Collaborating with developing country communities in planning, building, and maintaining their own water systems—in the 1970s and ’80s, a number of well-intentioned groups and agencies built water systems in developing countries. They were disheartened when many of these systems were not used or maintained. UNC School of Public Health researchers helped come up with a new policy framework for planning water systems in developing countries. Along with developing country colleagues and students, they are finding ways to measure the needs of communities and their willingness and ability to pay for and maintain water system infrastructures. As communities have become involved in projects, the success rate of water systems implemented in these communities has risen.

Evaluating water quality in U.S. distribution systems to help cities and towns maintain drinking water purity—Water treatment practices in the United States are intended to maintain even levels of disinfectants throughout distribution systems to prevent potentially harmful bacteria from growing in the water at the far ends of the system. Carolina water experts have worked with numerous U.S. water municipalities to find out why bacteria sometimes crop up again in distribution systems and to discover ways to limit re-growth.

Developing innovative ways to monitor water quality in lakes, rivers, estuaries and other bodies of water—UNC water experts have developed tests to quickly detect different kinds of bacteria in water that can be harmful to humans and fish. Two such tests can detect the DNA of Enterococcus and E. coli—bacteria found in fecal matter. Both tests can be completed in less than two hours. UNC water experts also co-direct FerryMon (www.ferrymon.org), an automated water-quality monitoring system aboard North Carolina Department of Transportation ferries that cross the Neuse Estuary and Pamlico Sound. FerryMon monitors these waters 365 days a year. UNC researchers collect and analyze water samples to quickly detect when water is polluted and may pose a danger to people or fish.

Developing ways to remove dangerous chemicals from groundwater—UNC water experts and their colleagues have developed patented processes to remove chlorinated solvents like trichloroethylene (TCE) and perchloroethylene (PCE) from contaminated groundwater. Chemicals left in groundwater can be a threat to public health for hundreds of years if not cleaned up. UNC researchers are working on better technologies to remove these chemicals.

Identifying pristine water sources—The best way to deliver clean, high-quality water to people is to start with the most pristine source possible. UNC water experts have long promoted watershed protection and helped identify the most appropriate sources—in North Carolina, across the United States and abroad. An example is Cane Creek Reservoir in Orange County, N.C., which UNC researchers identified and helped develop.

Testing household water filtration systems in developing countries—Students and faculty work with international organizations and businesses to test how well ceramic and biosand filters work in even the poorest homes in developing countries. UNC researchers are among only a few groups to have developed and tested these filters and then proven that using filters improves health. Both kinds of filters reduced the incidence of diarrhea by up to 40 percent. Our research has given international organizations data needed to step up distribution of these filters in developing countries.

Promoting water reclamation as a way to manage limited water resources and protect public drinking water supplies—UNC water experts have been among the loudest voices advocating for water reuse in the United States and abroad. One strategy advanced by UNC researchers is a “dual distribution system” design with larger pipes to provide high-volume water for non-drinking purposes (like irrigation and fire protection) and smaller pipes to distribute and maintain clean water for drinking.

Establishing water resource management agreements between North Carolina cities and towns to help them weather water shortages—UNC water experts have been leaders in creating water-sharing agreements between North Carolina municipalities, both in the Research Triangle area and eastern parts of the state, to help communities survive periods of drought.

Quick—What’s Polluting the Water?
At least a couple things can make a river or ocean unfit. For people, it’s microbes—such as disease-causing bacteria, viruses, and protozoan parasites—that contaminate water when a sewer pipe breaks or a hog-waste lagoon fails. For fish, the danger can lie in nutrients, such as nitrogen, which are washed into waterways when wastewater is pumped in or runs off from fertilized land. Excess nutrients can cause overgrowth of algae. Algal blooms can upset the water’s balance, causing dangerously low oxygen levels in some parts of the water.

For both these problems—microbial pathogen contamination and excess nutrients—Carolina School of Public Health researchers have been developing better, quicker ways to know when water is polluted.

On Monday, July 1, 2005, the thing you hope never happens did: a main sewer line from Wilmington, N.C., ruptured, spilling several million gallons of raw sewage into Howeletts Creek, a small tributary of the Cape Fear River. Swimming in water contaminated with sewage can cause diarrhea, abdominal cramps and skin infections. The state closed all the waters between the Wrightsville Beach bridge and the Intra-coastal Waterway near Peden Point: no fishing, shellfishing or swimming.

To advise the state, scientists at UNC-Wilmington sampled the waters and performed tests for bacteria that are found in sewage, particularly E. coli. They also sent some bottom sediment samples to Dr. Mark Sobsey, Kenan Distinguished University Professor of environmental sciences and engineering at Carolina’s School of Public Health and director of the School’s Environmental Virology and Microbiology Laboratory. Sobsey tested the sediment for coliphages, which are viruses that infect E. coli. Coliphage levels are an indicator of fecal contamination and are good predictors of the presence of human enteric viruses, such as noroviruses and hepatitis A. Testing sediments was important since contaminants can persist in sediments, re-contaminating surrounding waters when disturbed by swimmers and changing weather conditions.

By July 4, the creek and surrounding waters were still closed. “The state and the local authorities were under tremendous pressure to open the beaches back up,” Sobsey says. But he and his colleagues advised them to wait until coliphage levels were back to normal.

How long would that take? “We said, ‘We’ll have to keep measuring,’” Sobsey recalls. The problem was, whenever the scientists brought a sample into the lab, with available chemistry technique that carries a very high licensing fee. A rapid test isn’t much good if the state of North Carolina, for instance, can’t afford to use it. “Most water quality agencies operate on very small budgets,” Noble says. “They have their hands tied as far as how much they can afford to spend.”

Noble is also at work on a rapid test for a bacterium that is native to North Carolina’s estuarine and coastal waters—Vibrio vulnificus. This organism has caused deadly wound infections in people who are immunocompromised, such as people who are susceptible to infection, like people with diabetes,” Noble says. “There have been some deaths in North Carolina as a result.”

The test would be especially useful in waters used for shellfish harvesting. The bacterium can cause disease when people eat infected shellfish or swim in infected waters with an open wound.

A sudden success

Back in Sobsey’s lab, David Love, a 2007 doctoral graduate from the School’s Department of environmental Sciences and engineering, has made a breakthrough in developing a three-hour test to detect coliphages (the viral pathogens that infect E. coli). Before this success, Love had spent nine months looking for a DNA or RNA test for coliphages, without making much headway. Sobsey tells the story: “David came to me and said, ‘I’m now thinking I should look at proteins—antigens. Has anybody tried what’s known as particle or latex agglutination tests for this?’ Love knew that such tests are used in medical diagnostic labs to detect viruses in human fecal specimens.

UNC School of Public Health researchers have developed rapid tests that detect the DNA of two different kinds of bacteria found in fecal matter—Enterococcus and E. coli. Both tests can be completed in less than two hours.

Right now the U.S. Environmental Protection Agency (EPA) is evaluating Noble’s Enterococcus test for approval to use in marine waters. The E. coli test isn’t far behind, she says.

David Love, a 2007 doctoral graduate from the School’s Department of Environmental Sciences and engineering, conducts a laboratory experiment. Love has developed a rapid fecal indicator test that can be used to monitor the microbiological quality of drinking, recreational and shellfishing waters.
At least a couple things can make a river or ocean unfit. For people, it’s microbes — such as disease-causing bacteria, viruses, and protozoan parasites — that contaminate water when a sewer pipe breaks or a hog-waste lagoon fails. For fish, the danger can lie in nutrients, such as nitrogen, which are washed into waterways when wastewater is pumped in or runs off from fertilized land. Excess nutrients can cause overgrowth of algae. Algal blooms can upset the water’s balance, causing dangerously low oxygen levels in some parts of the water.

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Aimee Trombley (right), age 6, of Carolina Pines, N.C., goes for a run along the south shore of the Neuse River below Carolina Pines.

Dr. Hans Paerl (previous page) samples a blue-green algae (cyanobacteria) bloom on Lake Taihu, in China, where he conducted research in July 2007. This lake has been impacted by toxic cyanobacterial blooms caused by excessive nutrient deposits from wastewater, industry and agriculture.

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Noble’s tests not only are quicker; they also are less expensive than some rapid assays in development. They avoid using a particular licensing fee. A rapid test isn’t much good if the state of North Carolina, for instance, can’t afford to use it. “Most water quality agencies operate on very small budgets,” Noble says. “They have their hands tied as far as how much they can afford to spend.”

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Coliphages are good candidates for a rapid test, because they’re viruses which multiply quickly. “One virus makes thousands to tens of thousands within an hour,” Sobsey says. “But the challenge was developing a way to detect the viral growth almost immediately.”

Love’s test uses antibodies (immune proteins that attach to the coliphages) that are attached to latex beads. When the antibody-labeled beads are added to a water sample, if coliphages are present in the water, the antibody will stick to the coliphages. A positive result is easily visible as the plastic beads clump together in just a few seconds. The visual read-out and simple methods make this a good candidate for further development as a field-portable kit.

Love’s success came just in time for him to use the research this summer in two studies of beach water quality and swimmer health in Orange County, California, and Fairhope, Alabama, and in his doctoral dissertation, which he defended in April 2007.

Sobsey has been working with colleagues to combine water sampling data with satellite and aircraft data to develop graphic indicators of water quality that could provide rapid warnings of potential problems due to algal blooms. Scientists use these bodies of water 365 days a year since 2000. “The ferries are out there every day, sampling the waters as they move down the Neuse and the Pamlico, and they can give us highly informative data that would not be obtainable with weekly or monthly monitoring programs,” Sobsey says. “If you suspect there is a problem—for instance, reports of people having rashes or diarrhea after having been in the water—FerryMon would be our early-warning tool to immediately collect space-time intensive samples and analyze them for potentially harmful explosive growths or ‘blooms’ of algae and other water quality indicators that might adversely affect human health.”

Paerl also is working with colleagues to combine water sampling data with satellite and aircraft data to develop graphic indicators of water quality that could provide rapid warnings of potential problems due to algal blooms. This requires that Paerl, who’s an aquatic ecologist, work with scientists who understand and interpret remote sensing images generated by optical sensors. “Collaborations with others outside your field make the whole greater than the sum of its parts,” Paerl says.

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Sobsey and his colleagues now are developing an automated water-quality monitoring system aboard the North Carolina Department of Transportation ferries that cross the Neuse Estuary and Pamlico Sound. FerryMon has been monitoring these bodies of water 365 days a year since 2000. “The ferries are out there every day, intercepting the waters as they move down the estuary and the Pamlico, and they can give us highly informative data that would not be obtainable with weekly or monthly monitoring programs,” Sobsey says. “If you suspect there is a problem—for instance, reports of people having rashes or diarrhea after having been in the water—FerryMon would be our early-warning tool to immediately collect space-time intensive samples and analyze them for potentially harmful explosive growths or ‘blooms’ of algae and other water quality indicators that might adversely affect human health.”

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Satellite images such as those of the North Carolina coast (left) and Pamlico Sound (right), can tell researchers a lot. Satellites calibrated with biological sensors can provide data about the color of water, which can be used to tell scientists about water quality. UNC researchers are working with colleagues to use this technology to identify harmful algal blooms and clarify problems that might adversely affect seagrass, fish and shellfish habitats.

Dr. Hans Paerl (above, left) filters algae samples incubated with nutrient additions to determine potential problems due to algal blooms. Chlorophyll, the main pigment in plants and algae, turns the water green. Dissolved organic matter and sediments in the water turn it brown. In the Pamlico, for instance, a NASA satellite produces a snapshot of the water’s transparency and clarity every few days. FerryMon provides daily measurements of water quality to calibrate satellite images. A computer can use mathematical algorithms to correlate both sets of data. What emerges are images whose colors correspond to various levels of water quality. So by checking the latest satellite images, researchers could instantly “see” today’s water quality. “We can look at color with a satellite and then use our indicators to calibrate it so we can scale it up for the entire system,” Paerl says. “It’s called groundtruthing: using real data from our monitoring programs to allow the optical sensors to be scaled up to apply to the entire estuary.”

Paerl is seeking funding to try to do that. Because such a tool could provide an early-warning system, he says, “it would be very useful for looking at harmful algal blooms such as red tides or blooms produced by toxic blue-green algae—being able to spot them before they cause serious problems, or warn the public of potential health problems.”

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TIP: Join a community group to help restore a stream or clean a beach. For more information, visit: www.nrcs.usda.gov/technical/stream_restoration.