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# ENVIRONMENTAL HEALTH PERSPECTIVES

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In Katrina's Wake

X-Rays Get in Synch

Bisphenol A and Diabetes

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National Institute of Environmental Health Sciences

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NATIONAL INSTITUTES OF HEALTH
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## STUDENT EDITION

**There are some things you learn best in calm, and some in storm.**
Willa Cather
*The Song of the Lark* (1915)

FOOD SAFETY

# Allergen Labeling Takes Effect

Since 1994 food manufacturers have been required to list all the ingredients on their products' labels. A new law now takes this obligation a step further, requiring manufacturers to notify consumers in "plain language" of certain allergens contained in their products. This is good news for the estimated 11 million Americans who have food allergies. But some question whether the new labels might be too much of a good thing.

The Food Allergen Labeling and Consumer Protection Act of 2004, or FALCPA, applies to foods labeled on or after 1 January 2006. It mandates that the nutritional labels on food packages plainly identify any of eight specified food allergen sources—milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat, and soybeans—that are present in the product. Together, these eight food categories account for about 90% of all food allergies. The law stipulates that the warning label be placed near the ingredient list.

Stephen L. Taylor, who heads the Food Processing Center at the University of Nebraska–Lincoln, lauds the "plain language" requirement as an overdue development. "In the past, you've seen terms like 'casein' and 'whey,'" he says. "Consumers often had to learn the hard way that those terms are synonymous with 'milk.'"

But while the new law makes the presence of certain allergens in food products more understandable, Taylor also contends that the act is too strict in requiring that allergens be listed if they are present in the faintest traces. For example, he says, the law requires the listing of not only ingredients but also processing aids that may include allergens, such as soybean lecithin, which is used by baking companies as a stick-release agent for pans.

"My view is that in this particular application the exposure to soybean allergens is extremely low, but with the new labeling requirements you're going to be advising all soy-allergic individuals not to eat the vast majority of bakery products," Taylor says. "And I don't think that's particularly in their best interests."

The law makes clear that decisions about allergen labeling for food products will be an ongoing process. It requires that the Secretary of Health and Human Services provide a report to Congress in February 2006 that's to include information about unintentional contamination of foods with allergens stemming from equipment that is used for multiple food processes. In addition, the U.S. Food and Drug Administration has created the Threshold Working Group to examine approaches that could be used to establish thresholds below which manufacturers would not be required to list food allergens.

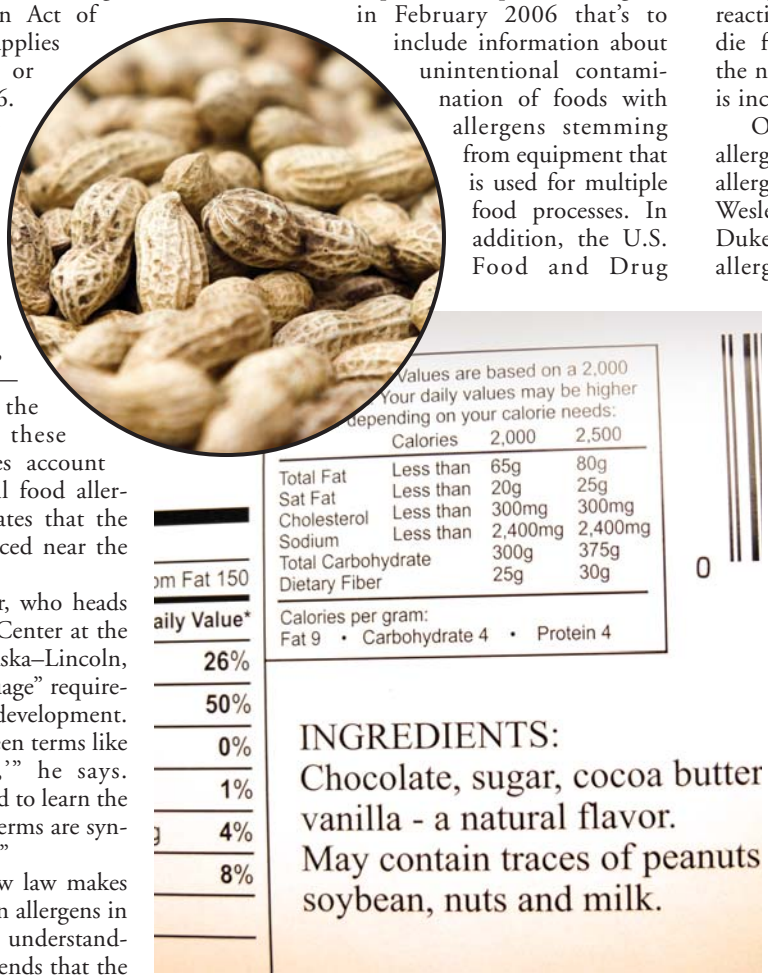
Anne Muñoz-Furlong, founder and chief executive officer of the Food Allergy & Anaphylaxis Network (FAAN), a nonprofit educational organization, considers the law an important step. "With food allergies, there's no cure," she explains. "[Allergic] individuals depend on other people, whether in a restaurant or the food industry, to provide accurate information so they can make the right choices."

According to figures from FAAN, each year some 30,000 Americans require emergency room treatment for allergic reactions to food, and 150 to 200 people die from such reactions. Furthermore, the number of people with food allergies is increasing around the world.

Of particular concern to many food allergists is the sharp increase of food allergies in children. According to A. Wesley Burks, a professor of pediatrics at Duke University Medical Center, peanut allergies have doubled over the last decade among children under the age of five.

Nobody really knows why allergies are on the rise. One theory holds that improved hygiene leaves the human immune system with less to do, Muñoz-Furlong says, so it identifies a particular food as dangerous and responds by attacking it.

Muñoz-Furlong believes that the next step in the development of allergen labeling should be to create binding guidelines for what is currently the voluntary use of "precautionary labeling," which warns of the possibility that an allergen might be present as the result of shared production processes. As for the longer-term issue of how to establish threshold levels, Muñoz-Furlong says that most of the parents of food-allergic children she's talked to believe the answer is simple: "They want zero. They don't want to risk that their child might be in that small percentage of the population that's below the threshold." **–Richard Dahl**




**Plain talk about allergens.** New labeling requirements should make it easier for allergic consumers to tell if a food is safe for them to eat. Next up? Some suggest codifying the now-voluntary use of precautionary labeling (large photo).

Top to bottom: Daniel Gilbey/Stockphoto; Matt Ray/EHP

CHILDREN'S HEALTH

# Breastfeeding: Nature's MRE

Low breastfeeding rates and inadequate emergency planning left many infants dehydrated and hungry in the wake of Hurricane Katrina. Health and educational organizations responded rapidly with breastfeeding information and assistance. Through direct contact with mothers and emergency responders, the groups strove to implement long-standing international guidelines for feeding infants in emergencies.

**Comfort food.** Breastfeeding, as in this refugee camp in Thailand's Mae Hong Son Province, is best for infants in emergency situations.

Top to bottom: EyeWire; Dean Chapman/Panos Pictures; John Hollerton/Stockphoto

Breastfeeding provides optimal nutrition, protection against infection, and a safe, reliable food source for babies—attributes that are critical in emergencies. International health organizations including the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) promote breastfeeding as the best way to feed infants in a crisis. Although formula is an adequate substitute when a child does not receive breast milk, it must be available with a supply of clean water and containers, and instructions for feed preparation must also be available. Yet potable water, formula itself, and even mixing containers may be impossible to acquire in an emergency.

The WHO and UNICEF have long had guidelines that strongly favor breastfeeding in crises. Current guidelines stem in part from the March 1999 Kosovo crisis in which war forced thousands of Kosovar Albanians into refugee camps. Andrew Seal, a lecturer in international nutrition at the London-based Institute of Child Health and coauthor of a 1999 report based on the Kosovo experience, says, "I think the guidelines are quite good, but it's like any other specific technical sector—it depends on having people within the organization who have the interest and awareness to champion that particular cause when there are one thousand and one other things to be thinking about."

Breastfeeding should begin at birth, but a full milk supply can be established even several days after birth. If a nonbreastfed infant is less than six months old, a mother may be able to relactate; beyond that, it is sometimes possible to induce lactation for a partial milk supply. Health organizations dispute the common beliefs that stress "dries up" a mother's milk and that malnourished mothers cannot produce milk, but emphasize that optimal breastfeeding requires a supportive environment.

Guidelines issued by the American Academy of Pediatrics in 2005 emphasize that children younger than six months old require no other food or fluids beyond breast milk and recommend that breastfeeding continue after solid foods are introduced for at least the first year of life or longer if mother and child wish to continue. The WHO and UNICEF recommend breastfeeding for at least two years.

One significant problem in the Gulf Coast crisis was a lack of breastfeeding knowledge in the affected population. "We sent . . . board-certified lactation consultants into the shelters to start working directly with the mothers who wanted our help," says Katy Lebbing, herself an international board-certified lactation consultant with La Leche League International, an organization that supports and promotes breastfeeding. But few women were already breastfeeding. "Not only did we have to help people with breastfeeding, but we also had to educate people about breastfeeding," she says.

Getting breastfeeding support and information to people in crisis is problematic, though. Says Seal, "We need integrated interventions that acknowledge the reality of a mother's established feeding decisions."

Indeed, one reality is that breastfeeding rates are extremely low in many areas, including Louisiana and Mississippi, which have some of the lowest breastfeeding rates in the nation, according to the Centers for Disease Control and Prevention. Nevertheless, Lebbing hopes that breastfeeding promotion efforts after Katrina planted a seed. "Natural disasters and other types of disasters happen," she says. "The best choice is to breastfeed because you don't have to worry about your baby's milk supply." **–Julia R. Barrett**

## Liver Library

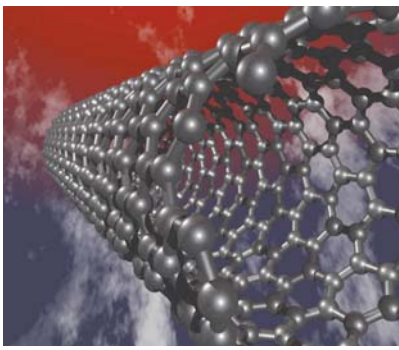
Johnson & Johnson's pharmaceutical research and development division has contributed a library of expression profiles for 100 paradigm compounds, primarily hepatotoxicants, to the Chemical Effects in Biological Systems (CEBS) knowledge base based at the National Center for Toxicogenomics, a part of the NIEHS. CEBS users can select arrays corresponding to one or more compounds from the library and use knowledge base tools to identify genes with significantly changed transcript levels. Lists of altered genes can then by annotated with current annotation provided by CEBS or projected onto biological pathways from groups like BioCarta, KEGG, and the Gene Ontology Consortium. CEBS is accessed at http://cebs.niehs.nih.gov/.

## Action for Indoor Air

At its 4 September 2005 congress, the International Academy of Indoor Air Sciences called on the governments, institutions, and corporations of the world to invest more in reducing indoor air pollution. According to the academy, indoor air pollution in developing countries can exceed international health-based guidelines by 20 times or more, and the use of coal contaminated with arsenic and fluorine is poisoning millions in China. The World Health Organization estimates that indoor solid fuel burning causes about 1.6 million premature deaths annually, mainly among women and children. These problems are easily solved, however. Low-cost interventions including education, improved cooking devices and fuels, better stove placement and ventilation, and a focus on reducing children's exposures have been shown to successfully reduce the health effects of indoor air pollution.

## Nanodatabase Unveiled

The International Council on Nanotechnology and Rice University's Center for Biological and Environmental Nanotechnology unveiled the world's first database of scientific findings on nanotechnology on 19 August 2005. Available at http://icon.rice.edu/research.cfm, the database was created by Rice University researchers, the chemical industry, and the Department of Energy, and will be updated and enhanced over the next year. The database is searchable by author, year, keyword, type of particle, and type of experiment. Currently the database houses only abstracts and summaries of papers from peer-reviewed scientific journals, but policy reports and commentaries on key papers in the field will be added in the future.



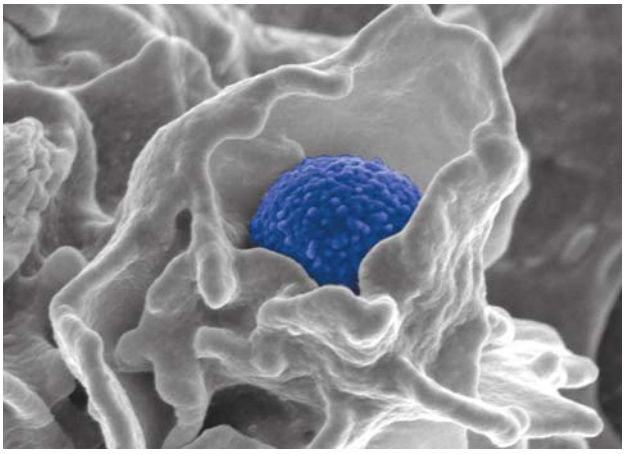
INFECTIOUS DISEASE

# Meaner MRSAs

Most methicillin-resistant *Staphylococcus aureus* (MRSA) infections are contracted in hospitals and other health care facilities. Antibiotic use, patients' weakened immune systems, close contact among people, and open wounds all make hospitals prime breeding grounds for these bugs. But community-acquired MRSA strains, which attack healthy individuals with seemingly normal immune systems, are becoming more prevalent. A recent comparison of representative strains of hospital- and community-acquired MRSAs now suggests that the latter are more virulent and that they excel at escaping destruction by white blood cells.

Infectious disease experts suspected that community-acquired strains can overcome a healthy immune system because they operate differently than those acquired from hospital or health care settings. Microbiologist Frank DeLeo of the National Institute of Allergy and Infectious Diseases' Rocky Mountain Laboratories led a multi-institutional team of researchers in comparing the two types. In studies described in the 15 September 2005 issue of *The Journal of Immunology*, they evaluated the potency of three community-acquired MRSA strains (MW2, LAC, and MnCop) and two hospital-acquired strains (MRSA252 and COL).

Healthy adult mice were injected with each strain. All the mice infected with community-acquired strains became ill, and several died. None of the mice infected with the hospital-acquired strains died, and only one mouse became ill. Then the MRSA strains were mixed with human neutrophils (white blood cells), the body's first line of defense against bacterial invasion, which kill bacteria by producing hydrogen peroxide and other toxic oxygen metabolites. After half an hour, the community-acquired strains survived neutrophil destruction better than the hospital-acquired ones. After six hours, the community-acquired strains had begun rupturing the neutrophils and were actually growing.



**One bad bug.** Community-acquired methicillin-resistant *S. aureus* (in blue) overcomes the immune system by destroying neutrophils, thus breaching the body's first line of defense.

Next the researchers used microarrays to uncover genes that differed during interaction with neutrophils. Not surprisingly, genes that encode virulence factors, toxin production, and stress responses were induced in all the MRSA strains. However, about two dozen genes that encode surface or secreted proteins of unknown function were upregulated only in the community-acquired strains. Gene knockout experiments are under way to identify whether these genes contribute to neutrophil killing. The researchers are also exploring how the community-acquired strains withstand neutrophils' toxic compounds.

The findings suggest that community- and hospital-acquired MRSA strains differ broadly in their biology and genetics. Will this new information help physicians on the front lines who are fighting MRSA infections? "[The findings] do not have immediate therapeutic implications, but maybe down the line therapies will be developed based on such findings," says Henry Chambers, an infectious disease physician at the University of California, San Francisco, School of Medicine. **–Carol Potera**

INNOVATIVE TECHNOLOGIES

# X-Rays Get in Synch

Synchrotrons may have been designed with high-energy physics in mind, but now biologists are starting to see the light too. Jeffrey Gillow, a researcher at Brookhaven National Laboratory, has been making use of the X-ray microscope at the National Synchrotron Light Source (NSLS) in New York to see extremely fine details of bacteria biochemistry in a technique known as X-ray spectromicroscopy.

Gillow's team, funded by the Department of Energy Office of Science, uses "soft" X-rays (up to 800 electronvolts, a relatively small amount of energy) to study the chemical structure of organic compounds. "It's great because you get more than just a detailed picture," says Gillow. "You also get chemical information about your sample."

Gillow uses the synchrotron to precisely tune the energy of the X-rays, knocking carbon electrons out of their orbitals. The resulting disturbance changes the bonds of molecules, and the researchers can read the spectra to see which elements were bonded to which.

The precise nature of the X-ray microscope allows Gillow to see exacting chemical detail within bacteria. Recently, his team used the 30-nanometer resolution of the NSLS X-ray microscope to observe an immature spore develop within a *Clostridium* sp. bacterium, something far too minute and hidden within its host for any conventional electron microscope. These findings were published in the June 2005 issue of the *Journal of Electron Spectroscopy and Related Phenomena*.

Another strength of X-ray spectromicroscopy is that samples require only minimal preparation. Says Gillow, "There is no staining necessary. Basically you just put the sample on the window and away you go." Without staining or heat fixing, the bacterium maintains its naturally occurring biochemical composition.

However, X-ray spectromicroscopy does require that experiments be conducted in close proximity to a synchrotron. And even though there are currently 40 of these very expensive machines in the world, only a few have the capabilities to conduct this type of research. Further, no live specimens can be studied due to the extraordinary amount of radiation they receive.

Regardless, X-ray spectromicroscopy offers environmental scientists chemical detail and unaltered observations like never before, which is key to understanding the complex biochemical reactions that bacteria undergo in the environment. For example, groups interested in bioremediation can now see on a molecular scale how bacteria alter the chemistry of metals and radionuclides and remove them from soils and waters.

A better understanding of subcellular microorganism chemistry, specifically sporulation, might also help authorities neutralize bioterrorism threats before they become a problem. "Finding ways to interrupt sporulation could stop bioterrorism attacks," says Gillow. "But I doubt you will ever see a synchrotron at an airport scanning your luggage." **–Graeme Stemp-Morlock**

David W. Dorward/Rocky Mountain Laboratories

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## CDC: Environmental Concerns After Hurricane Katrina NIEHS: Natural Disaster Response

Since Hurricane Katrina struck the U.S. Gulf Coast on 29 August 2005, Americans have sought reliable information on how to safely reenter flood-damaged environments. The U.S. Department of Health and Human Services (DHHS) has been at the forefront of the effort to assist those affected by this disaster. Two DHHS agencies, the Centers for Disease Control and Prevention (CDC) and the NIEHS, have developed websites offering information on dealing with post-hurricane conditions.

The CDC page, located at **http://www.bt.cdc.gov/disasters/hurricanes/environmental.asp**, gives visitors access to information from both the CDC and the U.S. Environmental Protection Agency (EPA). The site contains a 38-page report, released on September 17, summarizing an environmental health needs and habitability assessment of the city of New Orleans conducted by these two agencies. The report provides conclusions about the habitability of the city as well as recommendations on how best to go about allowing citizens to repopulate the city. There is also a health consultation on the Murphy Oil Company spill, which released 25,110 barrels of mixed crude oil into the area around Meraux and Chalmette, Louisiana.

The site also includes several documents to guide residents as they resume life along the Gulf Coast. There is basic information on cleaning up mold, disinfecting wells, protecting oneself from debris smoke, avoiding carbon monoxide, dealing with animal and insect hazards, and managing chemicals released during flooding. The mold cleanup section also links to other information sources, some of which are available in Spanish and Vietnamese (many Vietnamese have settled along the Gulf Coast since the 1950s). For response and cleanup workers there are links to federal guidelines and recommendations on personal protective equipment, cleaning HVAC systems, and handling and burning hurricane debris.

The NIEHS Natural Disaster Response page is located at **http://www-apps.niehs.nih.gov/katrina/**. The page features geographic information system (GIS) maps that the NIEHS and its academic partners created that identify chemical plants, refineries, Superfund sites, and other potential sources of contamination. It also contains satellite images of the areas affected by the hurricanes. In the future, the section will feature a functional set of GIS layers that will let visitors customize their own maps. These images can help decision makers and others in identifying sources and routes of contaminants, analyzing the potential for future exposures, assessing human exposures in the immediate aftermath of the hurricanes, and predicting long-term health impacts linked with these exposures.

The Questions and Answers page brings together resources from several federal agencies to answer frequently asked questions about mold, sewage, and seafood consumption. This page also contains information on the NIH Katrina Call Center, available at 1-866-887-2842, which provides round-the-clock medical consultation by telephone to anyone affected by Hurricane Katrina.

The NIEHS Program Resources section of the page has links to four programs that the NIEHS had in place long before the disaster struck, which are now being called into action. One of these, the Worker Education and Training Program, offers a PowerPoint presentation for cleanup workers titled *Protecting Yourself While Helping Others*, developed jointly by the NIEHS and other federal agencies to guide those responding to the storms of 2005. This presentation is also available in Spanish and Vietnamese. Visitors can also find safety posters for responders, guidelines for the protection and training of mold cleanup workers, and other checklists, safety plans, and materials.

As a service to NIH- and NIEHS-funded researchers at flooded universities, this site provides links to information for grantees affected by Hurricane Katrina, including notices from the *NIH Guide*. **–Erin E. Dooley**

Top to bottom: Digital Vision; NOAA; FEMA

## Arsenic in U.S. Rice

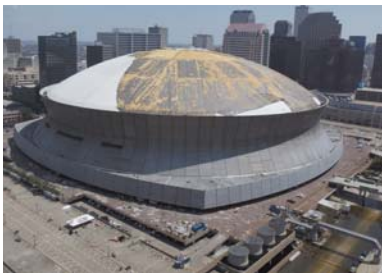
Researchers from Scotland's University of Aberdeen reported in the 1 August 2005 issue of *Environmental Science & Technology* that U.S.-grown rice contains an average of 1.4 to 5.0 times more arsenic than rice from Europe, India, or Bangladesh. Most U.S. rice is grown in fields that once grew cotton, which depends on arsenic-based chemicals to kill boll weevils and remove its leaves before harvesting. Because of the form that arsenic takes in plants, the rice may not pose a threat; arsenic found in drinking water is estimated to be five times more toxic. However, one of the few epidemiological studies on eating a subsistence diet of arsenic-contaminated rice has linked it with an increase in bladder cancer.

## Managing Chemicals Together

Representatives of the world's governments, intergovernmental groups, and other stakeholders met in Vienna in September 2005 to finalize the Strategic Approach to International Chemicals Management (SAICM). SAICM is a framework for global policy on chemical hazards and will ensure that by 2020 chemicals are manufactured and used in ways that minimize impacts on the environment and human health—a goal outlined at the 2002 World Summit on Sustainable Development. SAICM also promotes capacity building, technology transfer, and improved chemicals management, allowing better implementation of international treaties on chemicals such as the Basel Convention on the Transboundary Movement of Hazardous and Other Wastes. Three core documents from the Vienna meeting are expected to be adopted at a February 2006 conference in Dubai.

## Green Plan for Rebuilding NOLA

In the October 2005 issue of *Environmental Building News* (*EBN*), executive editor Alex Wilson outlines a 10-point plan for rebuilding New Orleans. The plan, developed with *EBN*'s editorial board and other sustainable planning and design experts, calls first for the formation of a Sustainable New Orleans planning task force. Coast and floodplain restoration is cited as the first priority. The plan also calls for salvaging and warehousing building materials, rebuilding a stronger levee system that is integrated into a perimeter park, mandating green building of both housing and commercial structures, creating more sustainable Gulf Coast fisheries, cleaning up the new brownfields using the greenest means, and partnering with industry to clean up factories in the region.



# NIEHS Responds to Katrina

NIEHS director David Schwartz knows firsthand what the country's worst natural disaster looks like. Within days of Hurricane Katrina's winds and waves, he led an advance medical team of 50 physicians, nurses, and health care workers from the NIH, the NIEHS, and Duke University Medical Center to Mississippi to respond to the disaster. There he found "nothing short of what one would expect in a war zone," as he wrote on the NIEHS website when he returned two weeks later. The extent of destruction was "overwhelming, with cars upturned, tractor trailers scattered like matchsticks, homes completely leveled, buildings destroyed."

Schwartz was just one of many NIEHS specialists who were, and in some cases still are, part of the largest disaster response mobilization in U.S. history. The institute's response to Katrina involved quick, extensive planning and organization within the NIEHS and across a span of sister agencies, such as the NIH, the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), the Centers for Disease Control and Prevention (CDC), the Department of Defense, the Food and Drug Administration, the U.S. Department of Agriculture (USDA), and the Department of Homeland Security and Federal Emergency Management Agency (FEMA).

"Katrina was an environmental health catastrophe, and [Hurricane Rita a month later] just added to the damage," says Allen Dearry, the NIEHS associate director for research coordination, planning, and translation, who has acted as the institute's response coordinator. "The institute's expertise is connecting environmental exposure to human health, and there are bigger questions as the result of this natural disaster than we have encountered before."

**At the ready.** NIEHS staff came soon after Katrina hit to help at a 500-bed field hospital in a Meridian, Mississippi, hangar.

### Immediate Response on Many Fronts

The NIEHS went into action shortly after Katrina hit. On August 31, the day after the New Orleans levees broke, Joseph "Chip" Hughes and the team he directs at the NIEHS Worker Education and Training Program (WETP) developed a PowerPoint safety awareness training primer for first responders and posted it on the NIEHS website. The group had produced 11 versions of the primer by October 27, updated as the scope of the disaster unfolded to include information on such health threats as trench foot, waterborne diseases, and mold. The primer—available in English, Spanish, and Vietnamese (since there are many Vietnamese in the Gulf Coast region)—has been downloaded at least 1,600 times, and more than 35,000 printed copies have been distributed. The WETP team has also delivered hands-on hazards training to federal employees and federally employed contractors in the field in Mississippi, Louisiana, Alabama, and Texas.

Just as human health was at risk, so was that of the animals left stranded by the hurricane. Starting September 7, William Stokes, director of the National Toxicology Program (NTP) Interagency Center for the Evaluation of Alternative Toxicological Methods, who also serves as the chief veterinary officer of the U.S. Public Health Service, headed the federal effort to assist with the rescue and shelter of those animals. Stokes led an initial team of 10 veterinarians and a public health nurse whose number quickly doubled to meet the overwhelming needs of two emergency animal shelters, one located on the Louisiana State University Baton Rouge campus, and one at a livestock exposition center in Gonzales. The shelters' residents included carriage horses from New Orleans, a pet alligator, an eight-foot-long python, pot-bellied pigs, birds, turtles, and a variety of other pets. A total of 35 Public Health Service veterinarians and countless volunteers examined and treated more than 5,000 creatures, inserted identifying microchips, took photographs, and moved many of the animals out to other shelters to await their owners.

"In addition to keeping all of these animals healthy, our goal was to ensure that as many as possible were returned to their owners in order to avoid further stress from the pet loss on top of all their other losses," says Stokes. He adds that in the future, he hopes evacuation policies will allow for animals to accompany their owners.


**Saving man's best friends.** Bill Stokes and a team of vets and volunteers helped stranded pets.

### Meeting of the Minds

As the extent of the disaster unfolded, the NIEHS continued to send out experts to assist other federal agencies. Mary Wolfe, director of the NTP Office of Liaison and Scientific Review, was sent to CDC headquarters in Atlanta for five days in mid-September to help assimilate field data from teams along the Gulf Coast who were assessing emerging health threats. Sam Arbes, an epidemiologist in the NIEHS Laboratory of Respiratory Biology who studies the health effects of mold, went to Baton Rouge with a CDC team to prepare a document that helped local and state officials assess environmental damage and public health issues as they planned for reentry of residents and restoration. The document addressed public health issues associated with drinking water, sewage disposal, roads and transportation, toxic exposures, housing, and schools, among other things.

NIEHS-funded environmental health sciences centers also swung into action. Immediately after the hurricane, Schwartz asked the center directors to work collaboratively to define the research questions that would surround the effects of the hurricane and the recovery of the population. Five working groups within the centers

Top to bottom: Bill Stokes/NIEHS; Mississippi National Guard

program addressed issues of worker surveillance and health, water quality and microbes, water quality and chemical contamination, mold and respiratory consequences, and outreach and education for the affected populations. The groups have since provided Schwartz with a critical assessment of the research questions that could be addressed.

Some action has begun. Staff from the centers' Community Outreach and Education Programs have banded together to create educational and outreach materials about the hazards that the populace may find in their homes [see "COEPs Contribute to Hurricane Relief," next article]. Centers will also be conducting pre- and postdeployment blood sampling and analysis of New York City firefighters deployed to help the relief efforts in New Orleans. And key experts from the centers have been invited by groups such as the American Red Cross to consult on environmental problems in the region that arose from the storms. They have done some sampling of water, molds, and sediment in the region.

Back home, institute staff developed an NIEHS Natural Disaster Response website to disseminate information to workers and residents about conditions in the Gulf Coast [see the EHPnet article, p. A27 this issue]. Dearry acted as a liaison with call centers set up by the NIH and the CDC, providing information on human and environmental health issues to pass along to callers. The call centers initially took calls just from health care providers, state and local environmental and health agencies, clinics, and other providers, but were soon opened to calls from the public as well.

## Long-Term Study of Environmental Health Risks

Some of the NIEHS disaster response efforts are unique programs that will help identify the environmental hazards produced by Katrina as well as provide long-term insights into the link between environmental toxicants and health outcomes. For example, the NIEHS website features a geographic information system (GIS) database that is designed to help expedite cleanup efforts, but which can be continually developed and updated as a tool to track environmental health.

Led by William Suk, director of both the NIEHS Center for Risk and Integrated Sciences and the Superfund Basic Research Program, the GIS overlays maps and high-resolution aerial photography of Texas, Louisiana, and Mississippi with a wealth of demographic, hydrographic, infrastructure, and industrial/agricultural data from publicly available sources. With the assistance of NIEHS academic partners at Duke University and the University of California, San Diego, supercomputing center, the interactive maps pinpoint the location of Superfund sites (four in New Orleans alone), scores of Toxics Release Inventory–reporting sites (those that release toxic contaminants), and the hundreds of oil and gas rigs, gas stations, chemical industries, refineries, and crude petroleum and natural gas operations in the Gulf Coast region.

Information now being collected on water and air sampling in the area will be added as a way to model the movement of contaminants and identify sources of human exposure. For example, one-quarter of the areas sampled by the EPA in New Orleans by late September showed benzene levels that were more than twice the NTP intermediate safety level. And there were hundreds of reported oil and toxicant spills—including gas that may have seeped from an estimated 350,000 swamped cars—as well as drowned industrial and toxic waste dumps. Suk and his team of institute scientists and academic partners are working 14 to 20 hours a day to pull in data from federal agencies such as the EPA, the CDC, and OSHA in order to create what he calls a "national model that can track environmental health, both for the short-term use of responders and cleanup crews and long-term assessment of health consequences." The model is available on the NIEHS Natural Disaster Response website.

Among the resources they are tapping are the Centers for Oceans and Human Health, supported jointly by the NIEHS and the National Science Foundation. The four centers have been sampling and analyzing floodwaters from New Orleans, and received $150,000 in National Science Foundation "rapid response" funding to collaboratively investigate the health of Lake Pontchartrain, into which 100 billion liters of New Orleans floodwater has been pumped. Researchers at these centers will sample and document the presence, abundance, and fate of waterborne pathogens such as *Escherichia coli* and *Vibrio vulnificus* (which produces a cholera-like infection and is already responsible for deaths in the area) as well as heavy metals and other toxicants in the pollution plume entering Lake Pontchartrain and beyond. They will also monitor the development of harmful algal blooms that could result from matter pumped into the lake. The information will then be linked to the GIS database.

Frederick Tyson, who administers the Centers for Oceans and Human Health program, says, "We have galvanized the talents we have to give us important answers to a public health crisis that is happening right now and that will impact public health in that region." Suk adds that Katrina has offered "an experiment that no one wanted but which we now have in place to study real problems that will allow us to gain a better understanding of environmental health risks." **–Renée Twombly**


RayKay Santa/UTMB

**Rebuilding safely.** The NIEHS WETP has developed a primer to guide construction and cleanup workers in rebuilding the Gulf Coast in a safe manner.

BEYOND THE BENCH

# COEPs Contribute to Hurricane Relief

The conditions in Louisiana and Mississippi following Hurricanes Katrina and Rita reminded us all of our commonality in the human experience and moved many to help. Among those moved to help were the staff at the Community Outreach and Education Programs (COEPs) of NIEHS Centers across the country. Responding to communities in need is one of the primary functions of the COEPs, so providing outreach to those areas on the Gulf Coast impacted by the hurricanes seemed a natural step to take.

"When our director volunteered our COEP [to lead efforts], we remarked that if COEPs had never existed, they would have had to be invented on August 28," says Pamela Diamond, director of the NIEHS Center COEP at University of Texas Medical Branch (UTMB) in Galveston. Adds Robin Fuchs-Young, director of the COEP of the Center for Research on Environmental Disease at the University of Texas, M.D. Anderson Cancer Center (UTMDACC), "All of us saw what was happening on television and felt compelled on a human level to help in whatever way we could."

## A Helping Hand

Says Diamond, "Most of the community outreach directors and staff across the country knew one another and trusted one another, and we could quickly organize a response. It was quite a pickup operation—cell phone calls, e-mails in the middle of the night. During our own evacuation due to Hurricane Rita, we sat on [Fuchs-Young's] back porch, planning supply deliveries, editing public service announcements [PSAs], and identifying scientists in distant states to provide reliable information and data for flyers."

Two teams from the UTMB COEP were dispatched in early October with different objectives. One team, led by Diamond, connected with shelters in rural LaFourche Parish and delivered humanitarian supplies including first aid equipment, diapers, and drinking water. The other team covered a wider range including Calcasieu, Jefferson, Orleans, Terrebonne, and LaFourche Parishes, as well as Baton Rouge and New Iberia and Port Arthur, Texas, to contact community-based environmental organizations whose operations had been disrupted by the hurricanes. These groups were asked how the events had disrupted their normal functions, what environmental damage they observed, what they saw as the greatest environmental threats facing residents on reentering impacted areas, and how they could unite their skills and networks with scientific and clinical expertise. These interviews were compiled in a DVD format and are being sent to the directors of each COEP and interested personnel at the national level.

The UTMB COEP is also collaborating with the Louisiana Environmental Action Network in funding the preparation and delivery of re-entry hazard protection kits for residents involved in recovery operations. These kits focus on mold and toxic residue hazards and—along with information prepared by the NIEHS, the Centers for Disease Control and Prevention, and the Federal Emergency Management Agency—aim to mitigate citizen exposures.

## Education for the Re-entry Process

The COEPs also recognize that the devastated areas will need resources to help them deal with the long-term environmental aftermath of the hurricanes. Soon after Katrina hit, reports indicated high levels of arsenic and lead in the floodwaters and severe mold contamination. The programs joined forces to provide long-term outreach, and divided into areas of strongest expertise to develop fact sheets offering clear, useful information for citizens in the affected areas.

"The strong desire to return families to their homes and to rebuild neighborhoods needs to be balanced with care to do things right," says Ruth Woods, program administrator of the Center for Child Environmental Health Risks Research and the Pacific Northwest Center for Human Health and Ocean Studies, both at the University of Washington (UW). "Environmental cleanup needs to be a high priority so that people are not made ill from [environmental exposures]."

The COEPs from UW, the Kresge Center for Environmental Health at Harvard University (in conjunction with Columbia University), the University of Iowa Environmental Health Sciences Research Center (EHSRC), and the Wayne State University Environmental Health Sciences Center in Molecular and Cellular Toxicology with Human Applications have developed fact sheets addressing various elements of returning home safely. Topics include lead and arsenic contamination from floodwaters, mold hazards, and safe cleanup procedures.

Some of the fact sheet material is based on Katrina-specific studies. Peter Thorne, director of the University of Iowa COEP, says members of his group have collected air and surface samples from water-damaged homes in New Orleans. One study showed that the mean airborne endotoxin concentration was 200-fold higher than in nonflooded homes, and levels of airborne mold spores were so high that N95 respirators—devices with a filter efficiency of 95%–are inadequate protection. Thorne says the fact sheets his working group created describe mold hazards and instruct residents on precautions necessary for safe re-entry and cleanup.

To date, the COEPs have distributed more than 67,000 flyers to local leaders in the storm-damaged area. "We are hoping that other . . . COEPs have information on the same or other topics that can be developed into flyers," says Lisa Pietrantoni, project coordinator for the Wayne State COEP.

What was particularly gratifying about the flyer effort was how clearly the flyers were needed. "I often encountered someone in a shelter who told me they had mold re-entry flyers," says Diamond. "When we looked at them, they were the flyers that had been created at UW or Wayne State, . . . copied by shelter workers, and passed down the line."

The COEPs are also using PSAs to get safety information out to residents. The program at the University of New Mexico Center for Environmental Health Sciences produced six PSAs on topics such as safe cleanup methods, water safety, and toxics, and is working with American Forum, a

**Pitching in.** Center staff stepped in at several points, including taking water samples (left, at the 17th Street Canal) and helping area victims sign up for assistance and humanitarian aid (above, at the LaRose community shelter).

Left to right: Fred Tyson/NIEHS; RayKay Santa/UTMB

nonprofit media company, to disseminate them to over 3,000 radio, television, and print media outlets in the Gulf Coast area. The UTMDACC COEP is developing PSAs for especially susceptible groups of people, including immunocompromised patients. Still more PSAs may be developed to target specific regional issues and incorporate data that emerge from environmental health studies being conducted. Spanish-language PSAs might also target workers doing the repairs and rebuilding.

### More to Be Accomplished

At the NIEHS Core Centers Annual Meeting held this fall at the Vanderbilt University Center in Molecular Toxicology, COEP staff discussed their outreach efforts and looked ahead to some next steps, such as community forums, town hall sessions, and continued data collection. They concluded that there is still much environmental health aid these towns and cities will need.

One potential partnership that could help the COEPs offer some long-term solutions is the Katrina Environmental Research and Restoration Network (KERRN), a vision conceived by John McLachlan, director of the Center for Bioenvironmental Research at Tulane and Xavier Universities in New Orleans. According to McLachlan, KERRN is "a network of researchers sharing data and ideas, crossing disciplinary, geographical, and institutional boundaries, providing models to respond to and recover from major environmental disasters." The network, funded by a grant from the National Science Foundation, could be a great help for the residents in the affected area. As Fuchs-Young notes, "Folks in the Gulf Coast want science and data. They want to know what's going to happen to their water supply and wetlands, and what will be the effect of flooded toxic waste dumps on their lives and livelihoods."

The communities located throughout the Gulf Coast have a long road ahead of them. There is no question in the minds of most that they can and should rebuild; many have lived in this area for generations, and don't want to change their way of life. But environmental health experts caution that much care must be taken because of the health threat that contaminants like mold can pose. States Thorne, "There remains extensive remediation work [in the Gulf Coast area] that will expose residents and contractors to mold hazards. The potential for allergy, asthma, and lung infections is high due to the enormous concentrations encountered. It is critically important that residents of Louisiana and Mississippi are protected from these exposures." **–Tanya Tillett**

Banana Stock

## Headliners | Immune Response

NIEHS-Supported Research

### Lead Disrupts T Cell Function

Farrer DG, Hueber SM, McCabe MJ Jr. 2005. Lead enhances CD4+ T cell proliferation indirectly by targeting antigen presenting cells and modulating antigen-specific interactions. Toxicol Appl Pharmacol 207:125–137.

Although lead has been banned from use in products like house paint, gasoline, and water pipe solder in the United States, it is still present in older housing, and is used in products in other countries. Besides its widely studied neurotoxicity, lead is also a well-known immunotoxicant, though little is known about its mechanism of action. Now NIEHS grantee Michael McCabe and colleagues at the University of Rochester have discovered how lead may work to disturb T cell function in the body.

Previous studies have suggested that lead's immunotoxic effects may occur at exposures even lower than those required for neurotoxicity to occur; thus, suboptimal immune function may affect people who do not even realize they have been exposed to lead. Older adults and lactating, pregnant, and postmenopausal women are at greater risk for lead exposure as lead stored in the bones is released back into the blood and soft tissues. Children are also at heightened risk for lead exposure because they engage in more hand-to-mouth activity and absorb a larger proportion of ingested lead across the intestinal epithelium than do adults.

The Rochester researchers used flow cytometry to analyze T cell division in cell cultures derived from lead-treated mice. T cells help regulate the body's immune system by attacking bacteria, viruses, foreign tissue, and tumor cells. At day 4 of treatment, the frequency of proliferating T cells was much greater in treated than in nontreated cultures. Lead appeared to target a type of cell known as antigen presenting cells, and its effect was based on specific peptide-major histocompatibility complex conjugate. The results suggest that lead may pose even more long-term health threats than originally thought. **–Tanya Tillett**

# In Katrina's

# Wake

Left to right: Mark Wolfe/FEMA; Stephan Savoia/AP Photos

**Comprehending the catastrophe.** (above) Phyllis Howley, 70, sits on what's left of the porch of her son's New Orleans home. (left) The beach in Biloxi, Mississippi, four days after Katrina.

Hurricane Katrina has been called the most devastating natural environmental calamity in U.S. history. Visitors to the scene say the destruction is worse than anyone can imagine. Scientists also say that some perceived health threats have been overblown and others understated. Months after Katrina roared into the Gulf Coast, the environmental health implications of the storm are still being assessed.

Katrina presented residents of the Gulf Coast with a bewildering array of environmental health hazards. Aside from standing floodwater, hazards included a lack of potable water, sewage treatment, and electricity; chemical spills; swarms of insects (with anecodotal accounts of vermin and hungry domestic dogs); food contamination; disrupted transportation; mountains of debris; buildings damaged and destroyed; rampant mold growth; tainted fish and shellfish populations; and many potential sources of hazardous waste. Some impacts, such as deaths from drowning and injuries from cleaning up debris, have been relatively easy to determine. Others, such as post-traumatic stress disorder from the loss of homes and loved ones, may never be fully quantified.

In the weeks following the storm, federal agencies such as the NIEHS, the Centers for Disease Control and Prevention (CDC), and the Environmental Protection Agency (EPA), as well as state environmental and public health agencies, sent scientists to the region to begin assessing the environmental and human health impact of the disaster. Much of what they found was presented on October 20 at a meeting of the National Academies Institute of Medicine's Roundtable on Environmental Health Sciences, Research, and Medicine (commonly known as the EHSRT), supported by the NIEHS, the CDC, the EPA, Exxon-Mobile Corporation, the American Chemistry Council, and the Brita Water Research Institute. Still more information continues to emerge today. And much simply remains to be seen.

## Katrina Hits

Katrina, rated as a Category 4 hurricane on the Saffir-Simpson scale, made landfall near New Orleans on 29 August 2005. Wind damage extended as far as 150 miles inland. Heavy rain battered the area, and the storm surge—measuring as high as 30 feet and sweeping several miles inland—breached several levees intended to protect New Orleans from the waters of Lake Pontchartrain. Water poured through the breaks in the days following the storm, covering approximately 80% of the city with water as deep as three meters. The American Red Cross estimates that more than 354,000 homes along the Gulf Coast were destroyed or damaged beyond repair by Katrina and, a month later, Hurricane Rita. Hundreds of small manufacturers or businesses using chemicals or fuels also were impacted.

Flooding, wind, and waves caused major damage to buildings and infrastructure whose integrity is key to the environmental health of the local citizenry. The EPA estimated that more than 200 sewage treatment plants in Louisiana, Mississippi, and Alabama were affected, with almost all the plants around New Orleans knocked out of action. Loss of power meant lift stations (which pump sewage uphill) could not work, causing sewage to overflow into houses and streets.

The region struck by Katrina and Rita is home to a large number of oil refineries and chemical plants. Prior to Katrina, the EPA had identified nearly 400 sites in the affected area as possibly needing cleanup because of their potential impact on human health. Following the storm, the U.S. Coast Guard reported numerous oil spills from refineries and tank farms in South Louisiana. A story in the September 30 *Boston Globe* reported that Katrina damaged 140 oil and gas platforms in the Gulf of Mexico, 43 seriously, including some that floated away or sank.

Across the Gulf Coast, more than 1.5 million people evacuated as the storm approached. More than 100,000 stayed behind in New Orleans, unwilling or unable to leave. As New Orleans flooded, thousands waded through chest-deep floodwaters to reach shelters or higher ground. Thousands more remained trapped in homes, hospitals, and nursing homes. Conditions in shelters rapidly became unsanitary. Many people were exposed to the elements for five days or more, living with little or no food, drinking water, or medicine. As of December 5, the death toll was reported at 1,071 in Louisiana, 228 in Mississippi, 14 in Florida, 2 in Alabama, and 2 in Georgia.

## First Response

Numerous federal, state, and local agencies, as well as private individuals and relief groups, swung into action in the wake of the storm. Troops from the U.S. Army, Coast Guard, and National Guard as well as state and local officials and private citizens rescued those they could. The Federal Emergency Management Agency (FEMA) was assigned the lead in disaster relief planning and administration, including provision of emergency food and shelter and contracting for debris removal. The Department of Health and Human Services (DHHS) declared a public health emergency in the Gulf states and directed the CDC to take appropriate action. The CDC deployed more than 600 professionals into the disaster zone, including specialists in public health nursing, occupational safety and health, laboratory science, medicine, epidemiology, sanitation, environmental health, disease surveillance, public information, and health risk communication.

The CDC also joined with the EPA to set up a joint task force to conduct an environmental health needs and habitability assessment to identify critical public health issues for the reinhabitation of New Orleans. This city was unique among the areas hit in that it was the only one left with standing water. Major urban areas in Mississippi and Alabama, while devastated, did not remain flooded.

In advance of the storm's arrival, the EPA had predeployed teams to the area, with the mission of guiding debris disposal, assisting in the restoration of drinking and wastewater treatment systems, and containing hazardous waste spills. Immediately after the storm, these teams used their 60 watercraft to help search-and-rescue efforts, rescuing about 800 people, according to EPA administrator Stephen Johnson. Five days after the storm, the EPA

**Hazards in wading?** Initial reports labeled the floodwaters through which many New Orleans residents were forced to wade a "toxic gumbo." Later testing of stormwaters found elevated levels of fewer contaminants than feared, but sampling was limited and the water may yet present long-term problems.

Top to bottom: Bill Haber/AP Photos; Chip Hughes/NIEHS

began testing floodwaters in New Orleans for biological and chemical contamination.

In coordination with the Louisiana Department of Environmental Quality (LDEQ), the EPA analyzed floodwaters for more than 100 hazardous pollutants such as volatile and semivolatile organic compounds, metals, pesticides, herbicides, and polychlorinated biphenyls. They also tested for biological agents such as *Escherichia coli*. Their testing revealed "greatly elevated" levels of *E. coli*, as much as ten times higher than EPA's recommended levels for contact. According to the EPA, agency scientists found levels of lead and arsenic at some sites in excess of drinking water standards—a potential threat given the possibility of hand-to-mouth exposure. The EPA posted these and other findings on its Hurricane Response 2005 website (http://www.epa.gov/katrina/), created after the storm.

Shortly after the hurricane struck, the U.S. Coast Guard began working with the EPA, the Louisiana state government, and private industries to identify and recover spilled oil along the coast. The team identified 6 major, 4 medium, and 134 minor spills totaling 8 million gallons. One of the most notorious spills occurred at the Murphy Oil Company plant, which dumped more than 25,000 barrels of oil into the streets of Chalmette and Meraux, Louisiana. As of December 7, the Coast Guard reported the recovery of 3.8 million gallons, with another 1.7 million evaporated, 2.4 million dispersed, and 100,000 onshore.

Meanwhile, the NIEHS was joining with Duke University Medical Center, the NIH, and the CDC to provide assistance with relief and recovery operations along the Gulf Coast, as well as working at home to establish a website on environmental health issues related to Katrina [for more information, see "NIEHS Responds to Katrina," p. A28 this issue].

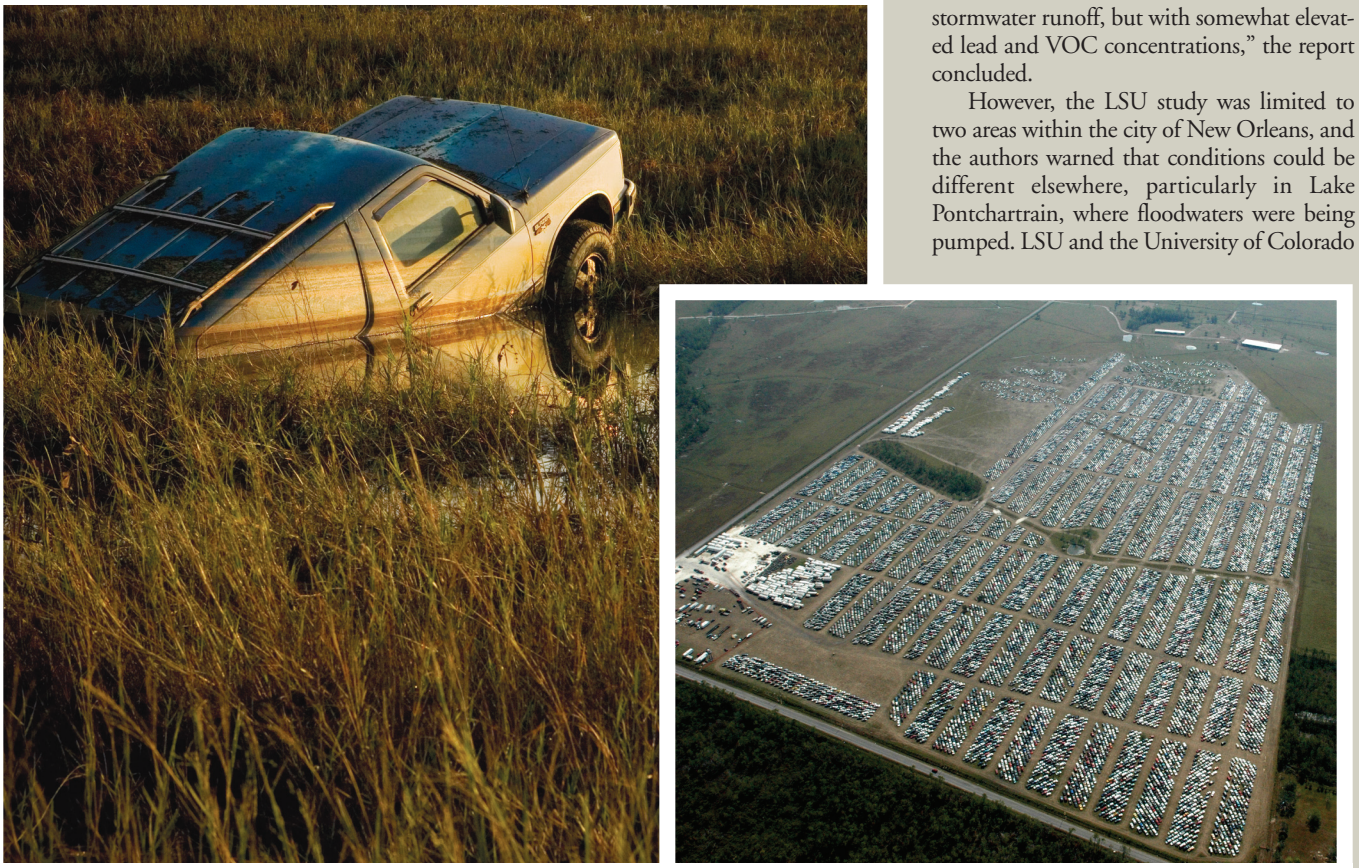
## Floodwater Hazards

Kevin Stephens is director of the New Orleans Department of Health. He was in charge of interpreting the EPA data and advising citizens and responders about the health hazards presented by the floodwaters. "I struggled every day to determine what [the data] meant and what to tell our health workers and the public," he says. "What does 'not an immediate health hazard' mean when you have people wading through the water? What does 'not in excess of drinking water standards' mean? Is it a danger if you get your hands wet and touch your mouth?" Journalists claimed the floodwaters were a "toxic gumbo" of dangerous chemicals and microbes, raising fears that any contact was a health threaten.

These concerns prompted a team of scientists led by John Pardue, director of the Louisiana Water Resources Research Institute at Louisiana State University (LSU), to conduct its own study of the New Orleans floodwaters. The report, published 15 November 2005 in *Environmental Science & Technology*, stated categorically that, contrary to claims in the media, the floodwater was not a "toxic soup."

"Chemical oxygen demand and fecal coliform bacteria were elevated in surface floodwater, but typical of stormwater runoff in the region," the report said. "Lead, arsenic, and in some cases chromium exceeded drinking water standards, but with the exception of some elevated lead concentrations were generally typical of stormwater." The LSU study also found only low concentrations (less than 1%) of benzene, toluene, and ethylbenzene even in places where there was a visible oil sheen. "Collectively, these data indicate that Katrina floodwater is similar to normal stormwater runoff, but with somewhat elevated lead and VOC concentrations," the report concluded.

However, the LSU study was limited to two areas within the city of New Orleans, and the authors warned that conditions could be different elsewhere, particularly in Lake Pontchartrain, where floodwaters were being pumped. LSU and the University of Colorado



**Vehicle slaughter.** Vehicles destroyed in the storm surge of Hurricane Katrina (left) are being stockpiled north of Gulfport, Mississippi (right). The thousands of automobiles are just the tip of the iceberg of waste that communities must deal with as a result of the hurricane.

Left to right: Clayton James Cubitt; Mark Wolfe/FEMA

are currently conducting studies of Lake Pontchartrain looking for a wide range of pathogens. The Colorado team is measuring aerosols created by pumping floodwater into the lake, while the LSU team is analyzing the lake water itself.

## More Water Hazards

Still other threats were posed by water. As of December 9, the EPA reported that 99% of the waste treatment and water supply systems were back online, but some had been out of operation for weeks. At the October 20 EHSRT, Howard Frumkin, director of the National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (NCEH/ATSDR), said that despite the percentage of sewage treatment plants already online at that point, the danger wasn't over. "We have no guarantees that sewage being flushed is getting to treatment plants," he said. "Raw sewage is going into the Mississippi River."

Though most water supply systems may be functioning again, the safety of distribution lines that were flooded can't yet be ensured either. "There are possible changes in pipe ecology due to the intrusion of contaminants," said Frumkin. "And we have additional concerns for homes on wells." Louisiana officials speaking at the roundtable said there are dozens of community water systems and tens of thousands of private wells that need to be tested for contamination.

Standing water poses a different threat, serving as a breeding ground for bacteria and mosquitoes. Even prior to Katrina, Louisiana had the highest number of reported cases of West Nile virus (66) of any state in the union, according to the CDC. West Nile virus can be transmitted to humans via mosquito bites, and the warm, wet weather following the storm was ideal for breeding of mosquitoes. The U.S. Air Force sprayed areas of standing water with pesticides to kill mosquito larvae. The CDC reported on its Update on CDC's Response to Hurricanes website that postspraying surveillance at ten sites found a 91% reduction in total mosquito density compared to prespraying surveillance results [for more information on this website, see the EHPnet article, p. A27 this issue].

The Gulf Coast is also known for the presence of the bacterium *Vibrio vulnificus.* This relative of the pathogen that causes cholera thrives in brackish waters in warmer times of the year. Humans may become infected by eating contaminated seafood or through open wounds exposed to water. While not harmful to individuals in good health, it can be fatal to those with liver damage. Health officials at the roundtable reported counting 22 cases of illness induced by *V. vulnificus* following the storm, including 5 deaths.

In late September, the EPA launched the Ocean Survey Vessel *Bold* to conduct water quality testing in the river channels and nearshore waters of the Mississippi Delta. The agency monitored 20 areas to determine whether fecal pollution from flooded communities had spread into these waters. All 20 monitoring stations showed that, at the time, the water was safe for primary contact, including swimming. The EPA said on its website, however, that the data "should not be used to assess the safety of consuming raw or undercooked molluscan shellfish."

In the wake of the storm, Louisiana, Mississippi, and Alabama closed their shellfishing waters until testing could be done. On December 8, the three states issued a joint press release saying that fish and shellfish samples collected and analyzed since the hurricanes "show no reason for concern about the consumption of Gulf seafood." Louisiana and Alabama subsequently reopened their waters, while Mississippi's oyster reefs remain closed pending additional studies.

**A slicker picker-upper.** Absorbent pads are used to clean up surface oil at the Bass Enterprises South Facility in Cox Bay, Louisiana, where Katrina caused the release of an estimated 3.8 million gallons of oil. Oil spills may have long-lasting effects on water supplies and surrounding ecologies.

Mike Lutz/USCG

## Toxicants in Sediment and Air

Health officials also anticipated a threat from contaminated sediment in the days and weeks following the storm. As floodwaters were pumped out of inundated areas, a dark sludge was found coating buildings, land, and pavement. *E. coli* was detected at elevated levels in many sediment samples taken from around New Orleans, implying the presence of fecal bacteria. The EPA has no standards for determining human health risks from *E. coli* in sediment, but warned people to limit exposure, and if exposed, to wash skin with soap and water.

The EPA was concerned, too, about the region's Superfund sites, which include former dump sites of pesticides and dioxins. The EPA identified 54 Superfund sites in the affected area. Officials worried that at least some of these sites might have been compromised, releasing toxic chemicals into the land or water. Johnson reported at the EHSRT that as of October 20, the EPA had visually inspected all of the sites and sampled many. As of December 5, the EPA's posted test results for these sites indicated that none were compromised in a way that would present a human health hazard.

Elsewhere, as late as November 20, chemical testing of sediment samples in Louisiana's Orleans and St. Bernard Parishes indicated the continued presence of petroleum. However, the EPA's website states that exposures of emergency responders at these levels are not expected to cause adverse health effects as long as the proper personal protective equipment is worn, such as gloves and safety glasses. Volatile and semivolatile organic compounds, pesticides, and metals including aluminum were found, but at levels below what the ATSDR and CDC consider to be immediately hazardous to human health. However, the site continues, "EPA and ATSDR/CDC continue to recommend that residents avoid all contact with sediment deposited by floodwater, where possible, due to potential concerns associated with long-term skin contact."

The Natural Resources Defense Council (NRDC) and a host of local environmental groups paint a darker picture of the contamination situation. In a December 1 press release, the NRDC stated that tests it had conducted revealed "dangerously high levels" of industrial chemicals and heavy metals in the sediment covering much of New Orleans. For example, tests found arsenic levels in some neighborhoods that exceeded EPA safety limits by a factor of 30.

"We found arsenic and other cancer-causing contaminants in sediment all across the entire city," said Monique Hardin, co-director of the New Orleans–based Advocates for Human Rights, at an NRDC

press briefing. "We also found hot spots where there were some nasty surprises, such as banned pesticides." The groups urged the EPA to begin cleaning up or removing contaminated topsoil across the city and to conduct further testing in certain neighborhoods.

The NRDC also challenged the EPA's assertion that the flooded Superfund sites posed no threat. The December 1 press release stated that NRDC's own assessment of one of these sites, the New Orleans Agricultural Street Landfill Superfund Site, showed "visible leachate emerging from the site and spreading across the street and onto a local senior center's property. Sediment testing at this site found contamination as much as 20 times higher than the EPA soil cleanup standards for four [polycyclic aromatic hydrocarbons]."

LDEQ toxicologist Tom Harris responded in press reports that the NRDC's findings were fundamentally flawed because arsenic levels are naturally above the EPA's residential standard in Louisiana and elsewhere. "I have never personally seen soil samples come back below the residential screening level for arsenic," Harris told PlanetArk World Environmental News on December 5. "It's a naturally occurring [element] you can find everywhere." The state of Louisiana and the EPA continue to perform testing of sediment to determine when to give an all-clear to residents with respect to exposure to sediment.

The EPA has also addressed concerns about air quality in the Gulf region. According to Johnson, most of the agency's stationary air quality monitors were knocked out by Katrina. The EPA reinstalled the stationary monitors and employed their Airborne Spectral Photometrics Environmental Collection Technology to undertake airborne monitoring. The EPA also employed two Trace Atmospheric Gas Analyzer buses, self-contained mobile laboratories capable of continuous real-time sampling and analysis.

Air samples were tested for volatile priority pollutants such as benzene, toluene, and xylene, which are commonly found in gasoline, as well as other industrial solvents. The screening results indicated that chemical concentrations in most areas were below the ATSDR health guidelines of concern. The EPA stated on its website, "The low level of volatile pollutants is not surprising as contaminants may be bound in sediment. Monitoring data directly around Murphy Oil spill reveal some slightly elevated levels of benzene and toluene that are associated with petroleum release. Long-term exposure (a year or longer) at the levels measured would be required for health effects to be a concern."

Air may also play a role in an illness known as "shelter cough," or "Katrina cough." Shelter cough is presumed to be an allergic reaction to some particulate matter in the air, according to Stephens. However, despite the presence of shelter cough and earlier concerns about a wave of infectious diseases in the wake of Katrina, acute respiratory illness have made up only 8.7% of diagnoses between August 29 and September 24, according to the October 7 *Morbidity and Mortality Weekly Report*. "We have no evidence of infectious disease outbreaks," Stephens said at the EHSRT.


**Waves of destruction.** (above) A motorcyclist rides past a mountain of trash, wallboard, and furniture removed from homes damaged by Katrina. (inset) Thousands of damaged refrigerators await safe disposal at a landfill near New Orleans. The freon in these appliances will need to be handled carefully.

Left to right: Nati Harnik/AP Photos; Don Ryan/AP Photos

## A Mountain of Debris

The amount of debris generated by Katrina is by all accounts staggering. FEMA estimates there are 39.9 million cubic yards of debris in Mississippi alone. Mark Williams, administrator of solid waste policy, planning, and grants at the Mississippi Department of Environmental Quality (MDEQ), says that state has enough space for the initial removal of debris to staging areas, but not for long-term deposition in landfills.

Jimmy Guidry, medical director of Louisiana's Department of Health and Hospitals, says Louisiana, too, lacks sufficient landfill space for all the debris: "We have more than three hundred thousand refrigerators that need to be disposed of. All these have freon in them." Guidry said at the roundtable that the Louisiana Department of Environmental Quality has approved dozens of temporary debris disposal sites, which will have to be carefully monitored.

Appliances can be recycled for metal content. Televisions and household computers pose a different problem. A single computer monitor contains 4.5 pounds of lead, and computer processing units contain trace metals that can leach out of unlined landfills.

As much as one-third of the debris is vegetative matter that can be burned or chipped for compost. The rest must be recycled or landfilled. Williams says burning of vegetative debris has been allowed in Mississippi for some months and is now largely complete. He adds, "EPA in conjunction with MDEQ has done some monitoring in the area [of controlled burns], which has indicated some elevated levels of formaldehyde and acrolein in certain areas." In the interest of minimizing air pollution, the EPA and MDEQ allowed only clean vegetative debris to be burned and strongly encouraged the use of air curtain destructors and other combustion units in the early stages of cleanup.

Williams says another daunting challenge was disposing of thousand of tons of food—chicken, fish, and beef—rotting in warehouses on the docks. Officials from Mississippi's Natural Resources Conservation Service said more than 6 million dead animals—poultry and livestock—had to be removed from farms

in the affected area. Now officials are dealing with wastes in homes, including such items as propane tanks, household pesticides, and asbestos from roofing, insulation, and other home sources. The waste is taken to staging areas where hazardous waste is pulled out for disposal by the EPA. As of October 31, the EPA had collected an estimated 1 million pounds of household hazardous waste in Louisiana (the agency did not report on collections in other states).

## Injury Protection

One of the major concerns officials have with regard to the handling and disposal of debris is the safety of workers. "We have a large number of workers coming to the Gulf seeking employment, and many of them are not properly trained and protected," says Max Kiefer, assistant director of emergency preparedness and response for the National Institute for Occupational Safety and Health (NIOSH). High-risk occupations include debris removal, levee rebuilding, residential refurbishment, and infrastructure rebuilding.

NIOSH is trying to keep workers apprised of health hazards. "We have assessed exposure to silica and metals during levee rebuilding, debris removal, and tasks involving the sediment," Kiefer said at the roundtable. "We also worried that people were wearing protective gear that may induce heat stress. After assessing certain tasks, we were able to downgrade our gear recommendations in light of that. Psychological stress on responders has been significant. But by far the biggest issue has been injuries—lacerations, falls, and trips." NIOSH is providing guidance for responders and providers on the CDC hurricane response website.

Private citizens also face significant risk of injury during cleanup. Officials talk of a "second wave" of injury following a natural disaster as citizens undertake to remove debris and repair buildings themselves. Will Service, the industrial hygiene coordinator with the North Carolina Office of Public Health Preparedness and Response, worked in a mobile hospital in Waveland, Mississippi, in the days following the storm. "We saw a lot of injuries from things like chain saws used during cleanup," Service says. "People are tired, their thinking isn't clear. They're doing things they don't normally do."

Illnesses and injuries associated with Katrina are being tracked by the CDC, with updates posted regularly on its website. Confirming what public health officials warned about a second wave of injuries, the most common diagnosis (26.2%) in reporting hospitals and clinics from September 8 to October 4 was injury. The major cause of injury was falling, followed closely by vehicle crash–related injuries (likely related to missing or nonfunctioning traffic signs and signals). Cutting and piercing injuries ranked third.

## Coming Home to Hazards

Mold growth in houses damaged by Katrina is of enormous concern to health and housing officials. Estimates of the number of homes suffering water damage range in the hundreds of thousands. Claudette Reichel, an LSU professor of education and housing specialist, says that virtually every home that sustained flood damage will experience mold growth. "Houses that people were not allowed back into for weeks will all have mold, and that mold will have had time to multiply, spread, and get really thick," she says. Says Frumkin, "The magnitude of mold exposure in the Gulf region will in many instances greatly exceed anything we have seen before, adding to the concern and uncertainty regarding health effects."

How or even whether mold causes human health problems is disputed by public health professionals, but most acknowledge a connection. "It is a very difficult science, because there is no clear-cut dose–response threshold," Reichel says. "It is highly dependent upon the type of mold, whether the mold is producing a mycotoxin, the susceptibility of the patient, and the amount of exposure."

The CDC states that people who are sensitive to mold may experience stuffy nose, irritated eyes, or wheezing. People allergic to mold may have difficulty in breathing. People with weak immune systems may develop lung infections.

Health and housing officials advise homeowners and renters to throw out any furnishings, insulation, and bedding that may have

**Opportunistic attacker.** The warm, damp conditions left in homes following Katrina provided the perfect medium for the growth of mold. Because mold can be extremely toxic and hard to eradicate, many homes may not be salvageable.

Left to right: Clayton James Cubitt; Marvin Nauman/FEMA

gotten wet, to clean walls and floors with soap and water, to ventilate, and then to close up and dehumidify the home.

The CDC also reported a spike in post-Katrina carbon monoxide poisoning in the Gulf Coast in the October 7 *Morbidity and Mortality Weekly Report*. From August 29 to September 24, a total of 51 cases of carbon monoxide poisoning, including 5 deaths, were reported in Alabama, Louisiana, and Mississippi. After the hurricanes, many residents used gasoline-powered portable generators to provide electricity to their homes and businesses. These devices produce carbon monoxide, which can build up to fatal levels if run inside a living space or garage.

A number of other health issues loom as residents begin returning to New Orleans, where health care services aren't widely available, sewer and water services are still spotty, and structural inspections aren't complete. Residents have asked city officials for a health assessment to address their concerns about oil spills, mold contamination, and the possible long-term health effects related to mold and chemical exposures. "We are developing an assessment tool for this purpose, and we anticipate that it will be developed for the beginning of [2006]," says Stephens.

Many health care professionals worry that mental health may be the most serious long-term health issue resulting from Katrina. Hundreds of thousands of people across the Gulf region have had their homes destroyed. Thousands are still living in shelters. Many have no jobs, no health insurance, and no job prospects. "We are seeing a lot of symptoms of post-traumatic stress disorder," says Marty Allen, a psychologist with the Mississippi Department of Mental Health. "The trauma was not just the day of the storm. People are still being traumatized by living in tents, not having jobs, and having to walk for miles just to get food and water."

Chuck Burton/AP Photos

**Chemical calamity.** A worker tests hazardous household liquids at the Fort Jackson "orphan" tank and drum staging area in Louisiana.

## Lessons Learned?

What lessons have been learned from Katrina with respect to environmental health? Debate about how to protect Gulf Coast citizens from hurricanes and storm surge was ongoing before the storm and will continue with renewed intensity.

In Mississippi, Governor Haley Barbour enlisted the Chicago-based Congress for New Urbanism to come up with recommendations for rebuilding the Gulf Coast. The Congress sponsored a week-long Mississippi Renewal Forum in October attended by some of the nation's leading architects, engineers, and urban planners. Working with local leaders, the teams produced reports for 11 coastal towns impacted by the storm. Recommendations include improving the connectivity between towns by moving the CSX freight line north and transforming the abandoned right-of-way into a boulevard for cars and transit, connecting the Gulf region towns with high-speed rail, realigning and revising U.S. 90 to become a pedestrian-friendly "beach boulevard," and creating a Gulf Coast bikeway.

A similar process is under way in Louisiana under the auspices of the Louisiana Recovery Authority created by Governor Kathleen Blanco. The authority is developing short-, medium-, and long-range plans to guide the rebuilding of Louisiana in the wake of the hurricanes. At the authority's request, the American Association of Architects, in collaboration with the American Planning Association, presented the Louisiana Recovery and Rebuilding Conference on November 10–12. The authority has developed a 100-day plan that includes completion of an environmental evaluation of damages caused by the hurricanes and development of recommendations for how to proceed with reconstruction.

Discussion will center on how to protect New Orleans from further flooding and whether certain low-lying parts of the city should even be reoccupied. Such decisions will be made in the months and years to come. Meanwhile, environmental and public health officials have drawn some conclusions about how to better respond to events like Katrina.

Officials at the EHSRT agreed that communication in advance and in the wake of natural and man-made disasters is key. Fears and rumors of disease ran rampant in the days following Katrina. Citizens, the media, and even public health officials did not know which factors presented a genuine health threat and which did not. Federal agencies conducted testing and provided data, but people often did not know how to interpret those data with respect to the kinds of exposures they were encountering.

"The public health community must be actively involved and articulate key health issues," said Kellogg Schwab, an assistant professor at Johns Hopkins Bloomberg School of Public Health. "We must keep the message simple and focused. We must develop effective strategies to provide targeted timely results. We must provide concise and accurate public health information and advice."

Officials also agreed that responders must be properly trained and deployed, provided with proper protective gear and an effective communications system (land lines and cell phones were inoperative in much of the area for weeks after Katrina). Health officials must be able to assess the particular kinds of exposures that people have been subjected to and respond accordingly.

"Your response strategy for exposure varies with each event," said Paul Lioy, deputy director of the Environmental and Occupational Health Sciences Institute at Rutgers University. "The World Trade Center [collapse] was an instantaneous acute air exposure event like we'd never experienced. Katrina for the most part involved an acute water exposure event, but the exposure was over a longer period of time."

Lioy pointed out the need for a national review of the kind of standards and guidelines necessary to ensure that the correct information is given out to the public about immediate hazards versus long-term exposures and risks. "Comparison to general drinking water or ambient air quality standards are not sufficient for guiding the public or public officials during an acute exposure event," he said.

Most of all, roundtable participants agreed, Katrina represents a chance for officials across all levels of government to do things better—evacuation planning, urban design, communication, environmental monitoring, and involvement of citizenry, particularly minority and low-income residents. John McLachlan, director of the Tulane/Xavier Center for Bioenvironmental Research, said that preparing for disasters like Katrina requires the involvement of virtually every academic discipline. To that end, Tulane and Xavier are creating a Katrina Environmental Research and Restoration Network (KERRN) of researchers who share data and ideas across disciplinary, geographical, and institutional lines. Paraphrasing one of his colleagues, McLachlan stated, "This is the mother of all multidisciplinary problems."

**John Manuel**

# Louisiana's
## A Lesson in Nature Appreciation

Hurricane Katrina's disastrous flooding of the Gulf Coast confirmed three decades of warnings by scientists. Most of New Orleans is below sea level, and South Louisiana's coastal wetlands, which once helped buffer the city from giant storms, have been disappearing at a spectacularly swift pace. Now some researchers are calling for restoration of wetlands and barrier islands to help protect New Orleans the next time a hurricane strikes.

An average of 34 square miles of South Louisiana land, mostly marsh, has disappeared each year for the past five decades, according to the U.S. Geological Survey (USGS). As much as 80% of the nation's coastal wetland loss in this time occurred in Louisiana. From 1932 to 2000, the state lost 1,900 square miles of land to the Gulf of Mexico.

By 2050, if nothing is done to stop this process, the state could lose another 700 square miles, and one-third of 1930s coastal Louisiana will have vanished. Importantly, New Orleans and surrounding areas will become ever more vulnerable to future storms. "New Orleans can't be restored unless we also address coastal and wetland restoration too," says Craig E. Colten, a geographer at Louisiana State University (LSU).

### A River and a City

The vast watershed of the Mississippi River ranges from Montana in the west to New York

# Wetlands

Bill Haber/AP Photo

state in the east. Spring rains send sediment-rich runoff into the river and its tributaries. For thousands of years, the Big Muddy has flowed down to the Gulf of Mexico, where great floods periodically burst over the riverbanks, allowing huge quantities of silt to settle and nourish wetlands. The land naturally sinks, or subsides, as loose sediments from the Mississippi River settle and compact.

The river slows as it reaches the gulf because of the tides pushing upstream; as it slows down, it spreads out and delivers much of its sediment load into deltaic deposits. The Mississippi Delta was fed by these influxes of mud, creating 5 million acres of South Louisiana before the twentieth century. Every millennium or so, the Mississippi River would change direction at its gulf outlet, meandering from east to west and back again. As a result, the river created six different delta "lobes" on which the entire coastline of South Louisiana was formed.

In 1718, French settlers founded New Orleans on a natural ridge of high land on a bend of the Mississippi River, with Lake Pontchartrain (which is actually an inlet of the Gulf of Mexico) to the north and coastal wetlands to the east, west, and south. But flooding was a problem. By 1812, the settlers had built levees on the east bank to Baton Rouge, 130 miles upstream, and on the west bank as far as Pointe Coupée, 165 miles upstream.

Over the next two centuries, the city drained surrounding wetlands to prevent disease and encourage development. The city eliminated swamps following mosquito-borne yellow fever epidemics that killed 40,000 residents between 1817 and 1905. As the city grew, the only lands available for development were low-lying areas north toward Lake Pontchartrain. At the turn of the twentieth century, the city created an integrated public works department, which was responsible for draining the wetlands.

"It was the draining of the lower areas that allowed suburbanization to occur," says Colten. But the lowlands, originally just inches above sea level, steadily sank. "When you drain these areas, you suck the water out of the peaty soils, which begin to compress, or subside," he says. "That's why these areas have continued to subside."

New Orleans also continually built higher and stronger levees to contain river flooding. In 1928, Congress authorized major levee improvements, and the U.S. Army Corps of Engineers began shoring up the flood control system, including levees, along the entire lower Mississippi and in New Orleans. By the 1950s, LSU geology professor James P. Morgan had begun to document dramatic rates of land loss in Louisiana's coastal zone, which stretches 300 miles from the Texas border to the Mississippi state line and 50 miles inland.

## The River Today

Today, South Louisiana is one of most intensively engineered places in the nation. Vast quantities of water are diverted or rerouted through a lacework of navigation corridors held in place by 2,000 miles of earthen, rock, and concrete levees. Walled off from the floodplains, the river can no longer provide enough silt to the delta to keep up with natural subsidence and sea level rise. About two-dozen dams also hold sediment back from the river and its tributaries. "We have tamed the river for the almost exclusive benefit of navigation," says David R. Conrad, a senior water resources specialist with the National Wildlife Federation.

The construction of high levees did end the spring floods along the lower Mississippi, but at an environmental cost, eventually eliminating many of the wetlands, floodplains, and barrier islands of the delta. "When you lose wetlands and floodplains, you lose their natural services including storage capacity during floods, and when you lose coastal wetlands, you lose wave and storm protections," says Sandra Postel, director of the Global Water Policy Project, a nonprofit organization based in Amherst, Massachusetts. "Katrina in South Louisiana was an example of what happens when you disturb the natural infrastructure."

In November 2005, the National Academies released a report, *Drawing Louisiana's New Map: Addressing Land Loss in Coastal Louisiana*. The report notes that building and maintaining levees and dams along the Mississippi River was a "more or less ubiquitous" cause of wetland loss. Another geographically widespread cause was voracious grazing by nutria, a nonnative species, which destroyed wetland vegetation.

But the report also points out that there were other causes "superimposed on these broad influences," particularly including activities by the oil and gas industry. Peaking during the 1960s through the 1980s, oil and gas companies dredged canals for exploration. There are currently 10 major navigation canals and 9,300 miles of pipelines in coastal Louisiana serving about 50,000 oil and gas production facilities. These canals, which are perpendicular to the coast, have created new open water areas, drowning wetlands and allowing saltwater intrusion into freshwater ecosystems. The result—land loss hot spots. "There is also evidence," the report says, "that extraction of large volumes of oil and gas has exacerbated the problems of inundation and saltwater intrusion"—that is, withdrawing oil and gas along geologic faults seems to exacerbate subsidence in coastal Louisiana.

The Mississippi Delta is also home to South Louisiana's port complex, which lines both banks of the Mississippi River for 172 miles as well as points offshore, including the Port of New Orleans, the Port of South Louisiana, the Port of Baton Rouge, and the Louisiana Offshore Oil Port in the Gulf. Because of its size and location, adjacent to oil and gas refineries and drilling platforms, this port complex is one the most important in the United States. Louisiana's coastline produces one-fifth of the country's oil and one-quarter of its natural gas. Through South Louisiana's ports the bulk commodities of U.S. agriculture—corn, wheat, and soybeans—are sent around the world, and the bulk commodities needed for American industry—steel and concrete, for instance—come into the country.

The Mississippi River Gulf Outlet, a little-used 40-year-old shipping channel connecting the Gulf of Mexico to the Mississippi River, is believed to have served as a funnel for Katrina's storm surge. The navigation channel and the eastern levee of the Mississippi River seem to have directed high water into the Breton Sound estuary southeast of New Orleans, according to Greg Steyer, a USGS wetland scientist. From there, the surge poured into Lake Pontchartrain and an industrial canal, where it overwhelmed levees, contributing to flooding in St. Bernard Parish and the Lower Ninth Ward of New Orleans. Like the oil and gas canals, the outlet also allows saltwater intrusion and tidal action into freshwater ecosystems, killing vegetation and turning the marsh into a stretch of open muddy water.

The Gulf of Mexico is also subject to the general sea level rise being observed worldwide, with potential ramifications for the Gulf Coast. Over the past century, the warming climate has pushed up mean sea level four to eight inches worldwide, and computer models suggest that this rise will probably accelerate, according to a 2001 report of the U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*. By 2100, global sea level is projected to rise an additional 19 inches along most of the U.S. coastline.

## Death of the Wetlands

This combination of factors has killed wetlands in South Louisiana from the inside out. "Some of the inner marshes have actually eroded faster than some of the extreme coastal areas," says Gary Fine, manager of the Natural Resources Conservation Service's Golden Meadow Plant Materials Center in Galliano, Louisiana. In the delta, sediment deposits from tidal creeks and rivers build up the banks, creating modest natural ridges. Land elevations fall toward the center of coastal marshes, freshwater swamps, and bald cypress forests. Starved of new sediments and flooded by tides, the inner areas become constantly submerged. "Especially in the salt marshes," Fine explains, "the plants start dying in the center due to rising water and decreasing sediments, and then the loss expands outward to the edges." As a result, South Louisiana has become a patchwork of open water and remnant wetlands.

"By 2050, the city will be closer to and more exposed to the Gulf of Mexico," noted authors of a restoration proposal, *Coast 2050: Toward a Sustainable Coastal Louisiana*. Hurricane Katrina itself pushed the city closer to the coast. The hurricane, making landfall in lower Plaquemines Parish, had a storm surge of almost 30 feet, which caused extensive erosion at the coastal edge. For example, Katrina almost wiped out the Chandeleur Islands, a 40-mile-long series of uninhabited barrier islands southeast of New Orleans. "The sand and marsh are gone," says Asbury Sallenger, an oceanographer with the USGS Center for Coastal and Watershed Studies in St. Petersburg, Florida. "Before Katrina,

the islands were five meters high; now there's a less than half a meter left."

Gregory W. Stone, a coastal geologist at LSU, says that if the current trend of wetland loss and barrier island erosion continues, it will worsen the effects of future hurricane surges in South Louisiana. "Storm surge and storm waves will increase if we lose more wetlands and our barrier coast," he says. "Wetlands and barrier islands are the first line of defense. That means areas such as New Orleans would become more vulnerable to inundation."

Further land loss would also endanger oil and gas facilities, the huge port complex, and the gulf's valuable fishing industry. South Louisiana's wetlands are critical nursery areas for commercially important marine species, including shrimp, blue crabs, oysters, redfish, and menhaden. Land loss in South Louisiana, says Stone, "is not a local problem—it's a national problem."

## Restoration Plans

In an effort to rebuild the state's natural infrastructure, Congress passed the 1990 Coastal Wetlands Planning, Protection, and Restoration Act, sponsored by Senator John Breaux (D–LA). The Breaux Act provides about $50 million each year for wetlands restoration projects in Louisiana. The Breaux Act has provided funding for 118 restoration projects, and 75 projects have already been built. But most of these projects are relatively small in scale.

In 1996, the state of Louisiana and a group of federal agencies joined with parish officials and the public to create a consensus document. The result, after 65 public meetings over 18 months, was *Coast 2050*, which outlined strategies and measures needed to restore the state's wetlands and barrier islands.

*Coast 2050* proposed that the Mississippi River be re-engineered to imitate natural processes. That is, some portion of the river's flow should be re-diverted via pipelines or canals to flush into the delta so that South Louisiana's sinking ecosystems could be built up. "*Coast 2050* essentially calls for putting holes in the straitjacketed Mississippi River," says Conrad. "This process could be one of the most interesting and expensive and important environmental engineering processes ever. It is a huge opportunity to put things back together if we have the will."

These water diversions would feed freshwater marshes and control saltwater intrusion from being pushed upriver by the rising sea level. The Caernarvon Freshwater Diversion Project, funded in the mid-1980s, could be one model for this approach. The diversion consists of a $26-million opening in the river levee built by the Army Corps about 24 miles south of New Orleans. A concrete culvert diverts water into a canal that feeds marshes behind Breton Sound, which had been losing land. This diversion has been shown to increase marsh and freshwater plant acreage.

*Coast 2050* also recommended that federal agencies dredge soils and ancient sandbars to create new marshlands; plug up the Mississippi River Gulf Outlet; and shore up barrier islands that are the first line of defense against approaching hurricanes. However, the cost cited in the report for all these projects seemed too huge to consider: $14 billion (by comparison, estimates for rebuilding after the 2005 hurricane season have been placed as high as $200 billion).

Kerry St. Pé, director of the Barataria-Terrebonne National Estuary Program, says there's no time to waste. Freshwater diversions alone are not enough to solve the land loss problem, he adds. Dredge material should be pumped immediately via pipes from navigation channels in the delta, including the Mississippi River, to shore up hot spots of wetland loss. "We need the sediment now," he says. The Corps of Engineers already dredges 40–45 million cubic yards of sediment from the delta's numerous navigation channels each year, he says, and the material is discharged off the end of the continental shelf because that's the least expensive method of disposal. "We could use that sediment to build wetlands," says St. Pé.

From 2000 through 2003, the Corps of Engineers and the state of Louisiana collaborated on a feasibility study for a $17-billion coastal restoration plan lasting 30 years. Yet this study, based on *Coast 2050*, also seemed far too expensive at the time. "It never went up to Congress because it exceeded what potentially could be funded," says Steyer. "We were asked to focus it on more of the near term, over ten years, addressing what are the critical projects that could be done."

In November 2004, state and federal agencies proposed a near-term effort, the Louisiana Coastal Area Ecosystem Restoration Study. The findings from this study led to the 2005 Water Resources Development Act, which calls for Congress to spend $1.9 billion over 10 years on restoration efforts in the delta; the bill is still being worked out in Congress. The act—intended to be a first, smaller step toward a 30-year $17-billion plan—follows the strategies of *Coast 2050*, says Steyer.

However, Oliver Houck, who directs the environment program at Tulane University Law School, says that nothing less than letting the river go its own way will solve the land loss problem. "*Coast 2050* is history," he says. "Katrina upped the ante so much. What has to be done now is to let the Mississippi River take its natural course and allow the full bed load of the river to rebuild the marsh." He adds, "The problem with *Coast 2050* and other restoration plans is that they fail to halt wetland destruction in the same areas they are trying to restore. New canals, deeper canals, expanded ports are all on the table. No way that works."

Indeed, if water control projects were destroyed and the Mississippi were allowed to take its natural course, it would inevitably become captured by the Atchafalaya River, which empties off the south-central coast of Louisiana. The combined flow and increased sediment load would help build up the most land-starved region of Louisiana's coast. But if the Mississippi River were set free, one of today's most important shipping channels would become water-starved from Baton Rouge to the gulf outlet.

So how would giant oceangoing ships reach the ports of South Louisiana? Houck recommends cutting an entirely new shipping channel from the gulf to the port complex of South Louisiana. Where would this channel be located? "That's up to the engineers," Houck says.

## A Muddy Future

No matter how it's done, there is a new urgency to address the land loss problem. Senator Mary Landrieu (D–LA) has proposed a Hurricane Katrina Disaster Relief and Economic Recovery Act, cosponsored by Senator David Vitter (R–LA). This proposal would provide $250 billion for hurricane reconstruction, including $40 billion in ecosystem restoration and levee improvements. Some feel, though, that this proposal actually hurt Louisiana's chances for restoration monies by appearing to reach for too much to fund a grab bag of projects. "Major restoration funding remains in doubt," says Houck, "as indeed does the mega-question: how to restore." At press time the bill had not made any progress.

It has taken a major hurricane to show the nation that it's necessary to rebuild the wetlands and barrier islands of Louisiana. Although stakeholders have generally agreed on a plan to rehabilitate these resources, major funding has not been available. To restore New Orleans to health after Hurricane Katrina, though, it seems clear that the nation must find a way to fund the largest ecological rehabilitation project in U.S. history, a comprehensive effort to rebuild South Louisiana's disappearing landscape.

**John Tibbetts**

Oosterschelde storm surge barrier

# Raising the Bar for Levees

Human beings have likely been battling rising waters since the dawn of organized agriculture. Farmers around the world have traditionally been drawn to the rich soils of floodplains, which are generally well worth the trouble occasionally caused by surrounding waterways. Densely populated urban areas subsequently grew up around many of these same places, attracted by additional assets such as access to fishing and easy navigation. These settlements often require substantial and ongoing engineering efforts to secure the physical safety of the community. While the fundamental principles and challenges of holding back water have not changed, the tools we can bring to the task continue to become more sophisticated.

As events in the Gulf Coast recently demonstrated, efforts to hold back the sea are sometimes doomed to failure. Engineers are debating how and even whether the levee system around the New Orleans area should be rebuilt. But the options today are much greater than when the Mississippi River levees were first built.

Levees built today may look the same as they always have but can incorporate design, construction, and maintenance

Micha Fleuren/iStockphoto

innovations that are finding their way into civil engineering. Some of these features smack of high technology, such as elaborate sensors to detect stresses and strains within the structure, so as to provide a warning of critical pressures that could signal serious damage or collapse. Similarly, impermeable lining materials known as geomembranes can be laid down underneath the structure before it is built, so that the seepage of water through the ground cannot erode foundations.

Above all, engineers continue to improve their understanding of water flows, taking advantage of ever more detailed computer modeling techniques to describe the implications of barrier design to experts in the field, political or legal authorities who may be responsible for those barriers, and members of the public.

**Hope for renewal.** Use of innovative construction and maintenance technologies may allow engineers to rebuild the New Orleans levee system (shown here flooding the Ninth Ward on 30 August 2005) stronger than before.

## Lessons from the Dutch

Perhaps no country has a more vested interest in levee safety than the Netherlands, which has occasionally paid a high price for sustaining major population centers well below the level of the stormy North Sea. In the winter of 1953, the sea breached a system of dikes that had been in place since the Middle Ages, causing floods that killed nearly 2,000 people. This catastrophe galvanized the nation's political and social commitment to mounting and maintaining a sophisticated system of barriers that has set the standard for the rest of the world.

From the 1950s to the 1980s, major dams were constructed to hem in hundreds of miles of the country's vulnerable coastline, knit together with earthen embankments and massive sluice gates over the delta stretching across the mouths of the Rhine, Maas, Waal, and Schelde Rivers, which all drain into the North Sea. The scale of this project—dubbed the Delta Works—is highlighted by the Oosterschelde storm surge barrier, which was completed in 1986. Designed to protect the ecological integrity of the surrounding estuary, the structure features 62 openings for tides to flow back and forth.

Engineers had never before attempted to erect sea defenses on this scale, and the Dutch became pioneers in the field. The five-mile-wide opening at the Oosterschelde, for example, called for 65 separate concrete piers more than 100 feet in height, which were built in place to an accuracy on the order of a few inches. Such precision was ensured by setting them on gigantic steel mesh "mattresses" filled with sand and gravel, which would prevent erosion that could shift the piers out of position.

In 1997 an even more ambitious undertaking was completed in the country's southwest, where the Maeslant flood barrier includes two hollow arched doors, each about 1,000 feet long and 70 feet high, which float in side channels when not in use. They are rotated into their protective posture by steel ball joints 35 feet in diameter. Once the gates meet in the middle, they fill with water and sink onto a concrete pad, effectively blocking any storm surge.

These engineering marvels are based on earlier measurements of river floods and storm surges, baseline data that go back only to the early twentieth century. "That's all [the data] we have to extrapolate to a situation of one in ten thousand years," says flood management engineer Jos Dijkman, referring to the need to design infrastructure to cope with millennial-scale events such as the most extreme flooding. "Such an extrapolation is by definition uncertain, and you can go into all sorts of statistical methods and techniques to fine-tune that prediction." Dijkman works for Delft Hydraulics, a Dutch company that has positioned itself as a leader in water management strategies.

## Ground Control

Dijkman says the country's engineering community has been moving away from a dependence on solid, immutable defenses. Designers have increasingly been looking to the natural landscape to mitigate the impact of flooding on developed areas, freeing up regions such as marshlands to take on excess water temporarily and so lessen a tendency to continue raising the height of levees as an exclusive means of enhancing protection. An example of this policy goes by the name "Room for the Rhine," which combines engineering principles with research into the factors affecting the health of floodplains, such as the relationship between vegetation and water quality. In places where the setting back of a dike has not been possible, the Dutch also reserve "green" rivers, areas between dikes where water flows only during floods.

"For the old-fashioned way of building a gigantic floodway, you don't necessarily have to know the [wetlands] system in all the details" says Dijkman. "If you want to develop a wetland that will absorb the energy of flood surge, you'd better know in detail what the processes are that drive the formation of these wetlands."

Following the devastating flood of 1953, Dutch engineers also began to develop a new generation of tough, synthetic textiles that could be used to anchor earthen levees from below, preventing movement of the soil and even the penetration of water. A domestic manufacturer, Nicolon BV, emerged as one of the leaders in this field, eventually setting up an American operation in Georgia to serve the U.S. market. In 1991, Nicolon joined forces with North Carolina–based Mirafi, which had been experimenting with even more sophisticated geosynthetic fabrics since the late 1960s.

This technology was used to refurbish and upgrade parts of the New Orleans levee system as recently as the summer of 2005. On that occasion, the U.S. Army Corps of Engineers used a 900-foot section to compare the effectiveness of three Mirafi products—an impermeable geosynthetic textile and two types of a more loosely woven material known as geogrid. Strain-monitoring

Jocelyn Augustino/FEMA

gauges were installed as part of this work. Although the geogrids lent slightly greater stability to the soil, the geotextiles perfomed nearly as well and saved nearly $340,000 (46%) over the cost of the geogrid.

### Feedback from Fiber Optics

Sheer physical mass will never be sufficient to protect against waters that would flood. Aftab Mufti, president of the Intelligent Sensing for Innovative Structures (ISIS) Canada Research Network, compares the situation of today's levee builders with one faced by a previous generation of aircraft designers. Prior to World War II, planes were built and flown without much attention to the specifics of performance, so that revisions to details such as wing span or tail height were being carried out constantly, based on in-service flight reports. But the push for high-performance military aircraft accelerated the emergence of a design philosophy that was premised primarily on theory and modeling, rather than simply building something and seeing if it would fly.

Today's aerospace engineers would be loathe to put something in the air that had not been modeled extensively on computers and in wind tunnels, using flight data obtained using avionics, so that the final working product differs little from the prototype. Mufti regards civil engineers as being ready to make the same leap in their field, after many generations of building structures that are far less modeled and monitored than they could be. He says the civil engineering discipline will have to develop "civionics" as the aerospace engineering has developed avionics to be able to monitor the health of civil engineering structures.

More specifically, Mufti endorses the use of electronic and fiber-optic sensors to assess changes in the geometry and forces within a built structure, such as a bridge, a dam, or a levee. These sensors can take advantage of time domain reflectometry (TDR), in which light signals sent through a fiber-optic cable (set, for example, into the soil of an embankment) with any interruption reflect movement that can be readily located. Over time, Mufti says, these readings can provide invaluable insight into how well a structure is holding up.

"What you get out of this is data which you can use to improve your designs in the future," he says, adding that these data can likewise be applied to future construction regulations. "Our codes at the moment are approximate, therefore conservative. We work in the laboratory and do the testing and monitoring of the structures and materials in the laboratory. Now what we're finding is that structures and materials behave and age in real life quite differently than what we are seeing in the laboratory."

Among the leading firms collecting such TDR data is Kane GeoTech, based in Stockton, California, which has carried out much of its work on the levee systems in the floodplain around Sacramento. The most likely model for use in New Orleans is a system deployed since 2002 by Kane GeoTech to measure pore pressures and seepage beneath a levee in the Sacramento River Delta. Vibrating wire piezometers measure water levels in the adjoining river, as well as pressures underneath the levee structure, correcting the latter against parallel measurements of barometric pressure above. These data are collected every hour, and can be downloaded by an inspector to a handheld computer from onsite monitoring stations.

Kane GeoTech has also installed a slightly more sophisticated system for railroad tracks that run along coastal cliffs for trains operated by the North County Transit District in San Diego. Here pulses are sent along cables every four minutes, and any spikes in the signal that would indicate ground movement are sent to a central office, which can immediately dispatch personnel to check out the situation.

Kane GeoTech representatives have suggested that similar TDR sensor cables could be installed in damaged New Orleans levees as they are being rebuilt, thereby minimizing the cost of introducing a similar monitoring system to this area. Given the communications technology that is now available, this instrumentation could well include modems that would transmit the resulting data over the Internet.

### Innovation of Another Sort

One thing that's certain is that Hurricane Katrina exposed the limitations of the traditional approach to levee building, as was obvious to a national panel of experts investigating firsthand how the storm surge after the hurricane caused the New Orleans structures to fail. The panel noted several instances where simple improvements could be made. For instance, a great deal of damage occurred when water overtopping the levees created waterfalls that tumbled over the normally dry sides of these structures. These steady cascades created "scour holes" that weakened levee foundations. This problem could be mitigated by placing concrete protective aprons at points where such waterfalls could occur.

Panelist Tom Zimmie, acting chairman of the civil and environmental engineering department of Rensselaer Polytechnic Institute, acknowledges that solutions to these problems may prove to be more expensive than even the most ambitious rebuilding effort will accommodate. But he argues that the scale of the project would make even the most modest improvements well worthwhile. "You're talking about millions and millions of cubic yards of dirt," he says. "There's three hundred fifty miles of levees; a lot of them have to be patched up. A small innovation, a small saving, is a big deal."

Dijkman notes, however, that building and monitoring infrastructure is not sufficient to fully protect against flooding. "A legal framework that requires regular reporting to the government about both the quality of the infrastructure and possible changes in storm conditions ensures that politicians are informed about any deficiencies," he says. "They can then use that information to appropriate funds to help the flood defenses meet their original objectives."

Dutch law not only specifies protection levels for flood-prone areas, but also requires levee managers to inspect their levees every five years, taking into account updated storm conditions. Dijkman suggests, "It could be worth considering such legislation in the United States. This could avoid any gap between the information available in the engineering and science community and the political arena."

**Tim Lougheed**

## Suggested Reading


[No author.] 2005. Case study: levee project comparison of geogrid and geosynthetic products. Available: http://www.mirafi.com/mirafactssummer2005/levee.htm.

Mileti DS. 1999. Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington, DC: Joseph Henry Press.

Rogers JD. Should I trust that levee? Available: http://web.umr.edu/~rogersda/flood_hazards/.

Silva W, Klijn F, Dijkman J. 2001. Room for the Rhine Branches in The Netherlands: What the Research Has Taught Us. Lelystad, Netherlands: Institute for Inland Water Management and Waste Water Treatment; Delft: Delft Hydraulics.

Smits AJM, Nienhuis PH, Leuven RSEW, eds. 2000. New Approaches to River Management. Leiden, Netherlands: Backhuys Publishers.

# Beach Bug Bingo

## Toward Better Prediction of Swimming-Related Health Effects

Swimming is a popular pastime in the United States. The 2000–2002 National Survey on Recreation and the Environment reported that each year an estimated 89 million Americans swim in recreational waters including lakes, oceans, streams, rivers, and ponds. But swimming waters may also be contaminated by human sewage from treatment plants and runoff, raising the risk of gastrointestinal (GI) illness in swimmers. The recommended test for measuring contamination requires culturing fecal indicator bacteria, which means that beach managers must wait 24 hours for results. This built-in delay is problematic, potentially exposing swimmers to unhealthy water quality and sometimes resulting in unnecessary beach closures. Now a team of federal researchers has shown that a rapid method for measuring water quality can accurately predict swimming-related health effects [***EHP* 114:24–28**].

The researchers conducted health surveys of beachgoers at two public beaches, one on Lake Michigan and one on Lake Erie, and compared them with thrice-daily water quality measurements along transects at the beaches. They evaluated water quality using a modified version of the polymerase chain reaction method (QPCR) to quantify indicator bacteria in water samples. The advantage of this method is that it can provide results in two hours or less. The researchers chose *Enterococci* and *Bacteroides* as their indicator organisms.


**Wave of the future?** If validated, a modified polymerase chain reaction method may become useful for earlier identification of hazardous beach water conditions.

Survey participants were interviewed as they left the beach; follow-up interviews were conducted by telephone 10 to 12 days after the beach visit. When researchers compared results of the water quality tests to participant reports of GI and other illnesses, they found a significant trend between increased reports of GI illnesses and *Enterococci* at the Lake Michigan beach and a positive, though statistically insignificant, trend for *Enterococci* at the Lake Erie beach. *Bacteroides* did not prove to be as powerful in predicting illness, with an insignificant positive trend found only at the Lake Erie beach and no trend at the Lake Michigan beach.

When results from the two beaches were combined, the trend for *Enterococci* and GI illness remained statistically significant, a finding that held true even when samples collected at 8:00 a.m. were compared to daily averages. Beach managers could thus test early-morning samples to assess water quality and, if necessary, close beaches before the majority of swimmers were exposed.

In spite of the promising nature of the findings, the authors caution that much research remains to be done before the results can be generalized. One of the key remaining questions relates to the method itself: QPCR relies solely on the presence of DNA to quantify organisms, so pathogens are detected even if they are dead and thus harmless. QPCR may therefore suggest a problem with the water when in fact there is none. The authors say additional studies should help determine if the approach is robust enough to be used in water quality regulations. **–Nancy Bazilchuk**

# Exploring the Roots of Diabetes

## Bisphenol A May Promote Insulin Resistance

Poor diet and lack of exercise are known contributors to the epidemic of type 2 diabetes spreading around the world. Now researchers have implicated another possible culprit in the rise of the disease [***EHP* 114:106–112**]. A team of Spanish and Mexican researchers reports discovering that the endocrine-disrupting chemical bisphenol A (BPA) causes insulin resistance in mice similar to that seen just before the onset of type 2 diabetes.

Type 2 diabetes occurs when insulin receptors throughout the body fail; this is known as insulin resistance. Complications of diabetes include heart disease, kidney failure, blindness, and nerve damage. The World Health Organization estimates that at least 154 million people around the world have type 2 diabetes, and predicts that number will more than double within 25 years.

Endocrine disruptors mimic the natural sex hormone 17β-estradiol ($E_2$), which is involved in the development of sexual traits. Scientists have known for years that BPA and other endocrine disruptors can diminish sperm production, accelerate the onset of puberty, and damage sexual organs. But they had not studied a link between the chemicals and glucose metabolism, even though increases in $E_2$ are known to cause insulin resistance.

The researchers chose to study BPA because its use is so widespread. Since the 1950s, it has been used in plastics for water bottles and jugs, baby bottles, toys, and the linings of food and beverage cans. People ingest BPA that leaches from containers into foods and

Jeremiah Deasey/iStockphoto

drinks. Studies in the United States showed that BPA appeared in the blood and urine of 95% of people tested.

The researchers tested BPA's effect on glucose regulation by measuring glucose and insulin levels in adult male mice treated with BPA injections, then comparing them with levels in mice treated with $E_2$ and a control group treated with corn oil. BPA caused oversecretion of insulin in mice at a dose of 10 micrograms per kilogram body weight per day (μg/kg/day) via a rapid mechanism, taking only 15 to 30 minutes. Treatment over a course of four days with 100 μg/kg/day induced the insulin resistance that precedes type 2 diabetes. $E_2$ had the same effects at the same doses. Glucose metabolism remained stable in the control rats.

These results are novel because the mechanism reported is the lesser known of the two major pathways used by estrogens and other steroids. It involves signaling rapidly initiated from the plasma membrane rather than the nuclear transcription pathway depicted in most textbooks.

The BPA dose high enough to cause insulin resistance in mice was in the same range as the 50 μg/kg/day reference dose established by the U.S. Environmental Protection Agency, which is based on a lowest-observed-adverse-effect level of 50 milligrams per kilogram per day. The researchers see the newly discovered link between BPA and insulin resistance as one more reason the agency should at least consider lowering the lowest-observed-adverse-effect level. They further suspect that because other endocrine disruptors mimic $E_2$, they too may hinder glucose metabolism. **–Cynthia Washam**

**Refreshing news.** Although some questions remain, a new data analysis fails to confirm fears that fluoridation of drinking water results in higher blood lead along with stronger teeth.

# Hypothesis Decay?

## Blood Lead–Fluoridation Link Not Confirmed

Numerous studies of various populations have shown that adding fluoride to drinking water prevents dental decay. However, a 1999 study in Massachusetts and a 2000 study in New York reported associations between the use of silicofluoride compounds in community water systems and elevated blood lead (PbB) concentrations in children. Now a team of researchers has tested the hypothesis generated by the Massachusetts and New York studies against findings from two other studies and found no cause for concern [***EHP* 114:130–134**].

As of 2000, the Centers for Disease Control and Prevention estimated that more than 162 million Americans were receiving fluoridated water. In the United States, several agents are used for fluoridation, including silicofluoride compounds (sodium silicofluoride and hydrofluosilicic acid) and sodium fluoride. Researchers with the Massachusetts and New York studies hypothesized that the silicofluoride compounds in tap water might enhance lead leaching from pipes and increase lead absorption from the water itself. Elevated PbB concentrations in children are associated with a host of cognitive, developmental, and behavioral impairments so serious that lead-based paint was banned in the United States in 1978 and lead water pipe solder was banned in the 1980s.

The current research group evaluated the relationship between water fluoridation method and PbB concentrations in children by conducting a large-scale statistical analysis of two other preexisting studies: the 1992 Fluoridation Census and the Third National Health and Nutrition Examination Survey (NHANES III). In analyzing data from NHANES III and the 1992 Fluoridation Census, the team improved on prior analyses by log-transforming raw PbB concentration and by including information on possible confounding factors missing from the Massachusetts and New York studies. These included poverty status, urbanicity, duration of residence, and year in which the dwelling was built.

The NHANES III sample was comprehensive, representing more than 52 million U.S. children. This survey also oversampled young children, older adults, non-Hispanic blacks, and Mexican Americans to ensure that population estimates for these groups would be statistically reliable.

The team found that, overall, the PbB concentrations of children who lived in counties receiving silicofluorides did not differ significantly from the PbB concentrations of children living in counties without fluoridated water. This was true even when researchers controlled for the year in which children's homes were built. Given these findings, the team states there is no support for concerns that silicofluorides in community water systems cause higher PbB concentrations in children.

Kati Neudert

**Toxics, toxics everywhere . . .** Many studies have looked at the health effects of arsenic in Bangladeshi well water. New data now show that manganese in the water may also cause adverse effects.

Karen Robinson/Panos Pictures

However, the investigators acknowledge that their analysis has limitations. For example, NHANES III did not measure the lead content of drinking water consumed by study participants. Also, the team did not control for factors such as density of older housing, and they were unable to control for the solubility of lead in pipes affected by different temperatures and water hardness.

Because of these limitations, the investigators cannot completely rule out a link between water fluoridation method and lead uptake in children, particularly in children living in older dwellings. They speculate that other studies, possibly those including chemical investigation and animal toxicology, could yield additional valuable data. They conclude that efforts to prevent dental decay via the use of fluoridated drinking water should continue unless a causal effect of specific fluoridation methods on PbB concentration is demonstrated by additional research. **–John Tibbetts**

# Manganese in Drinking Water

## Higher Doses May Hamper Intellectual Function

Manganese is an essential nutrient for humans, but its excessive consumption can cause adverse health impacts. Past studies have linked inhalation of excessive manganese to neurotoxicity in adults. Now a group of U.S. researchers suggests that ingesting high doses of manganese in drinking water can hamper intellectual function in children [***EHP* 114:124–129**]. These effects were seen most strongly on scales that measure performance aspects of intellectual function.

The same group had earlier observed a negative impact of water arsenic on intellectual function among children in Araihazar, Bangladesh. Though the manganese concentration in the water these children drank was much higher than its arsenic content, the independent impact of manganese on intellectual function could not be verified. The present study included 142 10-year-old children (including 54 children from the earlier study) who consumed well water with average concentrations of 793 micrograms per liter (µg/L) manganese and 3 µg/L arsenic.

The children's intellectual function was assessed on six tests (similarities, digit span, picture completion, coding, block design, and mazes) drawn from the Wechsler Intelligence Scale for Children, Version III. Results were summed to create Verbal, Performance, and Full-Scale raw scores. These tests were chosen as they could be applied to Bangladesh's rural context with minimal alteration. The results showed that manganese concentration had a significant negative dose–response association with all three raw scores.

The researchers found that children in exposure groups 1 (manganese lower than 200 µg/L) and 4 (manganese higher than 1,000 µg/L) differed significantly from one another for Verbal, Performance, and Full-Scale raw scores. Compared to group 1, children in exposure groups 2 (manganese between 200 µg/L and 500 µg/L) and 3 (manganese between 500 µg/L and 1,000 µg/L) had lower Full-Scale and Performance scores, but the differences were not statistically significant. Verbal scores of the children in groups 2 and 3 also did not differ significantly from those in group 1. Due to the lack of measures of intelligence standardized for use in Bangladesh, the team could not calculate IQ points lost.

Though the children's waterborne manganese intake was lower than the highest safe daily dose (6 milligrams per day) estimated by the U.S. Institute of Medicine, the authors write that additional dietary exposure could have pushed the total daily dose above this value. Moreover, bioavailability of manganese from food is very low, while it is high from drinking water. This could have contributed to neurotoxicity seen in children drinking water with higher amounts of manganese.

The authors point out that their findings are relevant in the United States as well. Data collected by the U.S. Geological Survey have shown that about 6% of domestic wells contain manganese concentrations higher than 300 µg/L. Based on these data and their study results in Bangladesh, the researchers suggest that some U.S. children may be at risk for manganese-induced neurotoxicity. **–Dinesh C. Sharma**