Argonne feeds bacteria into contaminated Kansas site to clean it

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This carbon tetrachloride-contaminated field in Centralia, Kansas underwent test injections of iron microparticles and bacteria, intended to clean the soil.

When cleaning the bathroom, we usually consider bacteria the enemy. However, a new study conducted by environmental scientists at the U.S. Department of Energy's Argonne National Laboratory has demonstrated a way to enlist bacteria in the fight to cleanse some of the country's most intractably polluted locations.

Last year, a team of Argonne scientists led by Lorraine LaFreniere injected iron microparticles underneath fields long-polluted with carbon tetrachloride near Centralia, Kansas. The researchers coated the microparticles with organic material, which served as bait for bacteria that created the conditions necessary to safely convert the toxic chemical into non-hazardous substances.

Back in the 1960s, carbon tetrachloride — or “carbon tet,” as it is more commonly known — was widely thought to be a miracle chemical. It worked as a powerful cleaning agent and as a refrigerant, and in the Midwest it was used as a pesticide to protect stored grain. However, scientific studies showed that exposure to carbon tet resulted in liver, kidney, and central nervous system degeneration as well as increased rates of cancer.

"Carbon tetrachloride was a real challenge to us because its chemical structure is extremely stable,” said team member and Argonne environmental scientist Jorge Alvarado. “It’s a hard case because the bonding within the compound is so strong.”

Even though the federal government banned the use of carbon tetrachloride as a grain fumigant in 1985, a good deal of damage was already done. In certain areas of high agricultural use, carbon tet leached from the soil into the water table, where large quantities have remained for decades. “The only sources of groundwater in these areas of the country are shallow aquifers, which are much more prone to this kind of contamination,” Alvarado said.

In its molecular form, carbon tetrachloride consists of a central carbon atom bonded to four chlorine atoms. To clean up the Centralia site, the Argonne group needed to find a way to break those bonds and chemically strip the individual chlorine atoms — which would then ideally become relatively harmless chloride ions — from the carbon at the center of the molecule.

In prior work, scientists using uncoated iron nanoparticles had been able to break some of the carbon tetrachloride bonds. At first glance, the mechanisms appeared to be very simple, but more detailed observations revealed additional complex pathways and products that could result from transformation of carbon tet.

This process, according to Alvarado, touches off a chain of other chemical reactions that result in the transformation of most of the carbon tetrachloride into another toxic compound, chloroform, which is an even greater hazard in drinking water. “The only way to prevent the buildup of chloroform was to find a way to remove the oxygen and produce the optimum environment for the right reactions to occur,” Alvarado explained. “Feeding the bacteria creates the conditions necessary for the whole process to work.”

Measurements taken at Centralia before and after the injection of a commercial product containing the specially coated iron microparticles showed a drastic reduction in the amount of carbon tetrachloride present in the soil. Within less than a month, the concentration of carbon tet fell from 2000 parts per billion (ppb) to 30 ppb and below maximum concentration limits after that. “This technique provides us with a new and powerful weapon in the fight against this dangerous and stubborn pollutant,” Alvarado said.

More information: The results of Alvarado’s study of the chemical aspects of the Centralia cleanup project can be found in the August 2010 issue of the *Journal of Environmental Monitoring* or online.

Provided by Argonne National Laboratory