

“Tunnel Vision” Tracks Emissions

In the basement of the ARS National Soil Tilth Laboratory (NSTL) in Ames, Iowa, a tunnel resting on a waist-high platform—and large enough for a person to fit in comfortably—stretches down a side hallway.

“We got it secondhand from an out-of-state university,” soil scientist Tom Sauer says. “It had been used for heat-transfer studies, and it was scheduled for disposal.”

Sauer and his colleagues are using the tunnel to model how air emissions from animal-production facilities travel across the landscape and to develop strategies for minimizing the impact of these emissions.

Air flows across the land the way water flows over and around rocks and other barriers in a stream. As winds approach a building, storage tank, or other structure, the air currents accelerate around the sides and over the top of the structures. The shift in speed creates new disturbances in the downwind airflow.

These dynamics dictate the effectiveness with which air traveling over an animal-production facility can pick up and transport problematic emissions from manure, dust, and other sources. Some of the prime offenders are ammonia and hydrogen sulfide, which have noxious odors, and methane and nitrous oxide, which are both greenhouse gases. Emission of tiny particulate matter—now known as a hazard to human health—is also a concern.

These emissions can come from buildings, fields, liquid-waste lagoons, or manure pits. Wind speed and direction, topography, structures, facility management, climate, and vegetative cover all affect airflow—and affect where these emissions end up. Even the smallest facility will have a range of variables that significantly affect the amount of emissions that are transported, the strength of those emissions, and their final destination.

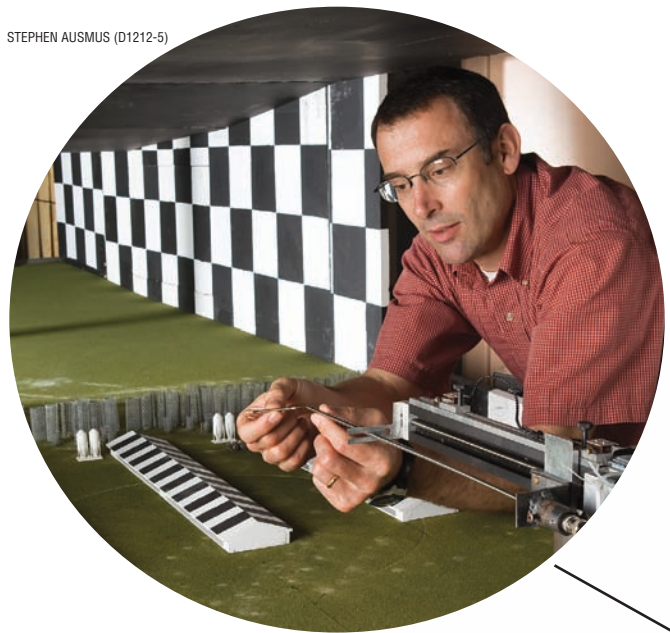
“Carrying out air emissions testing in an actual animal-production environment is expensive, and practically speaking, it’s just difficult,” Sauer says. “And if we do conduct studies at an actual facility, our results can only be applied to that facility and to the conditions that were present during the tests. Any data we collect will have limited value for developing general models of emission transport.”

Studies on a New Scale

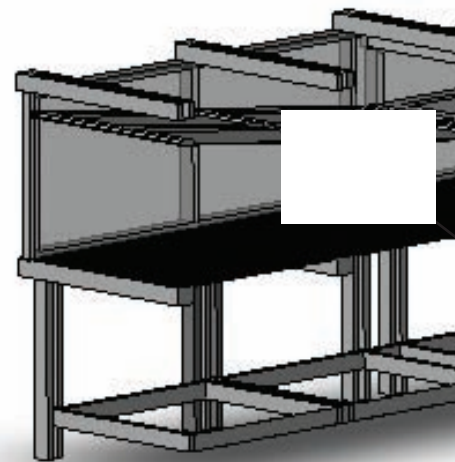
So Sauer and plant physiologist Jerry Hatfield—who is also the NSTL director—embarked on a 3-year study that involved a series of wind tunnel tests. They wanted to see how the location and placement of buildings and waste-storage facilities affect the transport of odor constituents like ammonia and hydrogen sulfide. The National Pork Board contributed financial support for this research.

Previous tests with enclosed wind tunnels—where the variables of dynamic airflow can be monitored on scaled-down versions of landscapes—have shown that these scale model studies provide accurate and reproducible assessments of field conditions. Wind tunnels had rarely been used to study agricultural buildings, but

STEPHEN AUSMUS (D1212-5)



With most of his upper body inside the wind tunnel, soil scientist Tom Sauer exchanges one of the highly sensitive sensor tips in the hot film anemometer before one of many experiments measuring airflow and turbulence.



Sauer and Hatfield saw them as a cost-effective tool for gathering data that would help define local airflow dynamics.

With a low-velocity wind tunnel, the researchers would have the ability to change air velocity and turbulence, air temperature, and the angles at which air swept past the models. And wind tunnel studies could complement data gathered at animal-production facilities by recreating similar conditions in a physical model and then repeating measurements with changing variables.

“We wanted to find out whether aboveground manure-storage facilities and lagoons that are located downwind of buildings or other structures are exposed to increased wind speed and turbulence—or if the upwind structures actually protect them,” Sauer explains.

Dispersal

Sauer arranged for an existing wind tunnel to be rescued and brought to Ames, where it took a year to reassemble and modify. When the 40-foot tunnel was ready for action, a 6-inch-square checkerboard pattern was painted along one wall to provide scale for photographs and flow-visualization tests.

The heart of the wind tunnel is a 1950s Army surplus blower with a 15 HP electric motor located at one end to generate maximum windspeeds of 30 miles per hour over the scale models.

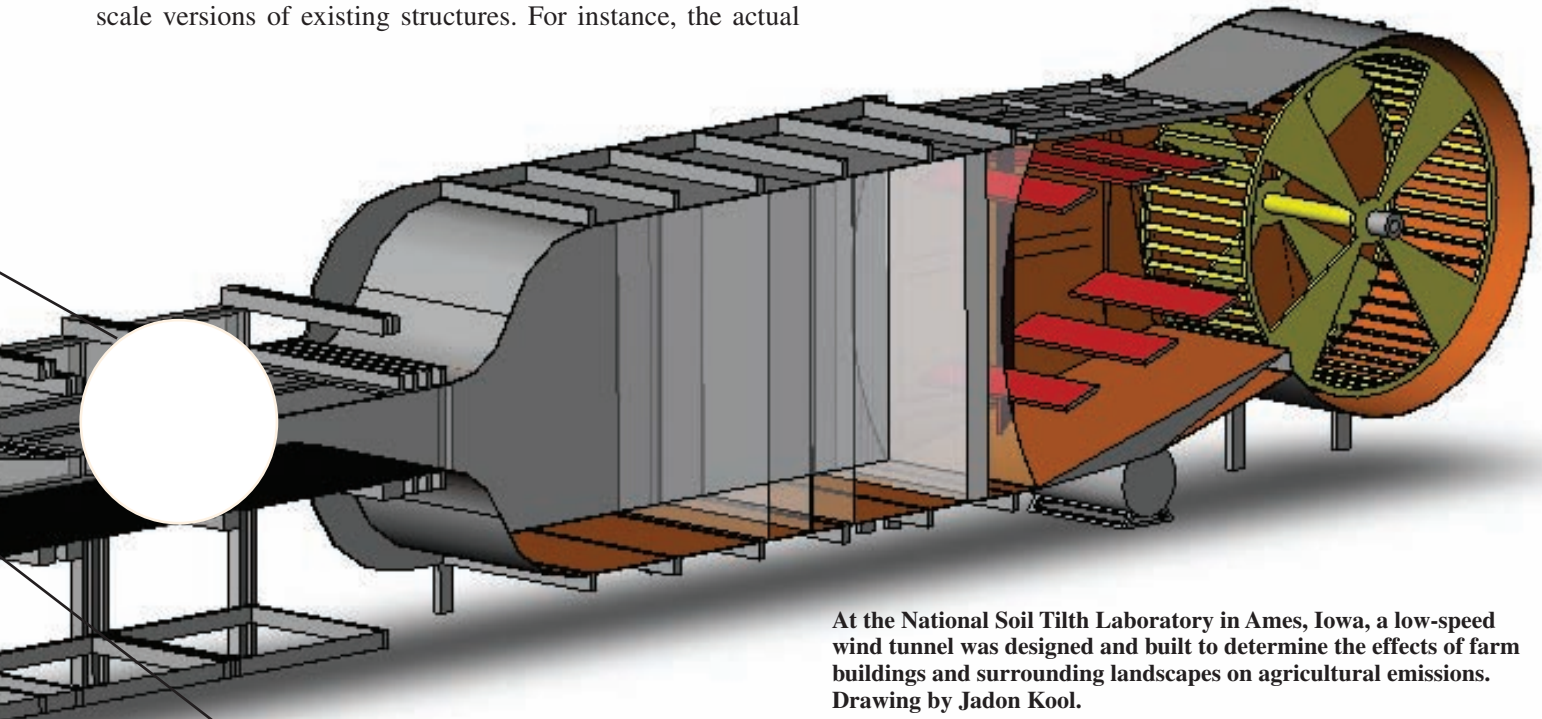
A Model Farm

Sauer and Hatfield then constructed their test farm, complete with scale replications of swine-finishing units, above-ground slurry tanks, and lagoons. Their balsa wood models were 1:300 scale versions of existing structures. For instance, the actual

pig-finisher units modeled were about 40 feet wide and 200 feet long, with maximum 17-foot peak heights.

The scientists arranged four of these model buildings on their “farm” in several different configurations with the model storage tanks. All the structures had magnets on the bottom, which allowed the scientists to easily reposition the models—and kept them from being tossed around by the variable breezes.

The floor of the tunnel near the models was covered with a vinyl mat—the kind used by model railroaders—which mimicked a groundcover of cut grass. In some tests, a windbreak, created from eight rows of 2-inch-high wire-mesh model trees, was positioned upwind of the building models and downwind of the manure-storage models.

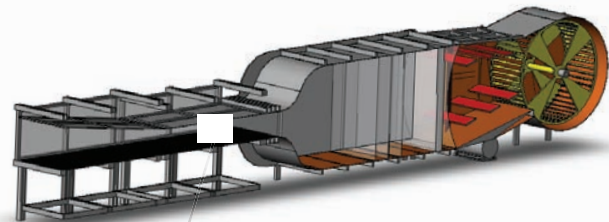


At the National Soil Tilth Laboratory in Ames, Iowa, a low-speed wind tunnel was designed and built to determine the effects of farm buildings and surrounding landscapes on agricultural emissions. Drawing by Jadon Kool.

To better interpret airflow patterns around physical structures, plant physiologist Jerry Hatfield (left) and Tom Sauer use smoke to help them observe airflow patterns inside the wind tunnel.



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Sauer and Hatfield also set up obstacles to create a surface boundary layer of air that would mimic the effects of Earth's atmospheric boundary layer. An array of triangular spires and a short fence upwind of the model facility helped to generate air turbulence of the correct scale and intensity, which then flowed through and around the obstacles.

Models of the lagoons and storage tanks presented a different challenge. The scientists did not want to use actual odor-generating vapors in their studies.

"We're in a laboratory facility," Sauer notes. "We figured the other people here wouldn't appreciate the authenticity." Instead, they used water vapor or smoke from dry ice to stand in for ammonia and hydrogen sulfate emissions.

When the miniature stage was finally set, they turned on the fan and held onto their hats.

A Mighty Wind

Air flow velocities and turbulence intensities were measured with a sensor attached to a robotic arm that could move in all directions. The sensor—which consisted of a very fine quartz-coated wire—could be heated to more than 900°F, and it measured how quickly the winds carried heat away at 83 points behind the building models.

STEPHEN AUSMUS (D1214-20)



Using model farm buildings, silos, and trees (wire mesh coils serve as trees), agronomist Guillermo Hernandez (left) and Tom Sauer evaluate the effect of model arrangements on airflow. Hernandez makes an adjustment to one of the highly sensitive probes as Sauer monitors the real-time data signal.

Sauer and Hatfield took pictures of the smoke patterns generated by the dry ice to capture airflow patterns around the model structures. They also measured evaporation rates from the model storage tanks and lagoons. For some of their trials, they added a "hill" and repositioned some of the other structures to assess the effects of surface roughness and topography on airflow and emissions transport.

After the winds died down, a computer program sorted out the data generated by the range of velocity patterns and turbulence intensities. The researchers found that when livestock buildings were situated parallel with airflow, small and discrete turbulent wake zones resulted. These zones converged at higher velocities, and partially dissipated by the time they reached the equivalent of 170 feet downwind.

But buildings situated perpendicular to airflow created a larger—and taller—turbulent wake zone and had a significant downwind flow that persisted out to the same distance.

Sauer and Hatfield also found that structures on average slowed air velocity by around 67 percent. Not surprisingly, buildings placed perpendicular to the airflow had the greatest effect, while buildings at a 30-degree angle only slowed air velocity by around 38 percent.

"These studies show how much the placement of animal housing units and manure-storage facilities can work in combination with prevailing winds and site conditions to affect the distance that potential agricultural air emissions can travel," says Sauer. "They strongly indicate that we should be able to reduce the downwind air-quality impacts from animal production by modifying the layout of a production facility."

"Now that we have wind tunnel observations on airflow velocity patterns, we'll also be able to suggest an optimal placement for field sensors when we carry out studies on actual facilities," Hatfield adds.

These findings also show that producers could derive a direct—and permanent—benefit of improved air quality with just the one-time cost of figuring out the best building placement.

"In our air-emissions research, we're dealing with the same type of questions that water-quality scientists work with," Hatfield notes. "How do agricultural practices fit into the landscape? How do they help producers and benefit the environment? We're trying to find the best ways to reduce the environmental footprint of agriculture and to enhance our natural resources."—By **Ann Perry, ARS.**

This research is part of Air Quality, an ARS national program (#203) described on the World Wide Web at www.nps.ars.usda.gov.

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