SRNS remote operators Matthew Easley (left) and Tony Craps take readings from a microblower that is used to remove underground chemical solvents. In the background, SRNS Senior Scientist Branden Kramer explains the solar-powered system to intern Sydney Goodlove. (Photos: DOE)

Savannah River's Passive Groundwater Remediation

Actively pursuing passive technologies for treating groundwater is paying off for DOE contractors.

Workers with Savannah River Nuclear Solutions (SRNS) at the Department of Energy's Savannah River Site (SRS) in Aiken, S.C., continue to expand their use of passive groundwater cleanup systems that rely on nature to help lower costs, consume less energy, and reduce carbon emissions.

"Using low-power, low-maintenance methods has proven to be a consistently viable cleanup option at SRS," said Mike Griffith, a project manager with SRNS, the site's management and operations contractor for the DOE. "It is a matter of using the right tool for the right job. We want to be efficient and cost-conscious while ensuring we have the full support of our environmental regulators as well."

Covering more than 300 square miles, SRS began to produce materials used in nuclear weapons, primarily tritium and plutonium-239, in the early 1950s. To produce the materials, five nuclear reactors were built, along with numerous support facilities, including two chemical separations plants, a heavy-water extraction plant, a nuclear fuel and target fabrication facility, a tritium extraction facility, and waste management facilities.

Irradiated materials were moved from the reactors to one of the two chemical separations plants. In these facilities, known as "canyons," the irradiated fuel and target assemblies were chemically processed to separate useful products from waste. After refinement, nuclear materials were shipped to other DOE sites for final application. SRS produced about 36 metric tons of plutonium from 1953 to 1988.

The processing of nuclear materials, done as part of the nuclear Cold War with the Soviet Union, resulted in the creation of hazardous byproducts consisting of several types of chemical and radioactive contaminants. These wastes were primarily stored in pond-like basins throughout the 1950s and 1960s and have been a source of many cleanup programs throughout the recent decades.

"Years ago, one of our first groundwater cleanup approaches was to use active cleanup technologies to remediate potentially hazardous chemicals in the groundwater under SRS," Griffith

SRNS engineering and technical support specialist Keith Hyde measures the flow of vegetable oil during an injection process that greatly increases the underground population of naturally occurring chemical-eating bacteria at SRS.

SRNS engineers George Blount and Jeff Thibault inspect equipment that is used as part of an innovative process to remove low-level contamination from groundwater contained near the center of the Savannah River Site in Aiken, S.C.

said. "These systems required large amounts of electricity, multiple industrial-size pumps, and frequent maintenance.

"The concept was to pump up massive amounts of water contaminated with organic solvents, chemicals similar to those found at dry cleaning stores, and blow air through it. As it turns out, the solvents like the air better than the water and would be exhausted along with the air up a stack and into the atmosphere. Very effective, but very expensive to operate, and we had to replace major components from time to time throughout the years," added Griffith. "Appropriately, we called these units air-strippers."

SRS will continue to use the active pump-and-treat systems in small areas. As groundwater cleanup projects mature and the systems remove the bulk of contaminants, however, SRS is transitioning to more efficient technologies, such as solar-powered, soil-vapor extraction units. Each of these systems requires between 20 and 40 watts of power, easily produced by a small solar panel.

"During a 10-month test, a single solar-powered unit removed 234 pounds of volatile organic compounds from chemically contaminated groundwater beneath SRS," SRNS Senior Scientist Branden Kramer said.

SRS developed many of these technologies with the Savannah River National Laboratory, working closely with the South Carolina Department of Health and Environmental Control (DHEC) and the U.S. Environmental Protection Agency.

Kramer acknowledged that the extraction units' microblowers eventually will be replaced by a simpler system relying on changes in atmospheric barometric pressure to force chemical vapors from underground through plastic pipes. As cold and hot weather fronts move through the area, causing the local atmosphere's air pressure to drop or rise, chemical vapors trapped beneath the earth's surface at SRS are forced upward and out.

"We currently have 87 solar-powered units and over 100 barometric soil-vapor units functioning at eight different locations on site," Kramer said. "We are down to just a few full-powered vapor-extraction units, so we've made significant progress toward low- or no-power passive cleanup technology."

Oil-eating bacteria

Another passive technology at SRS uses a common household product, vegetable oil, to harness and accelerate nature's own abilities to clean up chemically contaminated groundwater.

When highly concentrated amounts of oil are injected into the ground, the oil mixes with naturally occurring bacteria, along with the chemicals in the groundwater. Unable to differentiate between vegetable oil and the now oil-coated chemicals, the bacteria rapidly eat both. This treatment of groundwater also results in a population explosion for the bacteria, further accelerating the cleanup process.

"We like to call the vegetable oil-eating bacteria 'bugs,'" said Chris Bergren, SRNS manager of environmental stewardship. "When fed thousands of gallons of inexpensive vegetable oil, the bugs will destroy large quantities of organic solvents fairly quickly."

The simplicity and efficiency of this low-cost approach also includes the benefit that the voracious oil- and solvent-eating bugs rapidly deplete the oxygen in the affected soil.

"Lack of oxygen also destroys solvents," said Bergren. "We have been extremely pleased with the results to date, and others have noted the success of the project as well." Bergren further explained that the cost savings with this new process has been enormous over the previously used pump-and-treat technology.

Since the start of the alternative, less expensive method of injecting vegetable oil down multiple wells, recent testing indicates that the area is now approximately 98 percent free of organic solvents.

Tritium trees

About 60 acres of trees also serve as a passive remediation system that removes low-level radioactive contamination from groundwater near the center of SRS.

A small pond-like excavation was created in the path of slowly moving groundwater that is contaminated with tritium, which has a half-life of 12.3 years. The pond acts as a short-term holding basin, as the groundwater continuously seeps into it. To manage water levels, an inexpensive irrigation system is used almost daily to safely remove water from the pond.

"We use an extensive, aboveground system of plastic pipes and sprinkler heads to irrigate the 60 acres with water pumped from the pond," said Bergren. "It is 'man working with nature' and, in this case, using thousands of trees to safely absorb the radioactively tainted water, naturally evaporating it to the atmosphere."

Much of the water evaporates when it is sprayed into the air or as it pools on the forest floor and, in the process, releases the hydrogen-based contaminant into the air. The SRS trees and plants then absorb the rest of the water.

"We know that the levels of tritium we are seeing here do not represent an ecological issue. It does not biologically accumulate, and the energy associated with tritium is not going to create any kind of negative effects on the plants and animals in the area," said Bergren. "Multiple studies have confirmed this. In fact, the trees and animals receiving the irrigated water are flourishing.

"Photosynthesis and the fact that this particular nuclide quickly moves through the vegetation along with water means the trees can be harvested and sold for lumber after one or two years without irrigation."

The small amount of tritium released into the air with each irrigation cycle is negligible, considering it is dispersed into and mixed with the enormous volume of air that makes up the earth's atmosphere.

Bergren noted that the levels of tritium in the area after irrigating are so low that it is safe for SRNS workers to move about the irrigated area as needed without any form of protective clothing.

To date, more than 120 million gallons of water has passed through the extensive grid of irrigation piping, about 10 million gallons a year. An added bonus is the fact that this process generates no waste.

The irrigation system was designed and installed by the U.S. Forestry Service-Savannah River. Partnering with SRNS, they continue to operate and maintain the system.

SRS cleanup program

Since approximately 2003, extensive cleanup and closure work has been completed at SRS under a concept known as "area completion," which streamlines and accelerates the cleanup process. The SRS Area Completion Project (ACP) has removed excess facilities and remediated soil and groundwater in an integrated fashion, with the full support of the DOE, EPA, and DHEC.

ACP focuses on cleaning up contamination in the environment by treating or immobilizing the source of the contamination to mitigate transport through soil and groundwater and to remediate or slow the movement of contamination that has already migrated from the source. From capping waste sites to installing efficient groundwater treatment units, fieldwork is a top priority. Fieldwork includes the closure of inactive seepage basins, rubble pits, rubble piles, and disposal facilities. Major groundwater cleanup systems operate extensively in nearly every site area.

Remediation of more than 375 of the site's 515 waste units has been completed, with more than 2,000 regulatory milestones having been safely met. The deployment of numerous cost-effective technologies expedites the cleanup process.

Remediation is being executed in a fashion that completes environmental cleanup and facility decommissioning area by area until all areas at SRS are completed by 2031. Units at which waste is left in place will be under institutional controls that feature access restrictions, inspection, maintenance, and long-term stewardship monitoring. Typically, soils will be remediated to an acceptable residual risk for industrial workers. Groundwater will be addressed in a manner such that required cleanup levels, approved by regulators, will be achieved over time.

Much of the ACP work was accelerated through a significant investment of $1.6 billion at SRS in 2009 from the American Recovery and Reinvestment Act, including a 75 percent reduction in the cleanup footprint and the final decommissioning of numerous facilities, notably three production reactors, which are expected to remain in their present state for more than 1,400 years. ■

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