Changing the Environment

These four researchers are highlighting environmental inequities and improving the health of their communities

BY KATHERINE BOURZAC

One in four deaths worldwide can be linked to environmental conditions. Heart disease, cancer, chronic respiratory diseases, and more could be alleviated or even prevented by reducing environmental risks. Exposure to polluted water and air, flooding, extreme heat, and other dangers is driven in part by economic and racial discrimination, causing an unequal burden of disease. The political forces that drive this can be sweeping, but these four researchers are making a difference at a local level. They are attacking inequity, fighting historical wrongs, and helping to ensure a more equitable and healthy future.

KOFI AMEGAH

REVEALING AIR POLLUTION EXPOSURE

In 2015 Kofi Amegah traveled from Ghana to Switzerland for a World Health Organization meeting to share his work on how indoor air quality and nutrition affect the health of mothers and their children. After conferring with scientists from around the world, he realized Africa had a huge gap when it came to air pollution data. So the University of Cape Coast environmental epidemiologist decided to do something about it.

Rapid population growth and industrialization are creating a fast-growing problem, he says. Exposure to aerosol particles, specifically those 2.5 microns and smaller (called $PM_{2.5}$), increases the risk of heart disease, respiratory disease, and more. The WHO links this air pollution to 6.7 million premature deaths every year, 89 percent of which occur in low- and middle-income countries. As of 2019, 99 percent of the world's population lived somewhere with air quality poorer than that recommended by WHO guidelines.

Particulate matter in the air is an especially big issue in sub-Saharan African cities. To make a difference in people's health, Amegah needed local numbers. But air-quality monitors deployed by government-funded environmental agencies cost about $20,000 or more each, far beyond Amegah's research budget. Even in rich countries such as the U.S., these high-sensitivity monitors are distributed sparsely, obscuring inequities among neighborhoods.

Around the same time that Amegah went to the WHO meeting, relatively inexpensive air-pollution sensors began to hit the market. At just a few hundred dollars apiece, they are not as reliable as the more expensive regulatory monitors, but when carefully calibrated and combined into networks, they get the job done. Plus, their low cost makes it easier to distribute more of them to gather local data.

The Ghana Urban Air Quality Project started with one sensor in Cape Coast in May 2019, which Amegah paid for with his own money. The group he founded added two more in Accra by the end of its first year of operations. Today the team has about 60 air-quality sensors deployed across Ghana in the cities of Accra, Tema, Cape Coast, Takoradi and Kumasi. The project has also integrated 10 donated, regulatory-grade $PM_{2.5}$ monitors into the network to check the accuracy of the low-cost sensors.

Amegah established Breathe Accra last year. The nonprofit aims to identify air-pollution hotspots in Ghana's capital and to educate policymakers and residents about how to address them: governments can make regulatory interventions, for example, and schools can keep children inside on days when the air quality is bad. Amegah says he hopes Breathe Accra will act as "a blueprint other cities in Africa can follow."

This sensor network is also advancing Amegah's epidemiology research, which centers on the health of street vendors, who are exposed to high levels of emissions from aging cars and two-stroke motorcycle engines. Within this community, he says, "the most vulnerable groups are women and children." Women spend up to 12 hours selling their wares and then head home to cook meals over coal- or wood-burning stoves, their young children with them. And the neighborhoods they live in are "the most polluted in the urban landscape," Amegah says, the air filled with road dust and smoke from burning trash.

Today Amegah has sensors mounted in schools, hospitals and traffic hotspots and is connecting the data to health outcomes for street vendors and children.

"Kofi's on the cutting edge of the science," says Richard E. Peltier, an environmental health scientist at the University of Massachusetts Amherst. "He's got the whole package. He's got the monitoring expertise, he's got the chutzpah to set up the monitoring network, and he's bringing it back to human health."

Illustrations by Joel Kimmel

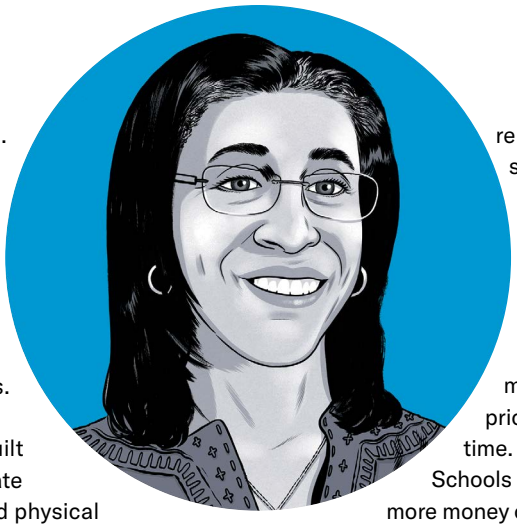
ERICA COCHRAN HAMEEN

RETROFITTING BUILDINGS FOR HEALTHIER SCHOOLS

As an architectural designer working in New York City, Erica Cochran Hameen was struck by how inequity had been built into the physical environment. Wealthy areas were lined with well-maintained public buildings, and schools in those districts had beautiful light and working doors. In lower-income neighborhoods, many buildings were disintegrating, and some public schools were far from parks and other green spaces.

Cochran Hameen began to question how built environments affect people, both physically and psychologically—and she wanted to quantify it. She returned to graduate school, where she began developing a set of more than 100 measures of indoor environmental quality. With her Ph.D. in hand, she started applying those measures to schools and probing how temperature, lighting, concentrations of various gases, and numerous other factors correlated with students' health and academic performance.

As an example, Cochran Hameen points to windows, which have a surprisingly strong effect on students' well-being and schoolwork. "You need a certain amount of daylight for your circadian rhythms," she says. That means large windows are better but only when they're also equipped with shades to mitigate glare and heat on sunny days.



These connections among the built environment, climate change, mental and physical health, and racial and social equity are complex and often overlooked. "Erica is working to make this [interplay] visible, tangible and meaningful," says Jenna Cramer, CEO of the Green Building Alliance in Pittsburgh. "Her research was early and groundbreaking." Talking about energy efficiency can sometimes feel abstract, but when people can see how energy use and environmental quality connect to children's learning and health, Cramer says, "it becomes a different conversation."

Cochran Hameen is now co-director of the Center for Building Performance and Diagnostics at Carnegie Mellon University, and her students are putting her metrics to work. They are assessing indoor environmental quality at schools and nonprofits in Pittsburgh and recommending upgrades based on their findings, some of which are relatively inexpensive—caulking holes, making windows operable and adding shades can make a big difference.

Other recommendations are pricier but pay off over time. Take energy costs: Schools in the U.S. spend more money on electricity than they do on books and computers. During on-site evaluations, Cochran Hameen found that some schools' HVAC systems set one temperature for the entire facility, so rooms with different uses, such as the gym and the math classrooms, were kept at the same temperature. When people opened windows or used space heaters to adjust their immediate surroundings, they wasted energy. Upgrading can save money and keep students comfortable and alert.

To make her resource-intensive evaluations accessible and affordable, Cochran Hameen has been collaborating with computer scientists at Carnegie Mellon. She wants to scale up her work by developing a sensor-laden robot that can navigate a building. "I want to show how architecture is beautiful but can also have a big impact on people," she says.

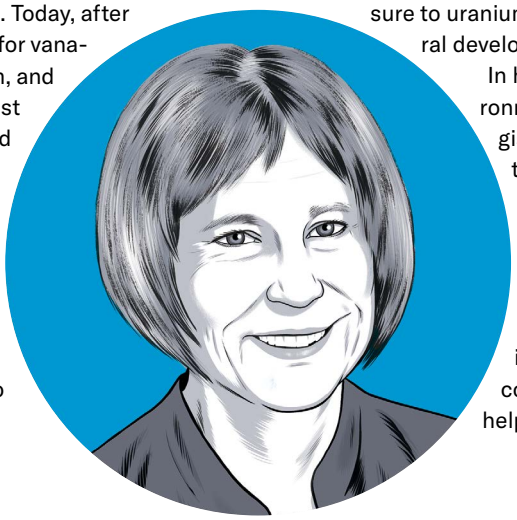
JOHNNYE LEWIS

CLINICAL TRIALS DRIVEN BY COMMUNITY PARTNERSHIPS

After Johnnye Lewis moved to New Mexico in 1989, she learned about the legacy of the land. She took a job as a consultant for Los Alamos National Laboratory, where she helped study the ecological and health impacts of nuclear research. That work, along with her involvement in community efforts to reconstruct historic radiation-exposure doses during the nuclear era, led her to start attending community meetings. She listened to residents discuss their concerns about the aftereffects of the atomic bomb, which was developed nearby, as well as ongoing health impacts from uranium mining on Navajo Nation land. It seemed to Lewis that scientists, politicians and members of Indigenous groups weren't using the same language to talk about these problems, and tribal members were paying with their health.

"I wanted to build a common language to move toward solutions," Lewis says.

In 1919 Congress permitted companies to excavate ore deposits on tribal lands with little oversight. Today, after decades of mining for vanadium, gold, uranium, and other metals, at least 160,000 abandoned mines remain in the western U.S. More than 500 abandoned uranium mines, along with 1,100 uranium waste sites, are on Navajo land, and people living there have been exposed for decades. At high doses, uranium in drinking water can cause kidney damage, and exposure to contaminated air can lead to lung cancer and other respiratory diseases. Preliminary results suggest that prenatal and early childhood exposure to uranium can impair neural development.



In her role as an environmental toxicologist and director of the University of New Mexico METALS Superfund Research Center, Lewis is connecting research with interventions that could immediately help people. Studies

BERENDINA VAN WENDEL DE JOODE

PESTICIDE PROTECTOR

Anyone who works on or lives near a banana plantation in Costa Rica is subject to relatively high pesticide exposure. That's because farmers don't leave anything to chance. Every time a banana tree sprouts a leaf, it's newly vulnerable to fungal infection, so farmers spray fungicide from crop dusters and enclose growing fruits in plastic bags loaded with insecticide to deter bugs.

Berendina van Wendel de Joode has been working to change that. In the 1990s, as part of an internship, she moved to Costa Rica from her home country of the Netherlands to study farmworker exposure to the herbicide paraquat. She returned to Costa Rica in 2004 and has been at the National University of Costa Rica ever since.

Van Wendel de Joode focuses her research on how prenatal and childhood exposure to pesticides affects health and development in rural areas of the country. It's a complex problem: in the populations van Wendel de Joode works with, environmental-health dangers from pesticide exposure are layered on top of limited education, poverty and low food security.

One of van Wendel de Joode's projects is the Infants' Environmental Health Study, a large-scale study of 300 mother-child pairs in the Matina District of Limón Province. The project aims to determine which factors—such as how far a child's home is from a plantation or whether their parent works in agriculture—lead to higher chemical exposures and how that affects overall health and neurodevelopment. So far early results have revealed that women with evidence of fungicide exposure during pregnancy had infants with more respiratory infections and impaired neurodevelopment at age one.

Van Wendel de Joode's research led the Costa Rican government to provide clean water to a community whose groundwater is contaminated with pesticides and *Escherichia coli*. After her work with agronomists showed that plastic fruit bags were just as effective against insect damage when treated with mustard or without any chemicals at all, growers began phasing out the insecticide-treated versions.

Van Wendel de Joode is building maps of aerial-pesticide hotspots to show which ones are near inhabited areas. And her team has started a pilot program to test a play-based learning program for schoolchildren, including those with pesticide-induced neurodevelopmental delays.

The next generation of Costa Rican environmental epidemiologists is now being trained by van Wendel de Joode, says Ana Maria Mora, a physician and epidemiologist at the University of California, Berkeley's Center for Environmental Research and Community Health.

Mora worked with van Wendel de Joode and holds her former mentor in high regard. "She's passionate about Costa Rica and improving people's health," Mora says. "As a Costa Rican citizen, I feel incredibly grateful for what she's done."

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by scientists at the center found that arsenic and uranium can displace zinc in proteins that repair damaged DNA, which might increase cancer risk. Lewis's group is now testing whether zinc supplements could counteract this displacement and improve people's health.

Lewis tailored the trial, as she does with all her projects, to the needs of the people she works with. She and her team have consulted with the Red Water Pond Road community, whose tribal land is sandwiched between two abandoned uranium mines in New Mexico, to design multiple clinical trials. With community members' guidance, for example, the scientists built their preliminary zinc trial to include both elders and people with chronic conditions such as kidney damage—groups that have had the highest exposure to metals but are usually excluded from such clinical trials by researchers seeking "clean" data.

Community members in the Red Water Pond Road area also helped Lewis and her team design the Navajo Birth Cohort Study, which followed pregnant women and their babies through the children's first year of life, tracing their development, health and environmental exposure to toxic metals. The study, which began in 2013, has been extended and will continue to track the children as part of the National Institutes of Health's ongoing National Environmental Influences on Child Health Outcomes initiative.

Teracita (Terry) Keyanna, who grew up in Red Water Pond, says other scientists had informed them that the land was contaminated but then left without addressing the problem, something that has made it hard for residents to trust outsiders. Lewis has proved herself by working closely with those who have the most at stake. She "has developed that rapport with the community, and we trust her," Keyanna says. "It's taken a long time to do that."

Lewis started out in community engagement, working on recycling and food co-op projects before returning to academics and specializing in toxicology. She says her background and her recognition of the interconnection between the environment and human health have helped her work with Indigenous communities. They, in turn, have helped her improve the science. "Science is a special training I have, but it should just be one piece coming to the table," Lewis says.

Katherine Bourzac is a journalist based in San Francisco, who covers environment, climate, chemistry, health and computing for *Nature*, *Science News*, and other publications.