Bacteria show promise in restoring aquifers used in uranium mining

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John Willford, coordinator of the instructional labs for the Department of Molecular Biology in UW's College of Agriculture and Applied Science, shows microcosms in a UW lab that demonstrated the effectiveness of uranium bioremediation using naturally occurring bacteria. Field study of the technique will begin this month at the Smith Ranch-Highland uranium mine in Converse County.

Wyoming's resurgent uranium industry could get a further boost from University of Wyoming scientists, whose research on post-mining environmental restoration is yielding extremely promising results.

Research in UW laboratories has shown that stimulating growth of native bacteria could be a more effective way to remediate aquifers tapped by in-situ leach uranium mining, the technique used in the vast majority of Wyoming's existing and planned uranium operations. If those findings are confirmed in the field, uranium companies could save significantly in groundwater restoration costs while achieving better results.

"The remediation process simply involves feeding the existing bacteria—no new bacteria are introduced," says Kevin Chamberlain, a research professor in UW's Department of Geology and Geophysics. "The result is a better restoration for less cost to the mining company—a win-win situation for the environment, the state and the company."

Wyoming, which once had a thriving uranium mining industry, remains No. 1 in the nation in uranium reserves and is seeing something of a renaissance in mining operations after decades of industry decline and delay. Cameco's Smith Ranch-Highland mine in Converse County is one of the country's biggest producers, and several other companies have opened or are preparing to start in-situ leach (ISL) operations in the state—which stands to benefit through job creation and tax revenues.

ISL uranium mining involves injecting a groundwater solution (fortified with oxygen and carbon dioxide) into underground ore bodies through cased wells. The solution permeates the porous rock, dissolving the uranium from the ore, and is pumped to the surface through other cased wells. The uranium-rich solution then is transferred to a water treatment facility, where the uranium is removed from the solution by adhering to ion exchange resin beads. The groundwater solution exiting the ion exchange system is then sent back to the injection wells for reuse.

Consequently, there is little surface disturbance in ISL mining, and no tailings or waste rock are generated.

However, not all of the uranium is removed from the water, and the process also liberates other metals such as selenium and vanadium. Federal and state regulations require mining companies to restore aquifers by fixing the suspended metals. Most companies now do that with expensive, repeated reverse-osmosis water sweeps, using large amounts of water containing metal-fixing chemicals, with mixed long-term results.

Bacteria Do the Job

At the Smith Ranch-Highland mine, Cameco, in the early 2000s, experimented with bioremediation: stimulating native bacteria to fix the metals. These bacteria live in the uranium-rich strata and use uranium as an electron acceptor in their natural life cycles. A number of substances, such as safflower, crude whey protein and even molasses, have been used to "feed" the bacteria, but the results were mixed.

In 2011, Chamberlain received a $100,000 grant from the UW School of Energy Resources' (SER) In-Situ Recovery of Uranium Research Program, with a $25,000 match from Cameco, to study restoration of the relatively deep uranium aquifers at the Smith Ranch-Highland site using bioremediation. He says it became clear right away that more laboratory work was needed before initiating a field study.

Chamberlain enlisted the expertise of others on campus, including John Willford, coordinator of the instructional labs for the Department of Molecular Biology in the College of Agriculture and Applied Science; Pete Stahl, professor of soil ecology and director of the Wyoming Reclamation and Restoration Center; Craig Cook, research scientist in the Department of Ecosystem Science and Management and director of UW's Stable Isotope Facility (SIF); David Williams, professor of botany and renewable resources and faculty director of SIF; and Calvin Strom, research scientist in the Department of Ecosystem Science and Management. Recently, scientists from outside the university—including the Los Alamos, Pacific Northwest and Lawrence Berkeley national laboratories—also have become involved.

Two UW laboratory projects were undertaken to determine the best "food" for the naturally occurring bacteria, and the optimum rate of feeding. The first project, which is complete, showed that the most effective substance to stimulate the bacteria at the Smith Ranch-Highland site is tryptone, a partially degraded milk protein commonly used in laboratories. The second project—which better simulated actual field conditions, tested different feeding rates and developed monitoring criteria—is nearing completion. It was funded by an additional $107,000 SER grant to Willford and Chamberlain, with a Cameco match of $50,000.

In the experiments, introduction of tryptone produced a 60 percent reduction in soluble uranium over 30 days, with higher reductions over the long term. The researchers believe the growth of bacteria will be long-lasting and effective in fixing the remnant uranium and other metals.

"We're not introducing anything but a little food," Chamberlain says. "We're restoring the natural balance by feeding the naturally occurring bacteria that use uranium as part of their life cycle. Essentially, we're just speeding up what's believed to eventually happen anyway to keep the metals from remobilizing. It does a better job, and it's less expensive."

From the Lab to the Field

With the knowledge gained from the lab studies, the UW interdisciplinary team of scientists plans to begin the field trial with tryptone at Smith Ranch-Highland later this month. The study is expected to take 10 months to a year.

"Now, we feel armed," Chamberlain says. "No. 1, we know bioremediation can work. No. 2, we've found a food that works well at this site. No. 3, we know the best rate at which to feed. We're excited to put it all to work in the field."

In addition, Chamberlain is developing isotopic metrics to effectively monitor the bioremediation process at a relatively low cost.

Cameco officials say they look forward to the prospect of using bioremediation, if the final results of the research confirm the laboratory findings.

"Cameco is pleased to be working with the world-class researchers of the University of Wyoming to hone restoration processes for the in situ recovery uranium industry," says Jim Clay, senior scientist for the company. "The work being done at our Smith Ranch-Highland mine in Converse County is a collaborative effort with these researchers that will benefit both the environment and the mining industry in Wyoming."

Chamberlain says this bioremediation technique has the potential to reduce the cost of aquifer restoration by as much as 90 percent, and may result in reduced regulatory bonding obligations for companies—along with improved results in the ground. While each ISL mining site is different, he and Willford believe the methodology used to develop the plan for the Smith Ranch-Highland site will work for other uranium operations as well.

"The system we developed for this should be applicable everywhere," Willford says. "We're working to find a good, long-term solution for the industry in Wyoming and elsewhere. Being the only research institution in the state, it's appropriate for us to do something to help this industry and the state's environment and economy."

The In-Situ Recovery of Uranium Research Program was established by the Wyoming State Legislature in 2009. Sen. Jim Anderson, R-Glenrock, says the bioremediation research is exactly the type of work that he and other legislators hoped to see.

"In-situ recovery uranium mining is a critically important industry in my district and the state of Wyoming," Anderson says. "It is important for Wyoming to invest in the most current science available to assist in improved production methods while protecting the state's environment. These investments made by the state are critical in allowing the industry to move forward while sustaining Wyoming jobs and the economy."

Provided by University of Wyoming

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