Superfund Scoop

The Newsletter of the UNC-CH Superfund Basic Research Program

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A Natural Approach to Hazardous Waste Cleanup

UNC-CH researcher seeks to understand how microorganisms break down contaminants and how to harness this process to clean up contaminated sites

Materials that contain polycyclic aromatic hydrocarbons (PAHs) — a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage or other organic substances — were once heavily used in industry. For instance, creosote and coal tar were used to treat lumber for railroad ties and telephone poles. Often, these liquids were poured into a ditch and the wood dragged through, allowing the chemicals to seep into the ground. Similarly, at manufactured-gas production plants that thrived until the 1950s — including over 30 plants in North Carolina — tar residue from the petroleum and coal used in the process was left in buried tanks and pipes that later leaked in some places. To this day, contaminants from these outdated industrial processes taint the soil and groundwater near these now-abandoned sites.

Many types of PAHs are found at Superfund and other hazardous waste sites around the country. The Environmental Protection Agency regulates 16 PAHs and has classified seven of them as probable human carcinogens. Since PAHs are organic compounds comprised of only carbon and hydrogen, the goal of cleanup processes is generally to bio-

Dr. Michael Aitken uses the laboratory's bioreactor to test remediation methods for contaminated soil. (Melanie Miller)

degrade these compounds into carbon dioxide and water, two ubiquitous and harmless substances. In practice, however, the process is rarely simple. There is a risk, for instance, of only partially degrading a PAH into another compound that is equally or more toxic, or perhaps more mobile in soil and groundwater, making it potentially more harmful.

Principal Investigator Michael Aitken heads a team at the UNC-Chapel Hill

CLEANUP | SEE INSIDE

Superfund Basic Research Program

The Superfund Basic Research Program (SBRP) at the University of North Carolina at Chapel Hill is one of 19 basic science research programs funded by the National Institute of Environmental Health Sciences (NIEHS).

The program's goal is to advance society's understanding of the human health and environmental risks associated with hazardous waste and develop new environmental strategies and technologies for the cleanup of Superfund sites to minimize human and environmental risk.

For more information on the UNC-Chapel Hill SBRP and our research projects, and for helpful links to other Superfund Web sites, visit our Web site at **www.sph.unc.edu/sfcoep**.

CLEANUP | **FROM FRONT COVER**

SBRP that takes a two-step approach to understanding how various PAHs biodegrade and exploring new ways to bioremediate PAH-contaminated soil (i.e., use microorganisms and organic processes to clean it up). "The first step is to understand how degradation occurs," explains Aitken, whose project was designated as the UNC-Chapel Hill program's most significant research in last year's report to the National Institutes of Health. "Because PAHs have been in the environment for a long time, there are microorganisms all around that are capable of degrading these compounds. We are studying organisms that already exist in contaminated soils to understand — if these organisms are already there and are capable of degrading these PAHs — why do we still have contamination 50 years after some of these places were abandoned?"

"One answer is that in some places the contamination is so heavy and the degradation rates are so slow, it would take hundreds of years before you would see these compounds removed to a noticeable degree. Most scientists also assume that because PAHs are not very soluble in water, and since these organisms can only degrade what's in the water, the degradation rate is slower. But there is actually little evidence that this is the main reason for the poor degradation of the carcinogenic PAHs." In the laboratory, Aitken and his team are using bacteria isolated from contaminated soil samples to study degradation rates of the carcinogenic PAHs. These results will help determine factors that may control the rate and extent of degradation in the much more complex contaminated soil environment.

Professor Aitken's research has the potential of engaging natural microorganisms in the cleanup of hazardous waste.

— Dr. James Swenberg, Director of the UNC-Chapel Hill SBRP

Aitken's group is currently using a laboratory-scale bioreactor to treat contaminated soil they obtained from a manufactured-gas plant site in Charlotte, NC. The reactor will be used to quantify rates of degradation of the carcinogenic PAHs, to understand more about PAH-degrading microorganisms in the soil under conditions that represent the situation in the field, and to test remediation methods that may emerge from this new learning.

Aitken is also focusing on "incomplete metabolism" of PAHs, where microorganisms biodegrade a PAH into another compound, or a byproduct, rather than converting it completely to carbon dioxide and water. He is examining whether this is a significant fate of PAHs and the potential toxicity of these newly formed compounds. So far, the project team has found that bacteria convert fluoranthene and pyrene — two of the most predominant PAHs at contaminated sites — into products that are toxic to these and other PAH-degrading organisms. In some cases, these byproducts virtually shut down the degradation of the carcinogenic PAH benzo[a]pyrene. In a collaboration with UNC-Chapel Hill SBRP Director James Swenberg's research group, one of Aitken's students has also found that these byproducts are toxic to human cells and are capable of causing DNA damage.

The next step in Aitken's research is to apply this growing knowledge about the PAH biodegradation process to develop new approaches to bioremediate hazardous waste. "Currently, bioremediation is not being used as much as other cleanup technologies that are less expensive and, at this point, do a better job," he notes. "But there are some situations in which bioremediation makes sense and might be economically feasible. We can only improve the rates and extents of PAH biodegradation by understanding what the limitations are."

"Professor Aitken's research has the potential of engaging natural microorganisms in the cleanup of hazardous waste," says Swenberg. "Understanding the factors that improve the efficiency of this process is critical for bringing such technology into regular use." ✲

"Guide to Assisting Citizens with Technical Issues at Superfund Sites" Available

This helpful guide, produced with funding from NIEHS, focuses on how citizens who live or work near hazardous waste sites can obtain the information and expertise needed to participate in cleanup decisions. It is based on interviews with citizens, agency officials, and technical advisors at three North Carolina hazardous waste sites. For a free copy, contact the ERP.

Research Highlights

An OSHA employee instructs a New York Police Department officer in the use of respiratory protection at the World Trade Center site. (Donna Miles/ OSHA News Photo)

MEASURING NEW YORKERS' EXPOSURE TO AIR POLLUTANTS POST-9-11

More than a year after the World Trade Center tragedy, residents of New York City are concerned that they are still being exposed to chemicals and particles released from "Ground Zero" following that fateful morning. The National Institute of Environmental Health Sciences (NIEHS) has awarded a one-year, supplemental grant to the UNC-Chapel Hill SBRP to investigate the levels of these contaminants in a sample of apartments in New York City.

Led by Principal Investigator Steve Rappaport, in collaboration with colleagues at Hunter College of the City University of New York, researchers are investigating 25 apartments near Ground Zero and another 25 in the surrounding boroughs of New York City. Novel air samplers were provided to the participants to let them monitor air levels of fine particles and volatile organic compounds (VOCs) inside and outside their apartments, in their workplaces, and in their breathing zones, 24 hours a day for two one-week periods. After sampling, the monitors are sent to UNC-Chapel Hill for analysis.

"The NIEHS is funding studies at other research institutions that are focusing on occupational exposures involving the cleanup, and on the reproductive effects among people living around the World Trade Center. We are the only ones looking at the actual residential exposures," Rappaport notes.

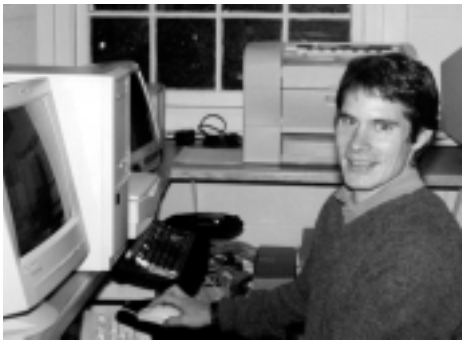
Results from the study are expected this spring. "We are starting with a small sample to test this new methodology, where participants monitor their own exposures. If the participants accept the methodology and the results seem reasonable, we'd like to use the same approach with several hundred New York City residents."

As part of this project, UNC-Chapel Hill SBRP researchers are also collaborating with the Environmental Protection Agency to measure the levels of polycyclic aromatic hydrocarbons (PAHs) from air samples taken near Ground Zero for six months after 9-11. Another team is investigating the levels of fine particles that were measured at several sites in New York City before and after 9-11. This information will allow the team to create a model to understand the size and scope of the burst of particles that were introduced into the air over the weeks following the disaster.

A HOLISTIC APPROACH TO ESTIMATING CONTAMINATION AND HEALTH RISKS

They call it "Project 7," mainly because few outside the scientific community would understand its real title, and even scientists find it a mouthful. In a nutshell, this project presents an innovative way to study human exposure and assess the related health risks for people exposed to contamination from Superfund sites when only a limited amount of monitoring data are available.

"It isn't feasible to build test wells every meter around a Superfund site, so generally we only have partial information from our samples at a few locations or in a few monitoring wells," explains Marc Serre, who worked on Project 7



Dr. Marc Serre demonstrates computer modeling software used to assess the degree of human exposure to toxic chemicals. (Melanie Miller)

as a post-doctoral candidate. Serre has joined the UNC-Chapel Hill faculty as assistant professor in the Department of Environmental Sciences and Engineering and continues to work on this project with Principal Investigator George Christakos. "The challenge is, using limited information and a mathematical framework, to estimate the level of contaminants in the soil or groundwater that people are exposed to at all points around the site over time."

"To do this, we use a holistic approach, looking at what has been done in many disciplines — sampling, mapping, dose-response modeling, and population-based analyses, for example. Then, we perform a statistical analysis to estimate the information that's not there."

Researchers are applying this science to several real world cases nationally and internationally. At North Carolina's Cherry Point Superfund Site, for example, they are estimating levels of lead in the groundwater where measurements from the wells varied greatly and were often too low to determine effectively. "We started with sampling data, then used our mapping software, and then looked at the potential effect on IQs if local children were to drink that water," says Serre, noting that since people do not drink this water anymore, that aspect of the study is theoretical.

Christakos and Serre, along with collaborators at UNC-Chapel Hill and other institutions, have created a space-time mapping approach that scientists worldwide are using to assess human exposure and risk assessment.

In the chemistry laboratory, Dr. Louise Ball uses a microbalance to weigh small samples. (Melanie Miller)

CHEMISTRY AT THE HEART OF SUPERFUND RESEARCH

Louise Ball might know more about the research taking place at the UNC-Chapel Hill SBRP than just about anyone except for Program Director James Swenberg. As principal investigator for the program's Chemistry Core, Ball leads a team of synthetic and analytical chemists who provide support for most of the research projects.

"Our job is to synthesize the chemicals that the research projects need as standards and to facilitate analysis of these compounds," she explains. "Project leaders look to us for chemicals that are rare, expensive, or totally unknown. We also provide support with analytical techniques — liquid or gas chromatography, mass spectrometry, nuclear magnetic resonance — to analyze a novel contaminant that somebody's just discovered in a soil or air extract, for instance."

The Chemistry Core also trains post-doctoral fellows and graduate students working on the individual research projects to help them develop analytical methods and learn laboratory techniques.

One of Ball's most enjoyable challenges occurs when a researcher wants help analyzing a new DNA adduct (an abnormal chemical structure on DNA) or a chemical contaminant. Not only must she and her team make the chemical itself, but also a reference standard — a closely related chemical that will behave similarly to the original but with distinguishing features — to compare with the original.

Ball has been a professor in UNC-Chapel Hill's Department of Environmental Sciences and Engineering since the mid-1980s. As a specialist in biochemical toxicology, she likes to go beyond providing and analyzing chemicals to help her fellow researchers approach problems from both a toxicology and chemistry standpoint. "I've always thought that life is really where it's at, but chemistry is what explains what goes on in life," she says. "Biochemistry is a good compromise, because it's the chemistry of living systems. And toxicology is the interface of where chemicals meet biological systems head-on."

According to Ball, "the Chemistry Core is at the heart of the UNC-Chapel Hill Superfund program: the services we provide are fundamental to most of the research projects. And because we work on so many of these projects, we also serve as a conduit for intellectual exchange between the projects." ✲

Outreach Core Partners with Environmental Groups to Address Electronics Waste

Where do old TVs, computers, VCRs, and cell phones go when they are no longer wanted? Advances in technology improve our lives, yet our growing dependence on electronics equipment at home and in the workplace has given rise to a new environmental challenge: electronics waste.

When electronics break or are replaced with newer technology, much of the outdated material ends up in landfills. These materials contain significant amounts of toxic metals and other contaminants, including lead, mercury, cadmium, and hexavalent chromium. If improperly handled, these toxins can be released into the environment through incinerator ash or from liquids that leach out of landfills and into groundwater.

As awareness of the potential health and environmental risks associated with electronics waste grows, more states, including North Carolina, are debating how to safely and cost-effectively manage electronics waste. The EPA and many environmental organizations recommend reusing and recycling the raw materials from electronics to conserve natural resources and avoid the greenhouse gas emissions and air and water pollution caused by manufacturing new products. However, limited reuse and recycling programs currently exist, and they can be expensive for local governments to maintain.

In North Carolina, a coalition of environmental groups has joined this debate and is calling for legislation that would provide funding to support reuse and recycling programs for electronics waste. The NC Conservation Network (ConNet), a statewide coalition of over 150 groups that focus on environmental and public health issues, facilitated this effort in 2002. In the early phase, ConNet asked the SBRP Outreach Core for research support. Grady McCallie, ConNet's environmental liaison, needed information on the public health impact of electronics waste, so he turned to Outreach Director Kathleen Gray, knowing that one of the SBRP's mandates is to provide technical assistance to North Carolina community-based organizations. Gray, assisted by UNC-Chapel Hill senior Scott Morrissey, researched the health impacts of the hazardous constituents of electronics waste and the management practices of other states and compiled a report for ConNet. The organization used this and other information to identify waste management alternatives with the lowest public health impacts, to create a fact sheet to educate policy makers and to draft a management proposal for electronics waste in North Carolina.

Discarded electronics equipment can present a health hazard by contaminating groundwater with heavy metals and other toxins. (Photo courtesy of Silicon Valley Toxics Coalition)

ConNet's campaign resulted in the introduction of legislation that would ban the disposal of electronics waste in landfills and would implement an advanced recovery fee (ARF) on each item when it is manufactured or first sold in the state. The money collected from the ARF would fund local government collection programs. This issue is still being considered by the NC legislature, and environmental organizations and local government supporters are hopeful that legislation will be enacted this year.

For more information, contact Outreach Director Kathleen Gray at 919-966-9799 or kgray@unc.edu. ✲

The Growing Problem of Electronic Waste

North Carolinians produce over 50,000 tons of electronics waste each year. —NC DENR

Electronics make up about 1 percent of the municipal solid waste stream in our country. —US EPA

Every year, 12 million PCs are thrown away in the United States. —Silicon Valley Toxics Coalition (SVTC)

Electronics waste accounts for 70 percent of the heavy metals found in landfills today. —SVTC

Less than 10 percent of outdated computers are refurbished or recycled. —SVTC

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Outreach Core Supports Under-Resourced Schools in NC

The Outreach Core continued to offer the *What's in the Water?* workshop in 2002, sharing it with middle school science teachers in Wake and Edgecombe Counties and reaching over 1300 students. One of our educational highlights was collaborating with the Carolina Center for Public Service (CCPS) to sponsor a workshop in Edgecombe County, which is a predominantly minority county with almost 20 percent of its families having incomes below the poverty level. The CCPS support enabled us to provide instructional modules valued at $200 for each middle school in Edgecombe County.

For more information about *What's in the Water?*, contact Science Educator Michele Kloda at 919-966-7754 or erp@unc.edu.

We rely on the UNC-Chapel Hill SBRP outreach program for **trustworthy information** *about the public health aspects of environmental issues. They translate obscure scientific research into language we can understand, and provide access to experts across the country. Their work makes it possible for us to be* **credible, fact-based advocates** *— which results in* **better protection** *for our communities and the environment.*

— **GRADY MCCALLIE**, ENVIRONMENTAL LIAISON, NORTH CAROLINA CONSERVATION NETWORK

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