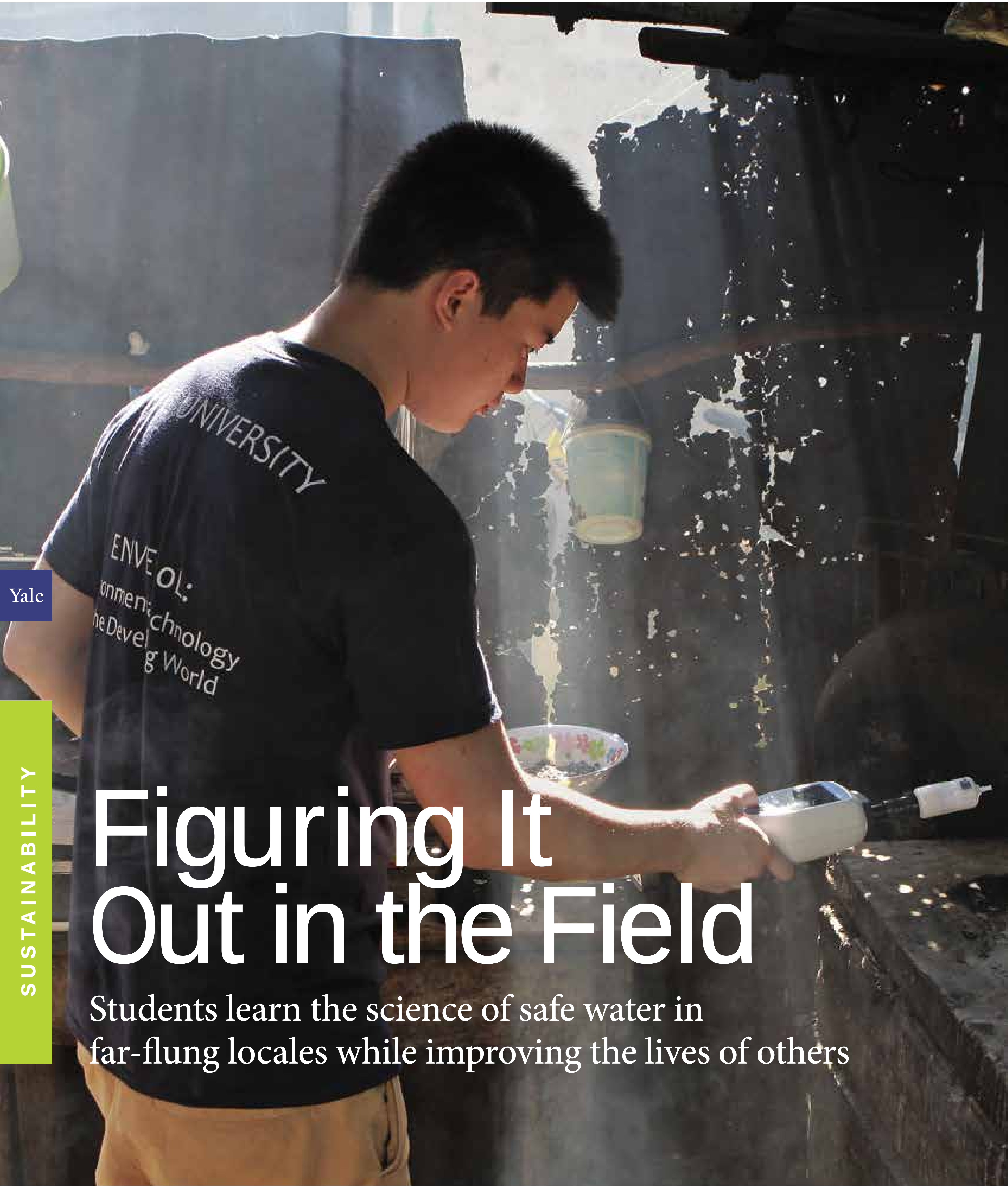
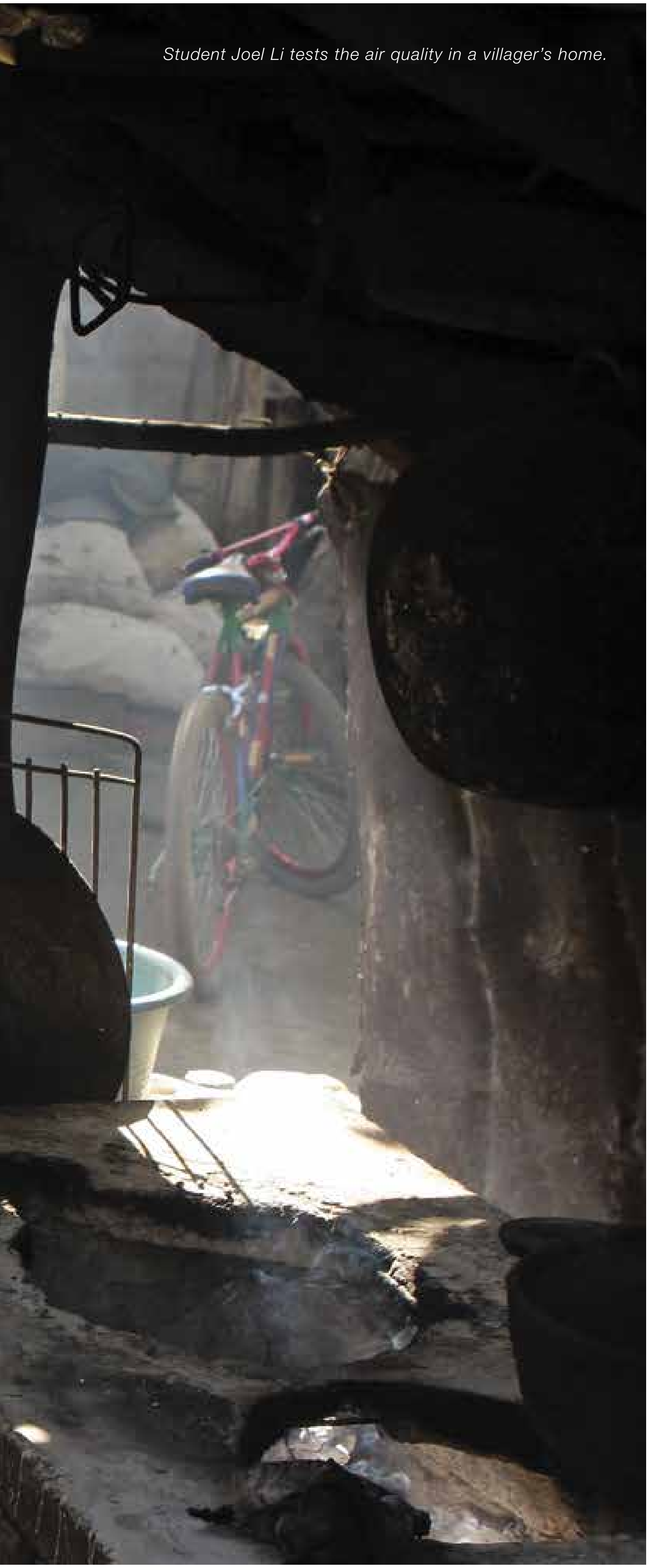
Yale

SUSTAINABILITY



Figuring It Out in the Field

Students learn the science of safe water in far-flung locales while improving the lives of others



Student Joel Li tests the air quality in a villager's home.

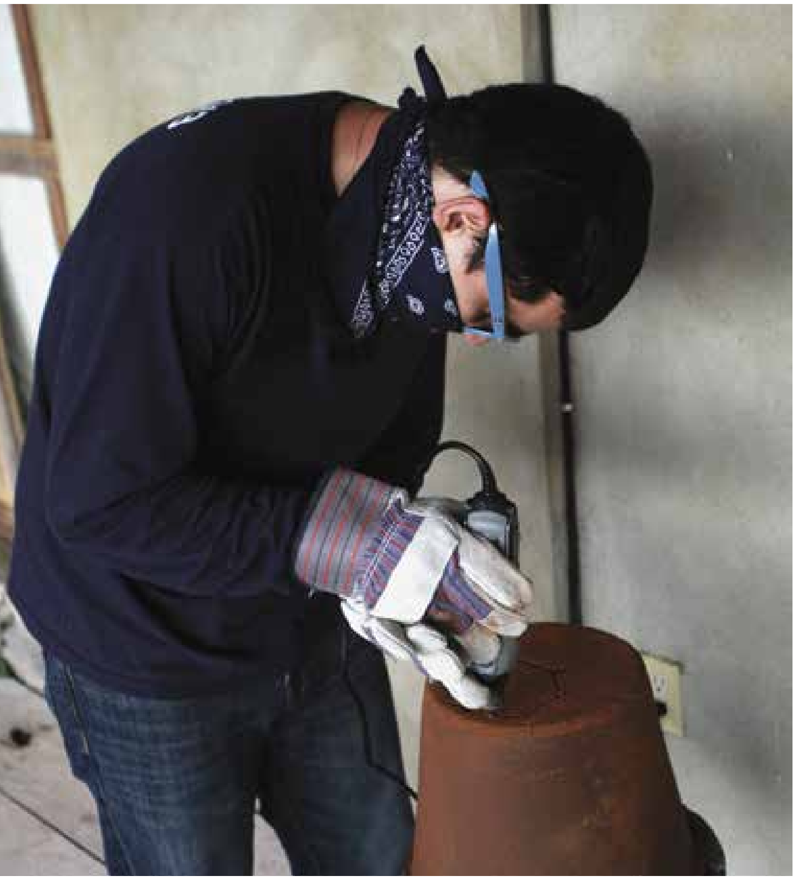
Yale College senior and chemical engineering major Hannah Fornero was at the point of frustration in a remote village in the northern Nicaraguan mountains. Sitting in front of ten rudimentary ceramic pot water filters, she had been tasked with cutting the fragile filters from the base of the pots without damaging them, then attaching small sections of each filter to a plastic water bottle. Fluid containing bacteria and virus-sized microspheres would then be passed through this improvised filtration system to test the filter's effectiveness at removing harmful pathogens from the water. But after hours of trying every adhesive available to her, Fornero felt sure she needed a new strategy.

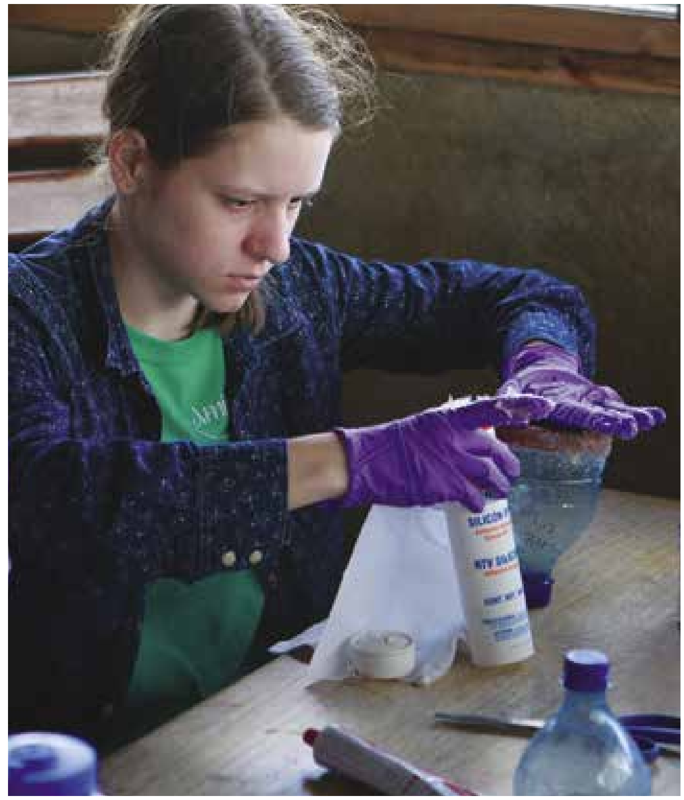
"That kind of frustration is true to the experience of being an engineer," says Jaehong Kim, professor of chemical & environmental engineering. "You plan, you fail, you get frustrated, you hope again, you fail again, feeling that it's impossible — until some alternative plan finally does succeed. By the time we're in the field, the students know that I'm OK if some things don't work right — I even hope they expect it — but one of the core challenges of this course is to react to those problems without giving up."

Kim's course, Environmental Technology in the Developing World, is one of the newest to be offered in Yale's Center for Engineering Innovation & Design (CEID). Like many CEID courses, Environmental Technology in the Developing World tasks students with improving a real world problem over the course of the semester under the mentorship of an actual "client" who works in the field.

But two things set Kim's course apart from other CEID courses. First, every student in Kim's course collaborates on the same project, for the same non-governmental organizations (NGOs), to better the lives of the same villagers. To accomplish this collaboration, each student is tasked with developing a proficiency in a specific scientific experiment that could be used to analyze the harmful pathogens, chemicals, and particulates in water and air.

Continued →





Students work to analyze and test ceramic pot filters of the Jinotega residents in an effort to reduce drinking water pathogens.

In the early weeks of the course, each student masters the technology and techniques needed to complete his or her task, then leads the rest of the team in performing the experiment. In this way, while only one student in the course becomes an expert in detecting chemicals in water with a colorimeter or analyzing the fine particulate air pollution from simple stoves, for example, every student becomes familiar with these tools for scientific investigation.

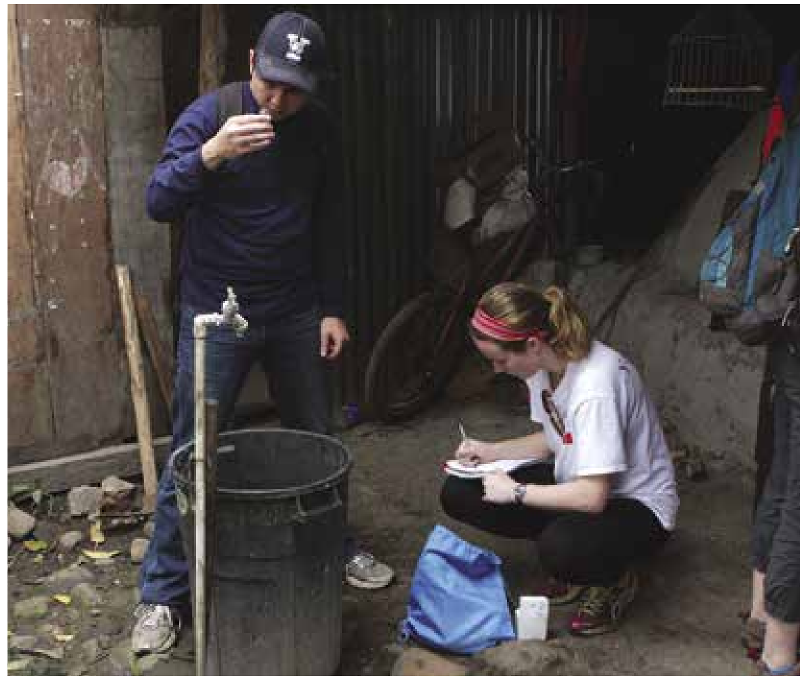
But for most students, the most unique and memorable aspect of the course is its focus on international travel to developing communities, including this year's trip to two rural villages in Nicaragua. "This course," says Kim, "is an opportunity for the next generation of researchers to not only learn about preventable water- and sanitation-related diseases, but also to actually make a difference. To me, that means organizing the class based on what a particular community or organization needs, and then going to that community to perform scientific research that can help that organization."

Taking place over spring break, this year's eight-day field trip to Nicaragua was the central turning point for the course, a simultaneous culmination of the weeks spent developing scientific expertise and also the launching point for the semester's later weeks spent analyzing the experiment results and preparing a report on their findings. During their trip, the students worked in collaboration with two NGOs: Amigos for Christ, which operates in Chinandega, and Comunidad Connect, which operates in Jinotega. "I've worked with these NGOs from the beginning, listening for what problems might become projects worth doing," says Kim. "And then I have buy-in, so not only are the NGO staff working with us while on location, but they're also the people with an investment in the outcome — they're waiting for the results, which the students produce as a formal report that they deliver to these NGOs. Then the students work hard not because they want a good grade but because they're passionate about improving lives. This is a class with a humanitarian emphasis, and while in Nicaragua, they learn about the realities of engineering outside of the lab."

The driving purpose for Kim's research, and in turn for this course, can be encapsulated in statistics: 1.5 million children die each year of preventable water- and sanitation-related diseases; in Latin America, 77 million people lack access to safe water and 100 million people lack access to sanitation. “Attempting to affect such a large-scale problem requires developing tools that might sound outrageous,” says Kim, “and that encouragement of big thinking is something my course has in common with other courses in the CEID. But during the field research, the identification of problems, and subsequently the research results, inevitably gets narrowed into specifics about the communities you hope to help.”

One way that this happens for Kim’s students is that they must conduct their research in a place where they can’t expect perfect lab conditions — a sometimes unpredictable challenge. In fact, that was the source of frustration for Hannah Fornero, the senior chemical engineering major. Fornero’s role this past spring was to analyze the ceramic pot filters that Comunidad Connect gives the residents of Jinotega to reduce drinking water pathogens. Her goal at the beginning of her trip to Nicaragua was to complete all filter tests on site, then analyze the data back at Yale.

Testing the filters in the field, however, turned out to be much more difficult than expected. For one thing, the filters would need to be irreparably separated from their ceramic jars during testing, so Fornero had to purchase new filter units to trade to Jinotega residents for the units they were currently using. Moreover, this trade had to be made with no advance notice. Otherwise, a well-meaning filter owner might perform an unusually deep clean on the filter and remove the buildup that reflects the filter’s everyday state. Even more challenging was the process of setting up the experiment, which necessitated using only a small section of the actual filter in each test due to limited quantity of fluorescence-emitting microspheres that she used. But the filters, made of clay and sawdust, are somewhat fragile, and even when Fornero removed the filters from the pots undamaged, none of the adhesives she found locally made a water-tight bond between the filter piece and the plastic bottle that would gather the water. After many hours of painstaking work, she determined that the tests could not be completed without additional resources, and she instead had to ship the filter materials back to Yale for testing in the CEID.



Students test the chlorine levels in the residents’ water for evidence of bacteria and viruses.

Despite such frustration, chemical engineering major Rahul Kini feels that the challenges of outside-the-lab research are the central appeal of the course. “In the lab everything is given to you: if you break a beaker, you buy another one; if something catches on fire, you replace it immediately,” he says. “But in the field, you have a finite amount of equipment, a finite amount of resources, not to mention time, and things always go wrong. That’s frustrating, but then it feels so good when you figure out how to work around it. I can tell what quality of engineer I’ve become over the past three-and-a-half years by how I react to things going wrong.”

In addition to facing these technical difficulties, human nature was also a crucial component of the engineering problems the students faced during this course. For example, when junior environmental engineering major Maddy Landon tested the additive chlorine levels at the first house she visited in Chinandega, the levels were perfect. But at later houses, especially as her testing carried into the afternoon, the samples had ineffectively low levels of chlorine that would make it possible for bacteria and viruses to multiply in the water.

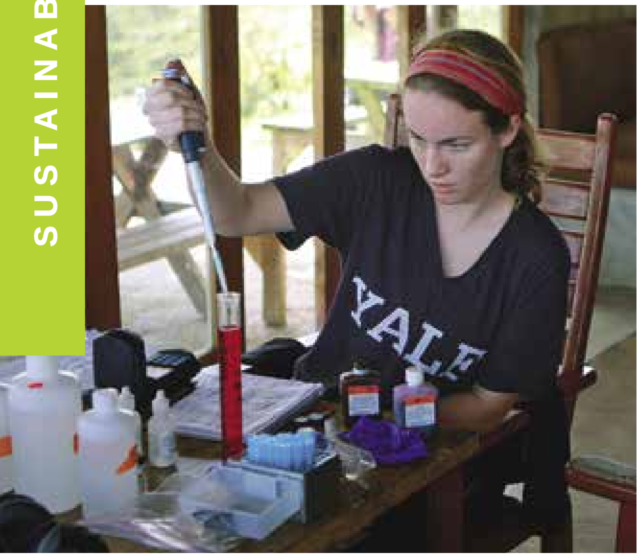
Continued →

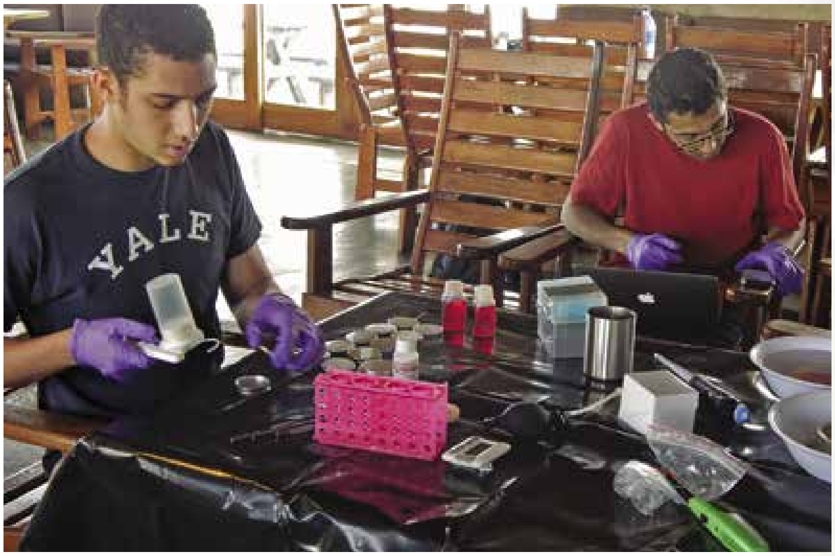
"It was clear that the chlorination system is working how it should," says Landon. "But Chinandega was founded long before the village had a reliable water source. What's happening now is that the villagers still believe they might run out of water any minute, so they collect the properly chlorinated water in plastic containers and cement tubs, perhaps with or without lids." In fact, one woman Landon met had roughly 500 gallons of water stored in her backyard. Although the water came from the village's treated system, the chlorine had evaporated from the water in the time between when the woman had drawn it and when Landon tested it. As a result, animals, flies, and dirt can recontaminate the water, even though the system is working as expected.

Landon further found that the individuals who choose to store that much water, in addition to making themselves vulnerable, also end up preventing others in the community from drawing water at all. "The water distribution system in Chinandega was thought out carefully by a civil engineer, and in theory, it should work perfectly," she says. "But it's gravity fed. Because villagers at the bottom of the hill are currently the higher-volume water collectors, villagers at the top of the hill can't create enough pressure to draw any water at all from their own spouts. It shows that even when it's easy to engineer systems, it's almost impossible to engineer people."

Yet at the same time as the students face these additional challenges, they also share experiences with these villagers that inform and ignite their drive to make a difference. For example, senior economics major Joel Li was in charge of testing the air quality within the villagers' houses looking for "fine" particulate matter air pollution, that can measure as small as 2.5 microns in diameter. These particulates, which are most often generated by the incineration of organic materials such as wood, can penetrate your lungs, affecting lung function and increasing the risk of lung cancer and heart disease. Li also tested the air for the presence of carbon monoxide — formed by the incomplete combustion of materials that contain carbon — and which can be fatal in high doses.

Through such measurements, Li aimed to compare the health risk of two different types of stoves, both of which are in current use in Chinandega. Such an evaluation





is crucial for women who often spend long hours in the kitchen cooking meals for their families. The fires that heat the stoves are rarely put out, so even when not kindled to a flame, the embers can release fine particulates into the air all day. Unless the air is properly exchanged with outside air, people in other rooms of the house could be affected.

To perform his measurements, Li was invited into the villagers' homes, where he had a close-up view of how they live. "While taking these measurements, I really felt how much there is to be done for these people, especially because of how little they have," he says. "There was this one house owned by one of the friendliest people I've ever met in my life. The house was very rural, very dusty, and with intermittent water access. But as she explained how she went about her business every day cooking for her family, she started cooking for us. It was just this incredibly heartwarming moment, and yet it was also soured for me knowing that she wasn't aware of the byproducts, the carcinogens, the particulates — all this very bad stuff that she's exposed to on a daily basis because of her cooking. It was eye-opening, and I'll remember it for a long while."

Kim regards such experiences with the same importance as the science itself. In his own research, he's developing futuristic materials to solve the same low-tech problems that his students are addressing: a water bottle that when placed in the sun, uses solar rays to disinfect the water inside it; a nanoscale "band-aid" that can repair the tears in membrane-based water filters. But the problems are too big, he says, to think that he could resolve them himself. He therefore considers it an important part of his career to inspire the next generation of researchers, to show them how valuable this work is and how valuable each human life is.

For this reason, Kim sees his course as a potential conduit for so many positive changes: providing evidence that can strengthen the collaborative efforts between the Nicaraguan villagers and NGOs to improve health in rural villages; offering scientific documentation and analysis that NGOs can use to secure grants that might expand their reach; and creating opportunities for Yale students to have life-changing experience that might shape them as engineers and as people. In this way, Kim's work ripples out into communities that he might otherwise have never affected by himself.

"The course epitomized what I want to do with my environmental engineering degree," says Landon. "It was a real-world application like I've never seen before in a class, and it made me feel like I could do something important."