Cleaning Groundwater — Two Approaches

Macroemulsion. . .

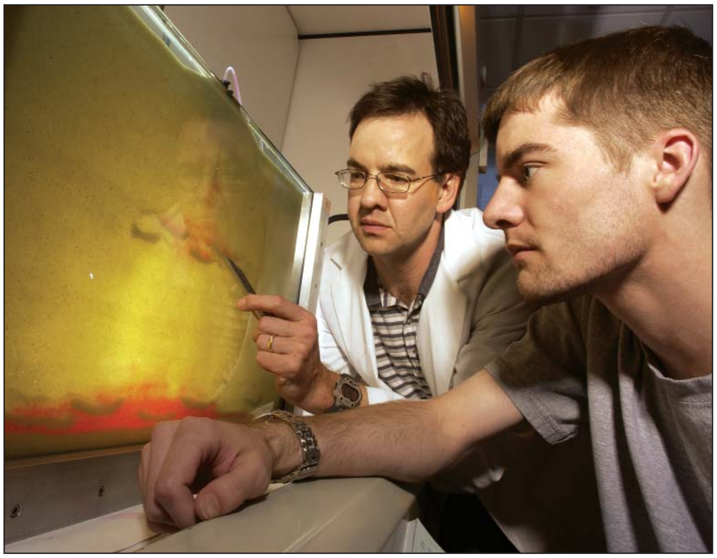
Environmental engineering researchers have developed a two-part approach for cleaning up toxic chlorinated solvents spilled into underground water supplies from former dry cleaning and industrial operations.

The patent-pending technique, which uses a macroemulsion composed of alcohol and food-grade surfactants, simultaneously reduces the density of the pollutant — to keep it from sinking farther into the groundwater — and helps separate it from soil particles so it can be flushed out. Known as density modified displacement, the approach could cut the cost of environmental remediation by reducing both the time required for cleanup and the amount of contaminated effluent that must be treated.

The technique was reported in the journal *Environmental Science and Technology*. Researchers from the Georgia Institute of Technology, the University of Michigan and the University of Oklahoma participated in the work, which was sponsored by the U.S. Environmental Protection Agency's Great Lakes Mid-Atlantic Center for Hazardous Substance Research.

"We're trying to make remediation of contaminated groundwater more efficient, because it is now largely driven by economics," says Kurt Pennell, associate professor in Georgia Tech's School of Civil and Environmental Engineering. "The idea is to make this process so efficient that the cost of cleaning up a site is less expensive than traditional approaches, which rely on groundwater extraction and long-term monitoring."

PHOTO BY GARY MEEK



Researchers Kurt Pennell, left, and Eric Suchomel examine an aquifer cell that simulates a spill of TCE, dyed red here.

. . .And Bacterial Detox

Researchers have isolated a novel bacterium that flourishes as it destroys harmful chlorinated compounds in polluted environments, leaving behind environmentally benign end products. The finding opens the door for designing more efficient and successful bioremediation strategies for thousands of contaminated sites that remain threats despite years of expensive cleanup.

"This organism might be useful for cleaning contaminated subsurface environments and restoring drinking-water reservoirs," Georgia Tech researchers report in the July 3, 2003 issue of the journal *Nature*.

The paper is the culmination of five years of field and laboratory studies funded by the National Science Foundation and the Strategic Environmental Research and Development Program.

Scientists and engineers have struggled for years with cleanup of groundwater and subsurface environments contaminated decades ago by unregulated use of the common solvents tetrachloroethene (PCE) and trichloroethene (TCE). These toxic compounds are primarily used in dry cleaning operations and degreasing of metal components. Complicating the situation are natural biotic and abiotic processes that transform these solvents to intermediate substances, such as toxic dichloroethenes, and cancer-causing agents, such as vinyl chloride.

In a step toward engineering better bioremediation strategies, Georgia Tech researchers have isolated a naturally occurring bacterium, designated Dehalococcoides strain BAV1, in a pure culture — without other microbial species present in the sample. Though some progress was made in the past decade in understanding the bacteria involved in partial degradation of PCE and TCE, this study represents a significant advance, researchers say.

"Isolating this bacterium will allow us to study the organism and the dechlorination process in more detail," says lead researcher Frank Loeffler, an assistant professor in the School of Civil and Environmental Engineering.

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Hold the Salt, Please

Researchers have found they can control the size of densely packed DNA structures by changing the salt concentration in solutions containing DNA. The finding could improve the efficiency of gene delivery for medical treatment and disease prevention.

Scientists are seeking to understand the natural mechanism of DNA condensation into nanostructures — in particular, toroids, which look like tightly wound garden hoses. Densely packed DNA is nature's efficient way of transporting genetic information, done particularly well by sperm cells and viruses.

Researchers want to mimic this process to improve DNA delivery for gene therapy and DNA-based vaccines, but they face challenges in the laboratory where DNA in solution typically exists in an extended, rather than condensed, state. Scientists have been able to cause DNA to condense into toroids by adding positively charged molecules to samples, but they have had difficulty finding the right molecules to achieve consistent, optimal toroid sizes of less than 50 nanometers.

In the journal *Proceedings of the National Academy of Sciences*, Georgia Tech researchers report that reducing salt concentrations below normal laboratory solution levels shrinks both the diameter and thickness of DNA toroids. This finding resulted from a combined investigation of how static DNA loops and solution conditions might be used to control toroid dimensions.

"But even without static loops present, DNA produces smaller toroids if you reduce the salt concentration," says Nicholas Hud, associate professor of biochemistry, who is leading the study funded by the National Institutes of Health. "We found a systematic relationship between reducing salt and reducing toroid size. It is surprising that such a study was not previously done because salt concentration is such a fundamental parameter in studying molecules in solution, particularly such highly charged molecules as DNA."

PHOTO BY GARY MEEK

Professor Nicholas Hud, left, and Ph.D. student Christine Conwell — along with Ph.D. student Igor Vilfan (not shown) — have made a significant advance in controlling the size of DNA toroids.

Maritime Logistics

Leaders from the state of Georgia have announced creation of the Savannah Maritime Logistics Innovation Center (SMLIC), a partnership between the Georgia Ports Authority and the University System of Georgia. The center will address maritime logistics and security issues of national and international concern.

Researchers from Georgia Tech, Georgia Southern University and Armstrong Atlantic State University will work with the Ports Authority to develop innovative technologies for the efficient, secure movement of freight.

PHOTO COURTESY OF GDIT

Photonic Progress

Researchers have developed a laser-based technique for creating patterns in self-assembled colloidal crystals produced from hydrogel nanoparticles — soft spheres that respond to heat by changing size. The development could make possible the fabrication of waveguides, three-dimensional microlenses and other photonic structures from the unusual crystals.

PHOTO BY GARY MEEK

Hydrogel photonic crystal samples are composed of various particle types and sizes.

In related work, Georgia Tech researchers have learned to use weak attractive forces between the soft spheres to produce uniform crystalline structures with particle concentrations much lower than possible with hard spheres. The developments were described in September 2003 at a national meeting of the American Chemical Society.

In April 2002, a research team led by Andrew Lyon, professor in Georgia Tech's School of Chemistry and Biochemistry, announced it had developed a family of hydrogel-based nanoparticles that could be used to create photonic crystals whose optical properties could be adjusted by thermally changing the water content of the particles.

The soft, conformable spherical particles provided a unique system for producing self-assembled periodic structures that could be tuned to transmit specific wavelengths of light. Applications were expected in optical switching and optical limiting.

The work discussed at the chemical society meeting moves the nanoparticles closer to practical application by providing a way to form complex patterns in the crystalline structures. The patterns could be useful as optical waveguides or lenses.

Labs on a Chip

Georgia Tech physicists have demonstrated a new optical technique for controlling the flow of very small volumes of fluids over solid surfaces. The technique, which relies on changes in surface tension prompted by optically generated thermal gradients, could provide the foundation for a new generation of dynamically reprogrammable microfluidic devices.

A paper describing the technique was the cover story for the Aug. 1, 2003 issue of the journal *Physical Review Letters*. The research has been supported by the National Science Foundation and the Research Corporation.

Existing microfluidic devices, also known as "labs-on-a-chip," use tiny channels or pipes etched into silicon or other substrate material to manipulate very small volumes of fluid.

Though many technical hurdles remain, Georgia Tech Associate Professor of Physics Michael Schatz and his collaborators believe their technique could be the basis for a miniaturized lab-on-a-chip used for genetic or biochemical testing in the field. The easily reconfigurable system would be able to transport, merge, mix and split off streams of fluid flowing across a flat surface.

"If we can build devices that move fluids at small scales in a reconfigurable way, then in principle we can do all kinds of assays in the field at very high densities," Schatz explains.

Ultimately, the miniaturization of microfluidic devices could do for fluid handling what the modern semiconductor technology has done for electronics, allowing assays, chemical studies and other macro-scale processes to become smaller, cheaper and faster." The shrinking of devices using microfluidics could be as revolutionary to our daily lives as microelectronics has been," Schatz says.

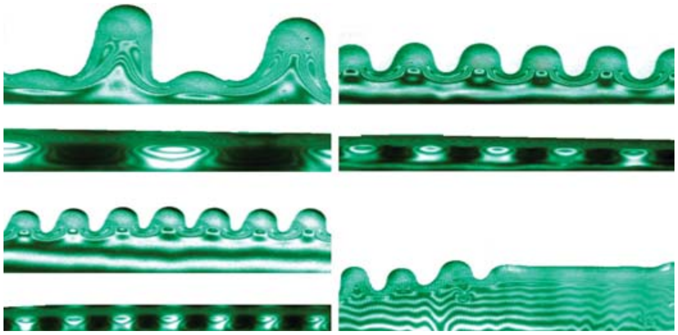

IMAGE COURTESY OF MICHAEL SCHATZ

Above right: Video images under monochromatic illumination show the optical selection and control of thin film flow patterns on horizontal substrates. For each of the first three images, the film pattern is shown at two different times. The lower third of each image displays a thin-film whose contact line is initially straight.

Internet Speed

By creating what are believed to be the fastest detailed computer simulations of computer networks ever constructed, Georgia Tech researchers hope to improve the speed, reliability and security of future networks, says Professor Richard Fujimoto, lead principal investigator of the project.

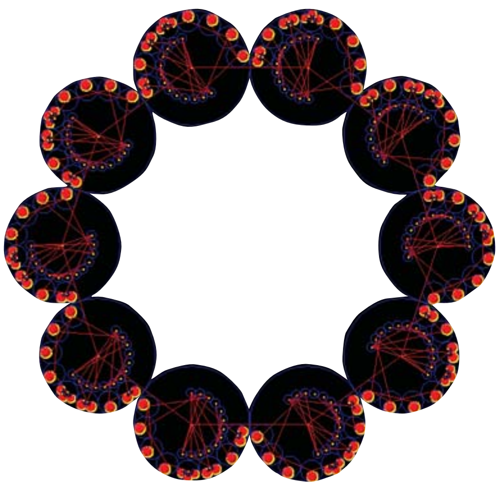

IMAGE COURTESY OF RICHARD FUJIMOTO

Georgia Tech researchers have demonstrated the ability to simulate network traffic from more than 1 million Web browsers in near real time.

"The end goal of research on network modeling and simulation is to create a more reliable and higher-performance Internet," Fujimoto says. "Our team has created a computer simulation that is two to three orders of magnitude faster than simulators commonly used by networking researchers today. This finding offers new capabilities for engineers and scientists to study large-scale computer networks in the laboratory to find solutions to Internet and network problems that were not possible before."

The Georgia Tech researchers have demonstrated the ability to simulate network traffic from more than 1 million Web browsers in near real time. This means that the simulators could model a minute of such large-scale network operations in only a few minutes of clock time.

Using the high-performance computers at the Pittsburgh Supercomputing Center, the Georgia Tech scientists used as many as 1,534 processors to simultaneously work on the simulation computation, enabling them to model more than 106 million packet transmissions in one second of clock time — two to three orders of magnitude faster than simulators commonly used today. In comparison, the next closest packet-level simulations of which the research team is aware have simulated only a few million packet transmissions per second.

These "packet-level simulations" model individual data packets as they travel through a computer network. Downloading a Web page to a home computer or sending an e-mail message typically involves transmitting several packets through the Internet. Packet-level simulations provide a detailed, accurate representation of network behavior (e.g., congestion), but are time consuming to complete.

Engineers and scientists routinely use such simulations to design and analyze new networks and to understand phenomena such as denial-of-service attacks. The project was funded by the Defense Advanced Research Projects Agency.

Ozone Layer Destruction

The rate at which ozone is being destroyed in the upper stratosphere is slowing, as is the rate at which ozone-destroying chlorine in that layer of the atmosphere is increasing — the first clear evidence that a worldwide reduction in CFC pollution is having the desired effect.

"This is the beginning of a recovery of the ozone layer," says Professor Michael Newchurch, a University of Alabama in Huntsville researcher who led the ozone trend-analysis research team that included Georgia Tech scientists. "We had a monumental problem of global scale that we have started to solve."

Using data from three NASA satellites and three international ground stations the team found that ozone depletion in the upper stratosphere has slowed since 1997. A damaging pollutant in the air near the ground, ozone in the stratosphere shields Earth from harmful ultraviolet solar radiation.

The results of this work were accepted for publication in the American Geophysical Union's *Journal of Geophysical Research*.

NASA grants and contracts supported the research by Newchurch and his co-investigators, postdoctoral fellow Eun-Su Yang and Professor Derek Cunnold in the Georgia Tech School of Earth and Atmospheric Sciences, Professor Gregory Reinsel at the University of Wisconsin, J. M. Zawodny at NASA's Langley Research Center and Professor James Russell III in the Center for Atmospheric Science at Hampton University.

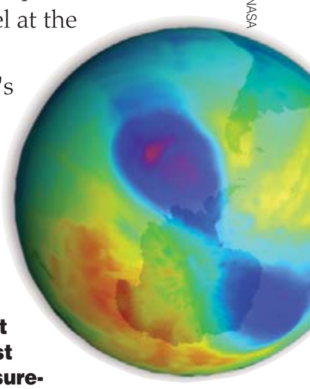

IMAGE COURTESY OF NASA

On Sept. 24, 2002, the Antarctic ozone hole split into two holes for the first time since satellite measurements have been taken. Dark blue indicates the hole, an area with at least 20 percent less ozone than normal.

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Mending Broken Hearts

Numerical modeling techniques, developed at Georgia Tech to simulate the flow of water around hydraulic structures, are being used to better understand the complex patterns of blood flow through artificial mechanical heart valves.

The research could yield the most accurate description to date of the turbulent flow environment blood cells and platelets are exposed to as they pass through implanted mechanical heart valves—

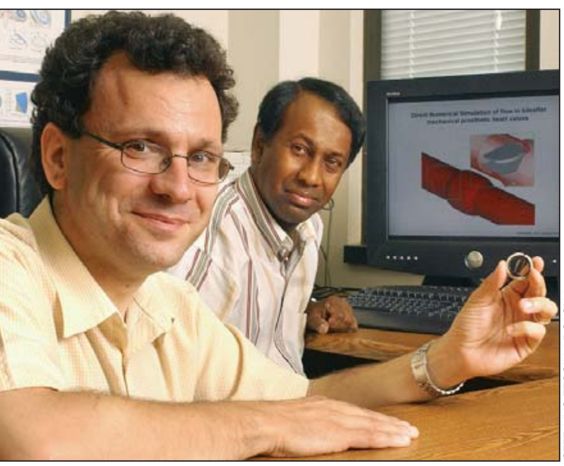

PHOTO BY NICOLE CAPPELLO

Georgia Tech researchers Fotis Sotiropoulos, left, and Ajit Yoganathan are applying advanced computational fluid dynamics modeling techniques to understand blood flow turbulence in mechanical heart valves.

information that researchers hope will lead to improvements in current mechanical valve testing and design procedures and help reduce the potential for thromboembolic complications.

Backed by a four-year, $1.4 million grant from the National Institutes of Health, the research is being led by Ajit Yoganathan, Regents' professor in the Wallace H. Coulter School of Biomedical Engineering at Georgia Tech and Emory University and an expert on artificial heart valves and cardiovascular fluid mechanics research; and Fotis Sotiropoulos, an associate professor in the School of Civil and Environmental Engineering and a leading expert in computational fluid mechanics.

To date, the fluid mechanics of heart valves have been largely studied using experimental approaches. The Georgia Tech research is believed to be the first comprehensive attempt to develop advanced computational fluid dynamics (CFD) techniques and apply them in conjunction with experiments to study blood flow turbulence in heart valves.

"Our numerical simulations can provide descriptions of the blood flow at a level of detail that far exceeds the insight one can get from experiments alone," Sotiropoulos says. "We will be able to go on a virtual journey, along with platelets and blood cells, through the valve and identify design elements that induce turbulence patterns, which could be harmful to blood elements. This cannot be done experimentally. Yet, we must rely on experiments to make sure that our virtual blood flow environment closely represents reality."

The team is working to adapt advanced CFD modeling techniques developed for simulating turbulent flows past bridge foundations in natural rivers and through hydraulic turbines in hydropower installations to prosthetic heart valves. In spite of many common elements with the hydraulic engineering application, the heart valve problem is so complex that its solution necessitates new advancements and innovation in computational algorithms.

Science for Kids

Researchers at the Georgia Tech Research Institute (GTRI) are creating an interactive Web site that will give middle-school students a chance to become amateur scientists and learn about ocean management. The SeaMaven project is in collaboration with the Skidaway Institute of Oceanography (SKIO).

SKIO has access to several naval flight training platforms about 60 miles off the coast of Georgia and has equipped these platforms with instruments to make a variety of observations. GTRI will upload this data on the SeaMaven Web site, enabling students and teachers to take a virtual tour of a 5,700-square-kilometer area of the U.S. southeastern continental shelf, record near real-time measurements of atmospheric and oceanographic conditions, and engage in electronic forums to discuss ideas and projects generated by their observations.

Funded by the National Science Foundation, SeaMaven is expected to launch in spring 2004.

PHOTO COURTESY OF SKIDAWAY INSTITUTE OF OCEANOGRAPHY

Skidaway Institute of Oceanography has equipped several naval flight training platforms off the Georgia coast with instruments to measure atmospheric and oceanographic conditions. Students will use the information to learn about science.

Prison Conservation

The cannery at Rogers State Prison in Reidsville, Ga., is saving about 24 million gallons of water and more than $100,000 per year thanks, in part, to assistance from Georgia Tech's Economic Development Institute (EDI).

As many as 130 inmates work at the facility every day, canning carrots, beans, peas, potatoes, squash and greens. The vegetables are cultivated on the prison grounds, and, ultimately, end up on the plates of inmates. In 2002, the plant produced approximately 192,871 cases of vegetables.

Michael Brown of EDI and Judy Adler of the Pollution Prevention Assistance Division of the Georgia Department of Natural Resources determined that water was wasted when inmates used hoses as brooms to clean the floors. "We determined we could save about 90 percent of water usage per day for this task by having the cannery maintenance staff do dry cleanup, using shovels, squeegees and brooms to push solid waste into a floor drain," Brown says.

And, the inmates were rinsing the vegetables with fresh water during all three stages of cleaning. Now, they use fresh water only in the end stage, saving approximately two-thirds of the water usage per day for this task by using recycled water in the first two stages.


PHOTO BY MICHAEL BROWN

The cannery at Rogers State Prison in Reidsville, Ga., is saving about 24 million gallons of water and more than $100,000 per year thanks, in part, to assistance from Georgia Tech's Economic Development Institute.

Faces in New Places

Ralph Merkle, inventor of the encryption technology that allows secure transactions over the Internet, is the new director of the Georgia Tech Information Security Center (GTISC).

William "Jim" Frederick Jr. moves into the director's job at the Institute of Paper Science and Technology. He leaves his post as CEI Professor of Green Chemistry and Chemical Engineering at Chalmers University of Technology in Gothenburg, Sweden. Frederick also will be on the faculty at Georgia Tech's School of Chemical and Biomolecular Engineering

Blair Carnahan, staff member of Georgia Tech's Advanced Technology Development Center, was selected to direct the new Columbus Regional Technology Center (CRTC).


PHOTO BY NICOLE CAPPELLO

Ralph Merkle is the new director of the Georgia Tech Information Security Center.

— Research Links edited by Carol Carter, freelance writer

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