ENVIRONMENT

Progress on Using Bacteria to Clean Aquifers

Project shows practical ability of microorganisms to 'eat' toxics that contaminate water

By Simson L. Garfinkel
Staff writer of The Christian Science Monitor

STANFORD, CALIF.

IN Lewis Semprini's basement laboratory, tall glass columns covered with aluminum foil and filled with sand rest on top of a workbench. The sand comes from a nearby underground water source, or aquifer, that is contaminated with hazardous organic chemicals.

But thanks to a growing colony of microorganisms, the sand inside the column gets a little cleaner every day. Fed on a mixture of oxygen and methane gas, the bacteria are working day and night to transform the chlorinated solvents into safe compounds like carbon dioxide and water.

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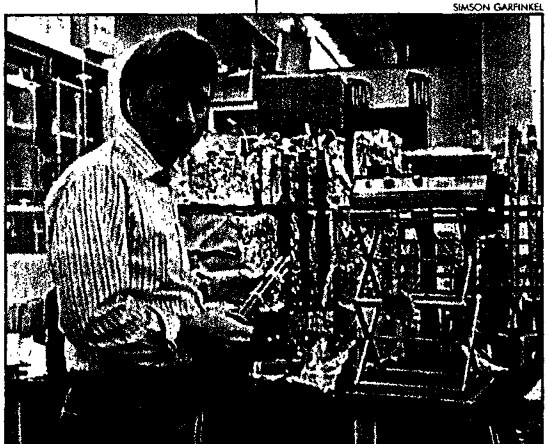

BASEMENT LAB: *Lewis Seprini, a research scientist in the civil engineering department at Stanford University, is perfecting an innovative hazardous waste cleanup process.*

"What we have done to date is work with bacteria in the subsurface, bacteria that are already there, and change the environmental conditions to enhance the transformation process," explains Dr. Semprini, a research scientist in the civil engineering department at Stanford University here.

Feeding the bacteria in the laboratory is easy: Just bubble the gases through the glass columns. Last year, a Stanford research group headed by Dr. Paul V. Roberts demonstrated that the bacteria can also be fed in their native environment. During a three-year experiment, the bacteria broke down as much as 85 to 95 percent of some hazardous compounds tested, according to the group's final report.

Bioremediation, the process of harnessing bacteria to break down hazardous, man-made chemicals, "has the potential to clean up many contaminated aquifers," says Semprini, the project's manager. For years, bioremediation has taken the back seat to other methods of cleaning up contaminants, but the technique is quickly gaining in popularity.

"We've been trying to make it a trendy topic for a long time," says Fran Kremer, a senior environmental engineer at the United States Environmental Protection Agency's office of research and development. This month, the EPA will sponsor a conference on biosystems technology development.

Since most environmental engineers have not been trained in bioremediation, says Dr. Kremer, informing professionals about the techniques and convincing them to consider biological methods when planning a cleanup is a big part of her job. Since biological methods can't be used at every site, "treatability studies need to be conducted up front," she says.

A prospective site must be surveyed to make sure that there are bacteria in the ground that can break down the chemicals that are present: hence the glass columns in Semprini's basement.

"When we started our field program, we got core samples" from a contaminated aquifer near the Moffett Naval Air Station, a half-hour drive from San Francisco, explains Semprini. "We tried to take them as aseptically as possible: You try to get the bugs that are [underground], not the bugs from the surface."

Back in the laboratory, the scientists wrapped the columns with aluminum foil to keep the soil in the dark, helping to simulate the underground environment. Then they exposed them to the mixture of methane and oxygen to see if the particular bacteria present could break down the hazardous organic compounds.

The choice of gases was not accidental, says Dunja Grbic-Galic, an associate professor at Stanford working with the group.

Since the mid-1980s, scientists have known that chlorinated industrial solvents like trichloroethene and vinyl chloride could be broken down by microbes called methanotrophs – bacteria that feed on methane.

"The chlorinated compounds which we wanted to degrade are not used by bacteria for growth or energy," explains Dr. Grbic-Galic, a molecular biologist. But the enzyme the bacteria use to break down methane will "fortuitously attack" the chlorinated compounds. "[The enzyme] doesn't have a very narrow substrate specificity: It can degrade not only its substrate for which it is made but other things [as well]."

The methanotrophs transform the chlorinated solvents into very reactive chemicals called epoxides, says Grbic-Garlic. "Once the epoxide is formed, and once it breaks down by itself, the product can be used by heterotrophs," another kind of bacteria that is also found in the aquifer. "That means the compound will be completely degraded."

After the group verified the presence of the required bacteria, they set up an automated research station on top of the aquifer. Water was pumped out of the ground at an "extraction well," run through a bubbler that filled it with methane and oxygen, and then pumped back into the ground at the "injection well," says Semprini. Three smaller wells pumped tiny amounts of water out of the ground for analysis, using laboratory equipment that the group specially modified to work unattended. A personal computer ran the entire experiment 24 hours a day.

THE system bubbled the methane into the water for four hours, then oxygen for eight. Alternating the gases, explains Semprini, kept "the methanotrophs [from] growing up and clogging the injection well." It also had the side effect of distributing the gases evenly through the test zone, which made the bacteria grow more uniformly.

The results of the experiment were encouraging: The bacteria started transforming the trichloroethene within eight days; after the first year, 20 percent of the chemical was gone, says the group's report. Another chemical, vinyl chloride, was completely degraded in less than two days. One of the most impressive results, says Semprini, is that the depletion of organic compounds in the water almost perfectly matched the group's mathematical predictions.

"I think it's excellent work," says John Wilson, who pioneered the use of methanotrophic bacteria in the early 1980s. "It is becoming a model for doing precise performance evaluations at the field scale."

Simply running the extraction pump might cause the concentration of trichloroethylene (TCE) to decrease because of dilution, says Dr. Wilson, a senior research microbiologist at the EPA's Kerr environmental research laboratory in Ada, Okla. Concentrations can also be reduced by the absorption of the TCE on the solids in the aquifer. "What is unique about their work is that they clearly separate all of the possible influences that attenuate the concentration of the contaminants concerned.

"TCE is one of the most common and economically important contaminants of drinking water in the industrial world," says Wilson. "The most common remedy is called pump-and-treat, where water is pumped from the aquifer and treated at the surface. Stanford's process, and the design model, can be used to shorten the time required for pump-and-treat by adding biological degra-

Drain-Cleaning Bacteria

BOSTON

INSTEAD of using bacteria to clean up ground water, one company is using them to keep dangerous chemicals from going down the drain in the first place. Bio-Care, Inc., in Campbell, Calif., has developed a strain of bacteria that attacks grease, soap, and starches. "They digest it: The byproduct is carbon dioxide and water," says Bud McMahon, Bio-Care's president.

Since July, Bio-Care's franchises have been selling the bacteria to restaurants and food processors around the country, says Mr. McMahon. Washing the bacteria down the drain once a week is enough to keep pipes from blocking up. The bacteria are nonpathogenic and approved by the United States Department of Agriculture for use around food.

Other drain cleaners on the market are caustic, says McMahon, "This is a natural process."

Now Bio-Care is spreading out to the home market. A new product uses the bacteria to clean septic tanks. Carpet cleaners and pet-stain removers are in the works.

"We are not only industrialists, but we are environmentalists. We are answering this question of the environmental safety, but we are also accomplishing a mission," he says.

– S.L.G.

dation, maybe by as much as one half, and that reduces the cost of the cleanup proportionally."

The Stanford group is now surveying a large Superfund site in Michigan to see if they can try the approach there. As with the experimental site, the first step is to find out if bacteria in the ground can break down the particular toxic chemicals present.

"Sites are very different," says Grbic-Galic, who is still studying the precise reactions that the bacteria use to break down the chemicals. "Just because one process works at one site does not mean that it will work at others."

Although it might be possible to pump down bacteria if they are not present, "I think it is easier if the bugs are already there to convince a regulatory agency [that the procedure is safe]," says Semprini. If the bacteria are already present, he adds, then they will be ributed throughout the site.

Underground biological treatment is a particularly attractive way to clean up contaminated aquifers, says Semprini. "With the appropriate microbial process, you can completely degrade the contaminants to nontoxic end products: You're getting rid of the problem," he says. Some pump-and-treat systems simply remove the contaminants from the aquifer and either release them into the air or deposit them on charcoal filters, which must then be disposed of.

Another problem with pump-and-treat techniques, he adds, is that the organic compounds tend to stick to the sand that make up the aquifer, making the process less efficient as time goes on. "What happens with the bacteria is that they are actually growing attached to the solids" right where the contamination is most likely to be, Semprini says.

But the approach isn't a cure-all for contaminated ground water, he quickly adds. For example, the methanotrophs broke down some contaminants that were in the aquifer but left others untouched. And even with a large-scale bioremediation system it might still take years to clean a large aquifer.

The EPA's Kremer says bacteria might be genetically tailored eat specific organic com- unds.

"We have some major research programs on-going within the agency. The main obstacle is the regulatory issue and [not understanding] a lot of the ecological impacts for utilizing genetically engineered microorganisms in the environment."

COMMENTARY

Earth to Aliens: Send Us a 'Hi' Sign

ALIENS on other worlds who want to contact Earth will soon have a new "number" to call.

The Planetary Society is shipping two sophisticated radio receivers to Argentina's Institute for Radioastronomy. When they come on line Oct. 12 (Columbus Day), they will give a big boost to the "Search for Extraterrestrial Intelligence" (SETI).

Almost all the SETI research has concentrated on the Northern Hemisphere. Now the institute's Raul Colomb will lead an effort to scan the southern sky.

No one knows whether there are any life forms – let alone intelligent life forms – elsewhere. Moreover, even if our galaxy is well populated with intelligent beings, no one knows if they fill the cosmos with messages we can detect.

But we'll never find out if we don't listen. This is the challenge that inspired many of the Planetary Society's 125,000 members in 70 countries to contribute $150,000 to fund what is the most extensive SETI program currently under way. The society calls it META for "Megachannel Extraterrestrial Assay." It's "megachannel" because the receivers listen on 8,400,000 very narrow radio frequency channels at once.

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META I – the Northern Hemisphere program – was dedicated in September 1985. It followed a less sophisticated search started in 1983 using a receiver that scanned 131,000 channels.

This Northern Hemisphere search, led by Harvard University professor Paul Horowitz, uses an obsolete 84-foot diameter radio telescope at the Harvard-Smithsonian Oak Ridge Observatory west of Boston. The META II receivers, built by Argentine engineers Juan Carlos Olalde and Eduardo Hurrel at the Oak Ridge site, will connect to one of two 98-foot diameter radio telescopes at the Argentine institute.

There have been a number of less extensive searches over the past few decades in several countries. The most ambitious program yet launched is the National Aeronautics and Space Administration (NASA) $100-million, 10-year SETI. This will use specially designed receivers on existing radio telescopes for an all-sky survey over a wide frequency range (1,200 to 10,000 MHz), plus spot checks at selected frequencies up to 25,000 MHz.

The NASA search will be some 300 times more sensitive than previous efforts – including META – and will take five years to complete. It covers something like 10,000 times more frequency "space" than previous SETI efforts. These have favored certain so-called "magic" frequencies such as the 1,400 to 1,700 MHz band associated with interstellar hydrogen. The META search centers on the 1,420 MHz hydrogen "magic" frequency. This is an obvious natural radio emission range where SETI scientists think aliens might broadcast if they want to attract the attention of others who might be scanning these frequencies as part of routine astronomical research.

The NASA receivers have been developed and are under test. The Northern Hemisphere phase of the five-year search is due to start on Columbus Day, 1992 to celebrate the 500th anniversary of the Italian navigator's arrival in the New World. The Southern Hemisphere scan is expected to start no earlier than 1995. The pace at which the program actually proceeds, however, depends on the uncertainties of the space administration budget.

None of the searches, so far, has turned up an interstellar "Hi" sign.

But as SETI pioneer Philip Morrison of the Massachusetts Institute of Technology in Cambridge, Mass., points out, these efforts have been like the casual search for a needle in a very big hay stack made by someone picking up a handful of hay when passing the stack in the course of daily business.

At this point, SETI is an exploration of the unknown done largely as an act of faith. We know so little about the prospects for extraterrestrial life that people can argue as cogently that we waste resources listening for an extremely unlikely signal as they can argue that the galaxy probably teems with radio chitchat.

Let's stay tuned.

Governing Gambling

By Brad Knickerbocker

WHEN professors of public policy collaborate on a work sponsored by the National Bureau of Economic Research, the result is likely to bring on the need for a nap in most people. But this book by two gentlemen from Duke University had me grinding my teeth, muttering under my breath, underlining like crazy, and littering the margins with exclamation points.

BOOKS

SELLING HOPE
by Charles T. Clotfelter and Philip J. Cook
Cambridge, Mass.: Harvard University Press
323 pp., $29.95

It's not that this detailed study of the "third wave" of gambling in America is filled with human drama or pungent narrative or particularly forceful writing. There's hardly a colorful anecdote about a subject that is filled with drama.

Instead, good researchers that they are, Clotfelter and Cook let the specifics of their study – heavily loaded with charts and graphs and footnotes – sustain the message without sermonizing.

The message is this: State governments are encouraging millions of people – including many children – to gamble. They are running gambling monopolies that aggressively market a government "product" using the most sophisticated techniques, including deception and hype. They are feeding on fantasies, undermining the work and savings ethic at a time when productivity and efficiency in the United States need all the help they can get, and in the process harming the public perception of government itself.

Beginning with New Hampshire in the mid-1960s, states began to adopt lotteries for these reasons: To raise revenues for worthwhile endeavors like education and public works; to undercut illegal gambling and reduce corruption; and because most citizens apparently didn't object.

Many political leaders and church officials (except the Roman Catholic clergy) argued against state-sponsored gambling on moral grounds. But when referenda and opinion polls showed lotteries had wide public appeal, the politicians – acting as followers rather than leaders – went for what many saw as a "painless tax." The result: three-fourths of all Americans live in states with government lotteries.

The authors indicate no evidence that lotteries have provided a windfall for education or any other high social goal. The fact is, as a portion of state revenue, lottery income remains a small fraction (about the equivalent of a one-cent hike in the sales tax). And rather than replace illegal numbers games and other rackets, the authors conclude, "the lottery boom is simply contributing to the general rise in commercial gambling."

There is also evidence that all those playing the lotteries are not deciding whether or not to gamble on the basis of full information. Most state lottery advertising does not reveal the real odds against winning big. There is also "the tendency for ads to portray wholesome surroundings and people who are younger and more affluent than the typical lottery player," conclude Clotfelter and Cook.

"Not only may this tendency be an attempt to recruit new players," the authors state, "but it also appears to reflect the effort by marketers, first noted by Vance Packard [in his 1957 classic "The Hidden Persuaders"], to build into products the traits consumers would like to see in themselves."

Just as with ads for beer and cigarettes, the private firms hired to set up and run state lotteries hide their persuasive talents in other ways as well – like calling themselves "Californians for Better Education" and spending millions to promote their cause at referendum time.

One of the strongest arguments against lotteries is that they constitute a regressive tax and that they prey on the poor, minorities, and impressionable youth. The evidence leads to the conclusion that "the implicit lottery tax is considerably more regressive than other widely used sources of revenue." Minorities – especially those of lesser means – are far more likely to buy lottery tickets. Surveys of teenagers before and after California's lottery began showed that "gambling among high school students increased sharply over the period."

Clotfelter and Cook see a parallel with the "military-industrial complex" that Dwight Eisenhower warned against. Is this the kind of activity state government should be in cahoots with?

Lottery agencies are looking for ever more attractive forms of state-sponsored gambling – like tapping into professional sports. It's not too late to head off such questionable activity. Nor is it too late to hope that the record of state lotteries to date could reverse the trend. "Selling Hope" should be required reading for anybody in a position to decide such issues.

■ *Brad Knickerbocker is on the Monitor staff.*