The good news: PCBs (polychlorinated biphenyls)—a class of hazardous chemicals used in coatings for electronics, sealants, adhesives, paint, and flame retardants—were banned in the 1970s. The bad news: these toxic compounds continue to linger in groundwater and soil as part of our food chain.

Where do PCBs lurk? “Across Kentucky,” says Bernhard Hennig, an expert in human nutrition who has been in the UK College of Agriculture’s Department of Animal and Food Sciences since 1984. He says Kentucky has more than 200 hazardous waste sites on the active list for control,
cleanup or monitoring under the federal Superfund program. One such site is the Paducah Gaseous Diffusion Plant—the only operating uranium-enrichment plant in the United States and one of the top 14 sites on the EPA’s national priority list.

Hennig says some fish caught in Kentucky rivers have high levels of PCBs. “PCBs are often stored in fat and pass from food to humans. These chemicals get into your digestive system, where they are absorbed in combination with other lipids (fat-soluble molecules), carried in the blood and deposited into tissue.

“PCBs can cause inflammation and oxidative stress—factors in disease progression. Our work has shown that PCBs can damage the cardiovascular system in this way. So it’s no surprise that PCBs are a problem in Kentucky, a state whose rates of chronic diseases like cardiovascular disease, cancer, diabetes, and hypertension are well above national averages,” Hennig says.

Is there anything people who live near toxic sites can do to fend off the PCBs in their bodies and blood? Eat better. That’s Hennig’s novel hypothesis. His research focuses on the effects of nutrition on PCB-caused dysfunction of endothelial cells (the cells that line the blood vessels). Hennig’s work and that of engineer Di- bakar Bhattacharyya, to use nanotechnology and free radicals to destroy these toxins before they can reach the human body, are two of five critical projects in UK’s $10 million grant from the National Institutes of Health Superfund Basic Research Program.

Hennig, who is the director of the UK Superfund Basic Research Program, says 2008 marked the second consecutive five-year Superfund grant for UK. He calls the 600-page proposal a huge challenge and admits, “it’s probably one of the reasons why I have so little hair left.

“Superfund grants are very competitive. Last year the NIH got 18 submissions and funded only two—us and Dartmouth. UK joined 13 other prestigious national universities with ongoing Superfund programs.”

What set UK apart? A unique interdisciplinary biomedical focus on PCBs and nutrition (with projects headed up by Hennig, Michal Toborek and Lisa Cassis) coupled with non-medical projects tackling chemical detection and cleanup (Sylvia Daunert and Bhattacharyya). “We’ve brought together more than 50 scientists and students representing more than 15 academic departments in the colleges of Agriculture, Arts and Sciences, Engineering, Medicine, and Pharmacy. UK is one of the few universities with a strong College of Agriculture and a College of Medicine.” And Hennig says he knows how beneficial such academic proximity can be.

“I received my Ph.D. at Iowa State University, a land-grant institution and,” he says, only half joking, “it’s a good place because there’s not much else to do but study. I moved on to Iowa City to do postdoc work at the medical school. But those two schools are 125 miles apart. At UK, because everything is together, we can all sit down and brainstorm. Progress comes when you talk to people who don’t do the same things you do. The NIH likes interdisciplinary research.”

UK’s Superfund program focuses not only on research, but also on student training and outreach. Leonidas Bachas in chemistry heads up the certificate in environmental studies program, while Lisa Gaetke in the College of Agriculture provides nutritional education programs for people in communities directly affected by PCBs.

Good nutrition can fend off PCB damage

So how did Hennig, a native of Germany who retains a marked accent, end up in the United States studying nutrition? “I intended to go to medical school to become an ophthalmologist and take over the family practice in Germany,” he says, but in the process of applying to medical school, Hennig happened to visit a distant relative in San Francisco.
“It was 1972, right after the hippie movement, and it was a beautiful time. I took some biochemistry courses at San Francisco State University and met my wife, then got accepted back in Germany. So I had to make a decision.” He pauses, and with a smile, says, “It’s not money that turns the world around, it’s love, right?”

He also stayed with biochemistry, and he became interested in nutrition, and specifically obesity. Hennig, who is now a faculty associate of the UK Graduate Center for Toxicology and the Graduate Center for Nutritional Sciences, says, “Even in those days Americans’ waistlines were growing faster than those of people’s in other countries.”

And today in Kentucky, high-fat diets and sedentary lifestyles are making people more susceptible to chronic diseases. “When you add in exposure to environmental pollutants, Kentuckians are even less able to fight off the toxic assault.”

Hennig has proven this hypothesis by studying the endothelial cells of animals on specific diets—healthy and otherwise. He adds that because he and the other Superfund biomedical researchers—Toborek and Cassis—share animals and tissues, they can see how PCB damage is related in various parts of the body. Toborek, in the College of Medicine, is looking at the ways in which PCBs can stimulate the growth of cancerous tumors and the spread of cancer. Cassis, in the Graduate Center for Nutritional Sciences, is studying the ways PCBs promote obesity and related cardiovascular diseases like atherosclerosis.
“Blood vessel constriction and vessel relaxation are regulated by endothelial cells,” Hennig explains. “Think of a garden hose. Water passing through the hose is like blood in a vessel. These cells make up the very inner layer. They communicate with components in the bloodstream and the underlying tissue.”

If a toxin floats by and activates the endothelial cells, they may signal for help in the form of cytokines. But these helpers bring inflammation (a protective attempt to remove the toxin as well as initiate the healing process), which can trigger the formation of plaque. Plaque buildup on the wall of a blood vessel can lead to a heart attack.

“We found that certain dietary fats can amplify the toxic response of endothelial cells to PCBs. But not all fats are equally bad,” Hennig says, suggesting that the widely touted omega-3 family may protect blood vessels from damage. Omega-3 is found in fish, flaxseed and walnuts.

Hennig also found that antioxidants like vitamin E can actually reduce the toxic impact of PCBs on endothelial cells, and he’s investigating the protective potential of “bioactive compounds” in fruits and vegetables. “Have you heard of the French Paradox? The French and the Finnish people eat about the same kind of fat, but the French are much more resistant to cardiovascular disease. And scientists think it’s because they drink wine.”

Hennig, who will spend four months this spring teaching a nutritional biochemistry course at the Universidad de Antioquia in Columbia, thanks to a prestigious Fulbright grant, says, “This work is fascinating because in trying to understand how PCBs are involved in chronic diseases, we’re discovering easy ways to modify our risk by manipulating diet.”

Ideally, PCBs won’t get a chance to reach the human body. That’s the job of a new breed of membranes to detoxify PCBs in soil and groundwater.

**Catching PCBs with nanoparticles**

Longtime UK chemical engineer and Indian native Dibakar Bhattacharyya, or DB as he’s known to colleagues and friends, says he can trace the origin of his current work on PCBs to an after-hours meeting in 1996.

It all started with a phone call from Subhas Sikdar, the associate director for science at the EPA’s National Risk Management Research Lab. “Dr. Sikdar said, ‘DB, I’ve got a challenge for you. Create a material that can capture toxic metals—like lead or mercury—in water at a pound-to-pound ratio.’” He meant 1 pound of metal captured to 1 pound of material used, DB explains, adding that the very best material at the time could pick up
only .01 pound of metal per pound of material. “If you can find a solution, I’ll make sure you get grant funding. But the deadline’s coming up, so you’ve got to hurry.” I said, “Give me one day to think.”

So DB went to his computer and, with help from chemistry colleague Leonidas Bachas, hammered out an idea. “I’ll take a membrane with big pores—holes about 200 nanometers wide—and inside those holes put a long chain of amino acids (the building blocks of proteins) called polypeptides. Polypeptides have multiple sites that can capture metal,” DB says, his voice rising as he remembers the excitement he felt at the time. He offers an analogy: “Think of an Indian goddess with many arms. Imagine that on each of her fingers I could put a different coating to catch a different chemical. I could pick up five chemicals at the same time with each hand. This is the principle.” With 100 polypeptide “fingers” to catch metal, DB calculated that he could get a pound-to-pound ratio. So he called Sikdar.

“That’s a brilliant idea,” Sikdar told me, “but you’re going to need to prove you can do it. Do some experiments and write a proposal.” I needed money to get the proof. So Leonidas and I went to see David Watt, a fellow chemist and then vice chancellor for research. He didn’t have time to talk and said, ‘Come back to my office at 8:30 tonight.’ I did and pitched him my idea. ‘I need $10,000 fast to prove I can do this. I can promise with 99 percent certainty that you’ll get your money back a hundred-fold.’”

Watt thought DB’s idea, which innovatively melded biology, chemistry and materials, was a winner, and the next day got DB that 10 grand. “With the aid of a postdoc, I ran some experiments and voilà—got the EPA cooperative agreement grant.” Four patents, numerous publications, and many industrial applications later, that $10,000 investment yielded half-a-million dollars in funding from the EPA, Department of Defense and industry.

And to combat PCBs, that polypeptide concept morphed into the new world of nanotechnology. “But before we get into that, you need to understand that membranes are beautiful things in themselves,” says DB, who is also a faculty associate of the UK Center of Membrane Sciences. He adds that membranes are the bread and butter of chemical engineering. “I teach a

Membrane expert Dibakar Bhattacharyya, who came to UK in 1969, is using nanotechnology and free radicals to destroy PCBs in soil and groundwater. His nanoparticles break down PCBs by removing chlorine; then free radicals destroy the toxins.
This miniature membrane roll is an example of the material to which DB’s team attaches nanoparticles to filter out the toxic chlorine in PCBs.

graduate-level course in which I challenge my students to make a synthetic membrane that can last 90 years. Everything we know about membranes we’ve learned from the human body. Your kidney separates out proteins, getting toxins out of the body, day after day for 90 years. Why can’t we make membranes to do that?”

He says membranes are mostly used for filtering out things—for example in water desalination, water goes through but the salt doesn’t. But DB wants to catch and hold toxins instead of letting them pass through. That’s where the nanoparticles come in.

“If you have nanoparticles, you have thousands of surfaces,” like the fingers in his previous analogy. He takes a membrane with big holes (about 400 nanometers across), attaches polypeptide-like materials and creates iron nanoparticles coated with a tiny amount of palladium (a rare metal similar to platinum), then passes contaminated water through it to successfully break down PCBs. “The nanoparticles don’t destroy PCBs, but they do make them less toxic by removing the chlorine.” To completely eliminate the toxins, DB takes a second step: “We mix citric acid (an ingredient of vitamin C), iron sulfate tablets and hydrogen peroxide to make free radicals. And the free radicals kill PCBs.”

Go figure. Free radicals—molecules with unpaired electrons that can wreak havoc in the human body and are likely culpable in Parkinson’s and Alzheimer’s—are the solution to PCB destruction. “We’ve already used this free-radical technology at an industrial site in Kansas, so we’ve seen it work.”

He notes there are several ways to deploy these membranes: grind them up and inject them underground, use them above ground in a pump and filtering system, or line a groundwater holding pond with the membrane. “And soon we’ll apply our free radicals and nanotechnology to the Paducah Gaseous Diffusion Plant groundwater decontamination project.”

DB says no one has ever used free radicals like this before, and it comes as no surprise when he adds, “My philosophy is to thrive on the frontiers of science. You can’t follow the crowd. A bold approach equals science that makes a difference.”