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ENVIRONMENTAL RADIATION MONITORING TECHNOLOGY: CAPABILITIES AND NEEDS (U)

by

K. J. Hofstetter

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

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Environmental Radiation Monitoring Technology: Capabilities and Needs

K. J. Hofstetter
Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

Abstract

Radiation monitoring in the Savannah River Site (SRS) environment is conducted by a combination of automated, remote sampling and/or analysis systems, and manual sampling operations. This program provides early detection of radionuclide releases, minimizes the consequences, and assesses the impact on the public. Instrumentation installed at the release points monitor the atmospheric and aqueous releases from SRS operations. Ground water and air monitoring stations are strategically located throughout the site for radionuclide migration studies. The environmental radiological monitoring program at SRS includes: fixed monitoring stations for atmospheric radionuclide concentrations, aqueous monitors for surface water measurements, mobile laboratory operations for real-time, in-field measurements, aerial scanning for wide area contamination surveillance, and hand-held instruments for radionuclide-specific measurements. Rigorous environmental sampling surveillance coupled with laboratory analyses provide confirmatory results for all in-field measurements. Gaps in the technologies and development projects at SRS to fill these deficiencies are discussed in the context of customer needs and regulatory requirements.

Environmental Radiation Monitoring Technology: Capabilities and Needs

1. Introduction

The primary function of the SRS initially was to produce plutonium, tritium, and other special nuclear materials for national defense and for other governmental or civilian uses. However, today the mission has dramatically changed from production of nuclear materials to waste management, facility decommissioning, site decontamination, and environmental remediation.

The SRS is located on approximately 300 square-miles of land in South Carolina about 25 miles southeast of Augusta, GA on the Savannah River. Radiological monitoring of the impact of SRS encompasses about a 30,000 square-mile area. There are approximately 500 air sampling stations, about 40 water samplers on site streams and on the Savannah River, and about 1200 monitoring wells located in this effected zone [1]. Samples are routinely collected from these sampling locations and returned to the laboratory for analyses.

Environmental monitoring at the SRS is designed to assess the actual or potential radiation exposure to inhabitants living in the SRS vicinity, to ensure compliance with existing federal, state, and local regulations and recognized limits, and to demonstrate positive control over radioactive effluents. The rigorous environmental monitoring program provides accurate, continuous records of normal and accidental releases plus it provides a source of continuing data on radionuclide migration through the environment. The monitoring of air, surface water, and groundwater provide the earliest indication of discharges as these media represent the principal dispersal pathways for SRS radioactive releases.

The air monitoring stations accumulate particulate on an air filter, radioactive iodine isotopes on a charcoal bed, and tritium on a desiccant. The air samplers run continuously and the composite samples are analyzed once each week. The filters are analyzed for gross α,β activity by proportional counting, γ-emitting radionuclides by γ-ray spectrometry, $^{89,90}Sr$ by chemical separation and proportional counting, and $^{238,239}Pu$ by chemical separation and α-spectroscopy. The TEDA-impregnated charcoal is analyzed for radioiodine by γ-ray spectrometry and the desiccant is analyzed for tritium by liquid scintillation counting (LSC) techniques [2].

The surface water sampling stations consist of a paddle-wheel sampler or a Brailsford proportional pump sampler. These samplers operate continuously and the composite samples are collected once each week. The water samples are analyzed by α-, β-, and γ-spectroscopic techniques. Tritium analyses are performed by LSC methods [2]. The monitoring wells are sampled and analyzed quarterly for the same suite of radionuclides by appropriate techniques and methods.

The SRS radiological monitoring program also includes direct measurement of dose rates by thermoluminescent dosimeters and the measurement of radionuclide concentrations in milk, food, drinking water, wildlife, rainwater, soil, sediment, vegetation, etc. While these measurements are important in modeling the deposition of radionuclides and assessing their impact on the public, they are not included in this discussion.

At SRS, many organizations are directly involved in the environmental radiation monitoring program. Those organizations with primary responsibility are the Environmental Monitoring Section, the Environmental Sciences Section of SRTC, and the Health Protection organization. Personnel from these organizations are responsible for conducting the sampling operations, maintaining the samplers, and performing the analyses. Other organizations with indirect involvement include the Savannah River Ecology Laboratory (SREL) and the U.S. Forest Service (USFS). SREL is part of the University of Georgia and conducts independent environmental research in the areas of biogeochemical ecology, wildlife and stress ecology, and wetlands ecology. The USFS provides forest management and is responsible for the biodiversity on site, which includes protecting endangered species, reforestation, wildlife management, and soil/watershed quality.

2. Installed Monitoring Instrumentation

Real-time radiation monitoring instruments are installed at critical locations within facilities and in the environment for rapid detection and preliminary estimates of routine and unanticipated releases. The composite samplers described above, provide the official measurements of record for releases and are used to assess the impact of site operations on the public and the environment. The radiation monitors installed throughout the site are designed to detect unusual radiation levels, to identify unusual operating conditions, and to limit area personnel exposure. They also provide early warning of unplanned releases and help mitigate the consequences of the release.

The reactor area radiation air effluent monitoring systems consist of Kanne ion chambers, noble gas monitors, tritium monitors, and total stack activity monitors installed in the air exhaust stacks [3]. Also installed in the stacks are several types of stack effluent samplers (particulate filters, charcoal for radioiodine, silica-gel for tritium, ^{14}C, etc.). The Kanne chambers are used during reactor shutdown to monitor for tritium and noble gases. The noble gas monitors measure the exhaust for ^{41}Ar, ^{131}I, ^{85m}Kr, ^{87}Kr, ^{88}Kr, ^{133}Xe, and ^{135}Xe during normal operations. The tritium monitors detect tritium in both the elemental and oxide forms in the presence of other gaseous radionuclides. The total stack activity monitors are gamma ionization chambers that will detect halogen and noble gas radionuclides in the stack exhaust.

The reactor effluent water monitoring systems are designed to measure radionuclides in aqueous discharges and help identify accident conditions, protect personnel, and limit radiation release to the environment. The cooling water gamma monitors are designed to detect a leak in the heat exchangers during reactor operation by measuring the short-lived radionuclides produced in the heavy water primary coolant and moderator. The tritium effluent water monitors are designed to detect leaking moderator during reactor shutdown by measuring the tritium in the moderator [4]. Proportional samplers are installed at these effluent locations to confirm analyses and monitor calibrations.

The separations facilities, effluent treatment facilities, waste solidification facilities, and heavy water purification areas all have similar monitoring instrumentation installed in the air exhaust stacks and aqueous effluent discharge canals.

Monitoring of trace radionuclides in the Savannah River is continuously studied because it provides the main drinking water source for Savannah, GA located about 100 miles downstream. Georgia Power has two 1000 MWe nuclear power plants (Vogtle Unit-I and -II) situated on the Savannah River directly across from the SRS. Both facilities draw water from the river and make routine aqueous releases to it. To distinguish between Plant Vogtle and the SRS effluent contaminants, special accumulating resin samplers are located upstream of both facilities, in the Vogtle release canal, and downstream of both facilities (U.S. Highway 301 bridge). Resin and sediment samples are retrieved from these locations and returned to the Ultra Low-Level Counting Facility at SRTC for analysis by high-resolution γ-ray spectrometry. As a further protection of the downstream water supplies, a specially designed underwater NaI(Tl) detector is located on a permanently installed monitoring platform at Highway 301 bridge. This detector and its associated electronics continuously record radiation spectra of dissolved radionuclides in the river [5].

3. Emergency response

Radiation monitors installed in the stacks of the reactors and separations facilities are linked to the WIND system emergency response computer. In addition to these signals, the WIND system computer receives real-time stream flow data, thermal monitoring data, meteorological data, and site perimeter radiation monitor data. All of this data is then automatically included as source terms in the emergency response codes. United States Geological Survey (USGS) map databases are linked to the emergency response codes to provide and display information on population distribution and dose, road networks, routing of emergency response vehicles, land use, topography, and maps of the impact regions.

4. Ultra low-level counting facility

An underground counting facility with cleanroom conditions was constructed and is used at SRS to measure radionuclide concentrations at ultra low-levels. The 3.0m x 4.3m x 2.4m counting chamber is located 14.3m underground and has 10.2cm thick walls of pre-WWII naval armor plate. The underground chamber is surrounded by 1.2m of specular hematite which yields a total overburden of shielding equivalent of 31.7m of water [6]. The ULLCF is used to measure low-level radionuclides in environmental and other special samples. Radionuclide concentrations at fCi/L levels are routinely measured in Savannah River water samples by HPGe spectroscopy in the ULLCF. This facility has also been used in the characterization of samples returned from NASA's Long Duration Exposure Facility. [7]

5. Mobile laboratory

A vehicle, originally designed for the Tracking of Radioactive Atmospheric Contaminants (TRAC), was developed at the Savannah River Laboratory to provide scientists with information on low level radiation in the environment [8]. This mobile laboratory is equipped with state-of-the-art radiation detection and monitoring equipment for real-time and in-field analysis of air, water, soil, and vegetation samples. The TRAC vehicle is equipped with a high pressure ion chamber for sensitive radiation dose rate measurements (1 micro-rem/hour dose rates) and can distinguish between man-made and natural radionuclides by gamma spectroscopy. The TRAC vehicle can make measurements of general area, atmospheric, and ground level radioactivity levels while in motion at environmental levels with corresponding locations using GPS (satellite) and LORAN (U.S. Coast Guard) position sensors. Instruments on-board include two liquid scintillation counters, an array of alpha pulse-height surface barrier detectors, three HPGe gamma detectors, a pressurized noble gas sampler, a high volume air filter sampler, charcoal trap for measuring radioiodines, and an array of large NaI(Tl) scintillation detectors. All data acquisition is recorded by on-board personal computers for real-time alert of operating personnel. These PCs are equipped with multichannel analyzers for pulse height analysis. The TRAC vehicle has been used in many training exercises, commercial reactor emergency response activities, tracking fallout from Chernobyl in the Southeastern U.S., standby operation for the Galileo and Ulysses launches by NASA, and to assess the impact of releases from SRS operations on the general public (e.g., the recent tritium release to the Savannah River (9-11)).

6. Aerial surveys

Aerial surveys are made of the Savannah River Site periodically to determine the extent of migration of man-made radionuclides released to the environment by SRS operations. The identification and extent of the contamination can benefit site reclamation and decontamination activities. These surveys are performed by EG&G Energy Measurements Corporation using a helicopter and large NaI(Tl) scintillation detectors [12]. The results of the surveys can predict the expected dose rates to personnel working in the areas. By flying a well defined grid over the area, areas of high radiation intensity and the isotopes responsible can be determined for corrective action, if required. Scientists at the SRS are exploring the use of unmanned aerial vehicles (UAV) for surveying remote environments at low altitude and low airspeed for detailed measurements [13]. A suite of sensors for radiation measurements, temperature, and spectral images along with simultaneous position coordinates is under development. The UAV platform can provide a safe, accurate, and cost-effective alternative to full scale surveys by rotary- or fixed-winged aircraft.

7. Special projects and analyses

Environmental monitoring requires a variety of nuclear and non-nuclear techniques for obtaining information on radionuclide behavior in the environment. Examples include ground water monitoring using high resolution gamma detectors for well logging, special underwater gamma and beta detectors for surveying ponds and rivers [14], permanently installed, in-plant instrumentation for process control, waste assay instruments, and many non-nuclear laboratory methods for measuring trace, long-lived radionuclides (e.g., ICP-MS) in environmental samples. All these techniques require specialized equipment, special methods, trained personnel, and an acceptance by the technical community of the validity of the methods. Collections of accepted radionuclide analysis methods for environmental analyses [15] are being published which are performance based but not prescriptive. Formal quality control of analysis methods is now required for regulatory compliance. Exchange of samples between laboratories [16] and confirming independent monitoring is also part of the procedure, method, or program validation [17].

8. Future needs and requirements

The commercial and governmental nuclear laboratories are faced with management directives to find "better, cheaper, and safer" methods for monitoring and measuring radioactivity in the environment. "Better" methods imply more accurate, precise, and sensitive analysis techniques. "Cheaper" methods imply rapid, automated methods requiring less manpower and consumables. "Safer" methods presume less radiation exposure to workers, less waste, and minimum exposure to hazardous chemicals or conditions. These mandates require innovative solutions to the measurement of radionuclides in environmental samples. One example is the use of ICP-MS for measuring low-specific activity radionuclides which involves no tracers and produces less waste than corresponding radiochemical methods. Other solutions incorporate in-field sample preconcentration methods to produce more accurate and sensitive results. Another improvement is the continued development of automated techniques for measuring radionuclides in air or water samples directly in the field.

Locating real-time monitors directly in the discharge of facilities has the maximum impact for mitigating the consequences of inadvertent releases during operation. The development of techniques to monitor specific waste streams presents many technical challenges. For example, inline measurement of α- and β-activity in aqueous, process and environmental streams is desirable. In-field measurement of radioactive noble gases helps to rapidly detect nuclear proliferation. The development of non-destructive assay (NDA) techniques for miscellaneous samples and waste is of great interest to the SRS and the nuclear community. All field-deployed systems must operate with minimum maintenance and high reliability. Transferring laboratory techniques to field application is often a difficult task requiring extensive design and engineering expertise.

The interpretation of data with minimum counting statistics is another area requiring development. For example, data from site surveys or NDA of waste containers often have very low counting rates due to the low activities and short counting times. These data require a combination of statistical evaluation, process knowledge, and modeling to properly interpret the results. Probabilistic analyses may also play a role when using these data to evaluate the impact of site operations on the public [18].

Another area requiring additional development is the relationship of radiation flux measurements with area contamination levels. For example, while γ-ray flux data can be obtained during an aerial or manual survey, the extent and amount of soil contamination is dependent on moisture, soil type, penetration, etc., and requires extensive modeling to infer contamination levels. Similar problems in β-contamination (e.g., from ^{90}Sr) surveys are encountered which are complicated by the continuum of beta energies and variable self-absorption. Sampling methods and statistical design are required for validating these survey techniques.

9. Summary

Environmental monitoring takes on increased priority in the DOE complex as the mission changes from production of nuclear materials to waste management, facility decommissioning, site decontamination, and environmental remediation. Radionuclide migration studies and models are being developed to assist in the implementation of these activities. Scientists and technicians at the SRS have generated many reports [19-22] on the status and behavior of specific radionuclides. Development work continues to design and test new sampling methods, analysis techniques, and real-time measurement systems. Transuranics and radionuclides which are pure beta-emitters pose special problems which require extensive radiochemical separations and do not lend themselves to field applications. Research on methods and techniques that can measure transuranics and pure beta emitters at environmental levels rapidly and cost-effectively is needed. While improvements in environmental management technologies have been suggested, the health and safety of the public is adequately protected by the existing environmental monitoring program at SRS.

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