of radioactivity in the water and the total amount of radioactivity in the formation (radioisotopes in solution and sorbed to subsurface materials), respectively. Analyzing a water sample collected at a discrete depth and comparing the quantity of radioactive material in the water with the total amount of radioactivity in the formation may allow for the estimation of partitioning coefficients.

Potential Uses and Applications

The INEL GSLS can be used to identify and quantify gamma-emitting isotopes with gamma-ray energies ranging from approximately 186 to 3000 keV with the detection limit of about 0.1 pCi/g. Both man-made and naturally occurring radioisotopes can be detected and quantified at the 95% confidence level. The man-made isotopes of concern are long-lived, radioactive fission products from the nuclear fuel cycle. These isotopes may be present in the effluent streams of nuclear fuel fabrication and reprocessing facilities, and commercial power plants. Included in this list of isotopes (but not limited to) are ^{235}U, ^{60}Co, ^{125}Sb, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{233}Pa.

A number of immediate uses have been identified at the INEL and other DOE facilities. These are described below.

- Numerous characterization wells have been installed at the INEL over the years in an effort to quantify radionuclide distribution in the unsaturated and saturated zones; although samples were taken and analyzed during well installation, no current data are available on contaminant movement in the unsaturated zone since installation. It is known that these contaminants can move in the unsaturated zone, but the only way to currently confirm and quantify this is by installation of new wells. This approach is prohibitively expensive and provides another potential pathway to the groundwater for other contaminants. In addition, routine monitoring of contaminated wells with the logging tool will allow determination of contaminant movement with time. This use is applicable to monitoring wells at TAN, RWMC, TRA, ICPP, and ANL-W.

- Several DOE facilities have systems which contain radioactive wastes. Currently the integrity of containment or migration of leachate is monitored by relying on groundwater samples, surface samples, or by obtaining subsurface samples. This approach is costly and could be avoided by using existing monitoring wells and high-resolution, in-situ gamma spectroscopy.

Potential customers include Oak Ridge National Laboratory, Savannah River Site, Los Alamos, and Sandia National Laboratory. It has also been proposed that this system be used on an international basis in areas of the former Soviet Union to aid in their clean-up efforts.

Conclusions

Use and application of the GSLS is almost limitless. Conventional water sampling may need to be done on an "as-needed" basis, rather than routinely- the GSLS can provide all the routine sampling needs in both the unsaturated and saturated zones through the use of existing wells. Although there are maintenance costs associated with the GSLS, these would be minimal when compared to the costs associated with hiring sample collectors and laboratories to analyze the samples.

The GSLS is ideal for a variety of site characterization activities, and provides numerous benefits over conventional water and soil sampling methods. Effectively, the lab (GSLS) is moving to the sample location, and eliminating any need for sample preparation, shipping, and chain-of-custody in addition to the associated costs.

Cost effective and practical radioactive waste remediation efforts will be the ultimate result of using high-resolution, in-situ gamma spectroscopy.