Chemical Buzz

Honeybees and their hives act as sensors for pollution

By CORINNA WU

The canaries that used to accompany workers into coal mines had a serious job to do, serving as crude air quality sensors for methane gas. A canary that died in its cage warned miners to be cautious of methane, which can ignite and explode.

Although more sophisticated sensors have since replaced canaries in mines, humans still occasionally tap into the sensitivity of animals to detect chemicals in the environment. Bluegill fish, for example, have been used to monitor stream temperatures and water quality near waste treatment plants. Comparable efforts for terrestrial monitoring haven't been as effective, however.

That may change if Jerry J. Bromenshenk and his colleagues at the University of Montana in Missoula succeed in their attempts to develop a modern version of the miner's canary. Instead of birds, they're using honeybees to collect and measure environmental contaminants. On their forays from the hive, bees pick up water, nectar, and pollen—along with particles from the air containing whatever contaminants happen to be present. The little scouts bring it all back to the hive, where the scientists are waiting to analyze the loot.

Millions of hives exist across the United States, each of which can serve as a monitoring station for an area up to a mile in diameter. Instead of having people go out to gather samples and bring them back to the lab for analysis, the Montana scientists hope to recruit a force of thousands of bees to do the job.

Because bees are very efficient and undiscriminating collectors, Bromenshenk and his colleagues are using them to conduct broad surveys of contaminated areas. The insects get into everything—air, water, soil, and plants, Bromenshenk says. They are like "flying dust mops," with electrostatic charges on their bodies picking up both pollen and dust particles. The bees also ingest water and nectar from flowers.

Once back at the hive, bees fan the air furiously with their wings to regulate the hive's temperature, thereby releasing the pollutants and circulating the contaminated air through the hive. By analyzing the hive air and the bees themselves, scientists can identify what chemicals may be in the area.

Bromenshenk began using bees as environmental monitors about 25 years ago. The first significant demonstration of their usefulness took place in Washington's Puget Sound area in 1982, where many mining and smelting operations were located.

He enlisted the cooperation of 64 local beekeepers to collect samples from their hives from July to mid-September. Traps

U.S. Department of Agriculture

A honeybee buzzes around the blossoms of an apple tree.

at the hive entrances scraped off and collected pollen from the bees' hind legs. The keepers also periodically vacuumed bees into plastic bags and froze them.

Bromenshenk measured the amounts of inorganic elements, such as arsenic, cadmium, lead, zinc, copper, and fluoride, in the bees' bodies. Using the results of the tests, he mapped out patterns of metal contamination in the area. They corresponded well to similar maps that local agencies had drawn by analyzing soil samples.

Garon C. Smith, an analytical chemist, joined Bromenshenk's team in 1991 to extend the monitoring to organic contaminants. "The organic ones have been more difficult because bees are very fatty little animals," Smith says. "It's very difficult to separate out contaminants from all of the organic constituents that are in bees and beehives."

Analysis of organic chemicals is nevertheless part of their current project, known as Bee Alert, a 5-year collaboration with the U.S. Army Center for Environmental Health Research at Fort Detrick, Md. The center is providing contaminated sites for the scientists to study. Smith and his colleague Ghassan Alnasser presented the group's recent findings in April at a meeting in San Francisco of the American Chemical Society.

The researchers are monitoring three sites at Aberdeen Proving Ground, Md., where the Army once manufactured chemical weapons and currently stores mustard gas in large tanks (SN: 5/3/97, p. 270). One site is a hazardous waste landfill that had been used to dispose of chemical weapons, phosphorus, and industrial solvents. The second site, where a chlorine plant once stood, lies along a creek that empties into a saltwater marsh. That site had been lightly cleaned up 2 years ago. The third site, 10 miles away, is on a farm owned by a hobbyist beekeeper. The scientists are using the farm as a reference for background levels of contaminants.

The team has installed new high-tech, portable electronic hives at the sites, each containing from 7,000 to 10,000 bees. A small copper tube attached to the side of each hive pumps air out for analysis without disturbing the bees. This air passes through filters that trap the organic components. When the filters are heated, the volatile organics go through a gas chromatograph and the separated compounds move into a mass spectrometer. The scientists can then determine exactly what each component is.

"You could technically put a copper pipe in any hive in the country and sample the air inside," says Smith. That vision translates into millions of potential sampling stations.

The researchers found that concentrations of contaminants inside the hive were much higher than those outside; the bees efficiently consolidated environmental substances. As expected, the dump site had the highest concentration of contaminants, but the hobbyist beekeeper's hives, surprisingly, had higher readings than those at the second Army site.

Of seven organic chemicals identified, the most prevalent at all three sites was perchloroethylene, a degreasing agent best known as a dry cleaning solvent. The dump site contained much higher amounts than the remediated site or the farm.

On the farm, the contaminants were mostly pesticide residues. The scientists also detected a compound there called hydroxymethyl furfural. It turned out that this substance wasn't present in the environment, it was in the corn syrup that the beekeeper fed to his bees as a nutritional supplement. The syrup supplier told the beekeeper that the compound is a by-product of fructose processing.

For metals and other inorganics, the researchers looked at the substances incorporated into the bees themselves. Overall, the concentrations were the same as background levels in other parts of the United States. No significant amount of arsenic was found, even though previous studies indicated that it contaminated the sites. If the element is still present, the bees don't pick it up.

That's an important distinction. Not all substances in the environment get into living organisms, whether bees, birds, or people. "This system shows you what's directly available to the biota in the region," says Smith. Instead of extrapolating from soil or water measurements, "here we're directly measuring what was bioavailable to something that is fairly low on the food chain."

The Army plans to release a complete report of the findings once they've undergone internal review.

In these studies at Aberdeen, the researchers are combining information from all the hives at each site. Bees from adjacent hives often collect from different locations.

To determine where the bees go to forage for food, a botanist examines the pollen grains under a microscope to see what kinds of plants they come from. Researchers can determine 75 percent of the pollen sources this way, says Dewey M. Caron, an entomologist at the University of Delaware in Newark who kept an eye on the Aberdeen bee colonies over the winter.

"A lot of times, beehives that are side by side show very different levels [of contaminants]," Smith says. "That's indicative that one hive found a hot spot, and the other hive was foraging in an area that wasn't contaminated. If all the hives in a cluster came back with high levels, then it would say that it's a general area wide contamination."

At the dump site, for example, four of the eight hives registered much higher contamination than the others. It turned out that the bees had found an abandoned, open chemical storage container.

To deal with the enormous amount of data from the beehives, the researchers are beginning to use artificial neural networks in their analyses (SN: 11/26/88, p. 344). In some preliminary tests, which Smith presented at the meeting, they used a commercially available neural network program to see if it could match a chemical fingerprint to a hive.

The hive fingerprints are the gas chromatograms, which show peaks corresponding to the substances in the air samples. The researchers characterized chromatograms taken from the hives in Montana with three values: the number of peaks, the height of those peaks, and the area under each peak.

They fed 80 percent of their data into the neural network program, essentially teaching it to recognize the chemical profile of each hive. "I can't look at a chromatogram myself and tell which hive it came from," Smith says.

Then, the researchers gave the program the remaining 20 percent of the data and asked it to match the chromatograms to a hive. The program got every one right, Smith says.


Smith

Three beehives outfitted with electronic sensors monitor a hazardous waste dump site in Maryland. A birdhouse on top conceals weather-monitoring equipment.

Ideally, the researchers would like to obviate the need to do chemical sampling at all. They think they may be able to find links between environmental contamination and the bees' activity levels.

The Montana group's electronic hives monitor bee activity through a sophisticated counting system that registers how many bees leave and enter the hive throughout the day. To go in or out of the hive, the bees must walk through tunnels at the entrance, passing two infrared beams on the way. On a typical day in Montana, the counters register 200,000 trips a day from a hive containing about 10,000 bees.

Other bee counters exist, says Michael Burgett, a bee scientist at Oregon State University in Corvallis, but Bromenshenk "has built the grandest one of them all."

The bees have learned to go through the tunnels so well, Smith says, that even when the beekeepers open up the front of the hive, the bees do a 90° turn to crawl through the tunnels before flying out.

The scientists are beginning to compare activity with factors in the environment. A weather station on top of the hives allows the scientists to correlate weather to hive activity. When a storm comes, for example, the entrance counts skyrocket, reflecting the large number of bees coming back to the hive to stay dry. On the other hand, when the beekeepers send puffs of smoke into the hive to calm the bees, the counts drop.

Among the seven hives at the hazardous waste dump in Maryland, the researchers found that the hives with the highest contaminant concentrations were missing their queens. They had either died or left to find better real estate.

The scientists intend eventually to use the same neural network program that successfully analyzed air chemicals to examine the activity profiles. That accomplishment would move the bee monitoring technology one step closer to automation.

Caron emphasizes that, so far, a lot of the work is focused on determining the baselines for honeybee behavior, in order to have something to which anomalies can be compared.

"Our ultimate goal is to use the bee behavior as a tip-off to the existence of a chemical problem," says Smith. "Running a beehive is fairly inexpensive, compared with doing ongoing chemical sampling. To sample the same milewide area with [conventional] samplers would just be unfeasible."

The researchers look forward to the day when the technique moves beyond assessing normal events, such as weather, and can warn them of chemical changes in the environment as they happen. Then, the busy bees will be working not only for their brothers and sisters in the hive but also for the humans watching their every move. □