Cleaning contaminated groundwater more effectively

S sometimes, very harsh, dangerous chemicals are spilled, thrown or leaked into important drinking water sources. They are hard to remove from water, especially groundwater, and they can be deadly.

A good example of these dangers was chronicled in the book (and movie) *A Civil Action*, which was based on a spill of the chemical trichloroethylene (TCE) that contaminated groundwater in Woburn, Mass., and caused a cluster of leukemia cases.

Cleaning up subsurface systems contaminated with chlorinated solvents, such as TCE, is one of the most difficult problems in the environmental sciences field, says Dr. Cass Miller, professor of environmental sciences and engineering at the UNC School of Public Health. “Such compounds are long-lived in the environment, of health concern at very low concentrations and devilishly difficult to remove once released into the subsurface.” Miller and colleagues have developed patented processes to remove chlorinated solvents like TCE and perchloroethylene (PCE) more effectively than current approaches can. During the last several years, their flow patterns can be seen or completely characterized — various mixtures of sand, silt, clay and rock — their flow patterns are very complex.

Solvents leave some of their mass behind in clays and silts, and they can pond up on the surface of impermeable substances in the earth. “This is what makes it so difficult to remediate,” Miller says. “Solvents trapped in porous materials such as sands, silts and clays beneath the earth’s surface can be a source of groundwater contamination and a threat to public health for over a hundred years if left unremediated.”

As water moves through a contaminated region, some toxins are dissolved into it and become threats to public health. “The common technology to remove such contaminants is called ‘pump and treat,’” Miller says. “A well is established between the contaminated region and any source of supply that you want to protect. As you pump that well, the idea is that you’ll remove water and contaminants from the source region. This hasn’t worked very well.”

Miller’s solution is to use brine, in this case, a calcium bromide mixture that is denser than both the solvents and water, to remediate a contaminated system. “We inject brine into the system, and because it’s denser, it can displace some of the contaminants upward and provide a barrier to prevent further vertical migration downward. If we mobilize these contaminants and move them downward, and we have a brine layer as a barrier, then they’ll stop at the barrier. Then we can remove them with an extraction well.” The method uses a food-grade surfactant (a wetting agent) to move the contaminants downward.

Miller’s team recently tested the process in a field study at Dover Air Force Base in Delaware. “Nature is complicated,” he says, “and though we try to make complicated systems in the laboratory, the size and the complexity of those can never really mimic what’s in nature.” The Dover facility had an impermeable clay layer 40 feet beneath the surface, and the test area had double-steel barriers to prevent groundwater contamination outside of the test region.

Funding was obtained from the National Institute of Environmental Health Sciences through UNC’s Superfund Basic Research Program; RETEC, a national environmental consulting firm; and the Dead Sea Bromide Group, an international partner. Miller’s team then deliberately contaminated the Dover site with PCE and attempted to remove it. This field study was instrumental in helping to mature their understanding and move them in the direction of further refinements to the process. “We learned we were able to add brine to the system, achieve the densities we wanted and when Class B biosolids can be applied to agricultural land,” says Dr. Mark Sobsey, UNC Renan Distinguished Professor of environmental sciences and engineering in the UNC School of Public Health. “Think of recent outbreaks of E. coli from contamination of spinach or lettuce because fecal matter from people or animals got on food which we eat raw. Pathogens can also migrate into groundwater.”

The rest are incinerated or spread on forest land or in landfills. Depending on how source sludge has been treated, biosolids may be pathogen-free (Class A), but most are currently treated by Class B processes, which do not destroy all pathogens.

Both classes are allowed to be spread on agricultural land — biosolids, in fact, are considered a useful amendment in the soil. But the practice is not without controversy, and there are many restrictions on where and when Class B biosolids can be applied because of concerns about exposing humans to serious health risks.

More than half of the biosolids are applied to agricultural land, according to estimates. The rest are incinerated or spread on forest land or in landfills. Depending on how source sludge has been treated, biosolids may be pathogen-free (Class A), but most are currently treated by Class B processes, which do not destroy all pathogens.

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“TIP: Dispose of household contaminants safely to avoid polluting groundwater. Collect old batteries, used antifreeze, paint and chlorinated solvents and take them to the landfill.”

Reducing health risks of treated wastewater

T he 16,000 municipal wastewater treatment plants in the United States produce about 6 million tons of biosolids every year, and all those solids have to go somewhere. “We know bad things can happen when fecal matter with undesirable levels of pathogens is applied to agricultural land,” says Dr. Mark Sobsey, UNC Renan Distinguished Professor of environmental sciences and engineering in the UNC School of Public Health. “Think of recent outbreaks of E. coli from contamination of spinach or lettuce because fecal matter from people or animals got on food which we eat raw. Pathogens can also migrate into groundwater.”

UNC School of Public Health researchers have investigated innovative treatment methods that result in safer Class A biosolids and are developing a protocol to investigate health concerns that might be
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Columbus, Ga., to investigate whether a conventional sludge treatment process could be adapted to produce Class A biosolids. In most sewage treatment plants today, wastewater goes through a multi-step process that aerates it and allows impurities to settle in a series of basins. What settles out contains biodegradable solid material that can attract vectors of disease (such as insects or rodents) and so must be treated before being released into the environment.

“Usually, the treatment is another biological process, referred to as the digestion process,” Sobsey explains. “In many places, that process is done without oxygen at moderate temperatures—either ambient outdoor temperatures or a little higher. While that process is reasonably effective at degrading some of the organic matter in sludge and making it more stable, it doesn’t do much to kill off pathogens.”

Billy Turner, president of Columbus Water Works in Georgia, earned a master’s degree in environmental sciences and engineering at the UNC School of Public Health. Francisco coordinated the North Carolina Annual School for Wastewater Treatment Plant Operators for 32 years. The problem, Sobsey says, was that “the way it’s typically carried out does not allow for all the sludge to be exposed to the higher-temperature digestion process long enough to have its load of pathogens sufficiently reduced. The project in Columbus intended to document that if the process was applied in such a way that all of the sludge could get exposed to the digestion process at thermophilic temperatures for a sufficient period of time, then indeed it would have its pathogen content dramatically reduced to the low levels EPA requires to be considered a Class A process.”

Aitken and Sobsey documented that at thermophilic temperatures — a process called thermophilic anaerobic digestion — would meet the EPA’s standards for producing Class A biosolids. Thermophilic anaerobic digestion degrades organic matter and reduces pathogens through the combined effects of biological activity and exposure to temperatures in the mid-50s Celsius. The process has been well known for several decades, and laboratory and field studies have documented that it reduces disease-causing microorganisms to very low levels.

“We suspect the process will become more widespread, and of course, that was the goal,” Sobsey says. “A lot more utilities will be able to make only minor modifications to their processes and have the benefits of being able to get Class A sludge.”

Developing protocols
Aitken also has been working with Dr. Steven Wing, UNC School of Public Health associate professor of epidemiology, to develop protocols for investigating reports of health concerns that may be related to the application of biosolids on agricultural fields. “What’s driven both projects is the underlying concern that potential human-health impacts of land application of biosolids have really not been well established,” Aitken says. “Municipalities like Columbus are much more interested in producing Class A biosolids because, by destroying the pathogens, they have removed a significant health concern.”

Complaints about land application of Class B biosolids have been so vociferous in some areas that some communities have prohibited the practice, Aitken notes.

Wing, the principal investigator for the project, says that some people who live near sites where biosolids have been applied report respiratory, gastrointestinal and dermatologic problems that they attribute to exposure to pathogens that migrate off-site. Biosolids contain nutrients and have value for the soil for agriculture, he notes, but they also can contain endotoxins, live pathogens, metals and chemicals that run off from streets or are flushed down the drain by industry. “When the material is applied to land, it can in some situations move off-site in the air. It’s also possible that when it rains, the material could migrate down into groundwater or run off into local surface waters.”

The protocol on which the team is working includes a health questionnaire that could be administered by a responding agency, such as a health department. It also includes various means to acquire information about sources of sludge; how sludge was treated, stored and applied; and its potential to migrate off-site. “We’re also including guidelines that could be used by an agency if they felt they needed to go on-site and investigate through inspection and other measures,” Wing says. The information that’s gathered also could be entered into a large database, which would facilitate an epidemiological study of links between biosolids and health. The project is funded by the Water Environment Research Foundation, a research agency supported by various wastewater utilities, state agencies, industries and consulting firms, as well as by the EPA.
related to the application of biosolids on agricultural fields. Sobsey and Dr. Michael Aitken, chair of the School’s Department of Environmental Sciences and Engineering, recently completed a project for the city of Columbus, Ga., to investigate whether a conventional sludge treatment process could be adapted to produce Class A biosolids. In most sewage treatment plants today, wastewater goes through a multi-step process that aerates it and allows impurities to settle in a series of basins. What settles out contains biodegradable solid material that can attract vectors of disease (such as insects or rodents) and so must be treated before being released into the environment.

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Approximately 3 million tons of biosolids (treated sludge) produced by U.S. wastewater treatment plants are applied to agricultural land each year. UNC researchers are investigating innovative treatment methods that result in safer Class A Biosolids and are developing a protocol to investigate health concerns that might be related to the application of biosolids on agricultural fields.

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As is typical, Columbus faced the problem, Sobsey says, that “the way it’s typically carried out does not allow for all the sludge to be exposed to the higher-temperature digestion process long enough to have its load of pathogens sufficiently reduced. The project in Columbus intended to document that if the process was applied in such a way that all of the sludge could get exposed to the digestion process at thermophilic temperatures for a sufficient period of time, then indeed it would have its pathogen content dramatically reduced to the low levels EPA requires to be considered a Class A process.”

Aitken and Sobsey first ran experiments in the laboratory to document performance of the process. A national environmental engineering firm, Brown and Caldwell, took time and temperature conditions Aitken and Sobsey determined to be adequate and designed a prototype system at the Columbus plant to meet them. Modifications ensured that all the sludge would be treated at known temperatures for a known period of time, long enough to get rid of the pathogens. Aitken and Sobsey documented that at the end of the modified process, the biosolids were free of viruses, bacteria and parasites. The EPA approved Columbus Water Works’ method as a Class A procedure. The prototype system received an award for excellence in environmental engineering from the American Academy of Environmental Engineers.

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TIP: Keep your septic system in good working order. Mow the septic field often, inspect your tank annually and pump it out at least every three to five years. Failing septic systems leach organic wastes that can cause excessive algae growth and disease-producing pathogens in water sources.

UNC faculty train North Carolina wastewater treatment plant operators

More than 7,200 North Carolina wastewater treatment plant operators owe their training to Dr. Donald Francisco, clinical professor emeritus of environmental sciences and engineering at the UNC School of Public Health. Francisco coordinated the North Carolina Annual School for Wastewater Treatment Plant Operators for 32 years.

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