B. ELBERT

WHAT IS THAT SMELL?

Jacek Koziel is a master of odours. On an pig farm in Iowa, he shows **Erik Vance** some of the peaks and troughs of life as a human detector.

Hooking up to Jacek Koziel's olfactometer is a little like having a photo album of your childhood shoved in your face. It can be offensive, sometimes painful, yet distinctly nostalgic.

Seated in Koziel's Iowa State University laboratory in Ames — with my eyes closed, and my ears covered by soundproof headphones to isolate the sense of smell — a glass cup over my nose delivers an olfactory slide show. The scents come at regular intervals. Some are strong, some less so. My job is to categorize them on a screen in front of me.

For the untrained, identifying the odours is surprisingly hard. Most of the time I get a memory rather than a name. One has a hint of lemonade and summer afternoons. Another smells like summer camp. A third reminds me of a high school girlfriend's lip gloss.

For each one, I click a tab from the computer list in front of me with labels such as 'floral', 'cardboard' and 'rancid'. Then one hits me like an angry bull. I recoil from the machine, regain my composure, and click 'fecal'. My reaction is probably not surprising because the sample came from the gas given off by swine manure.

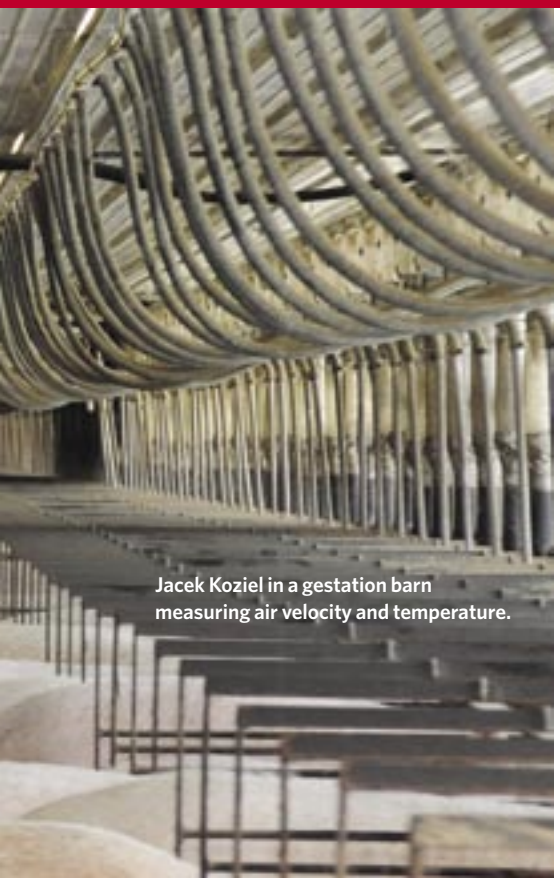
Koziel is an analytical chemist in the Department of Agricultural & Biosystems Engineering where he specializes in finding and identifying trace volatile organic compounds responsible for odour. His lab teases apart all kinds of odours, including corn (maize), wine, and the bitter fluids that insects use to defend themselves. But his "bread and butter" is livestock leavings, an incredibly complex chemical matrix. Koziel's lab is a leading authority, having catalogued almost 300 ingredients in swine manure — some of which only exist at concentrations of a few parts per million. His work is part of an international effort to understand and remove these compounds from daily life. It is a dirty job, but one that may have growing economic importance as residential areas increasingly encroach on farmland and demand for food grows.

"Early on it was exciting and that's when I made a lot of faux pas at home."
— Jacek Koziel

Koziel lives and works in a world of odour. A sign on the wall of the lab urges "good personal hygiene" while warning against wearing perfumes or scented deodorants. At the base of every whiteboard Koziel keeps scented markers to help researcher 'build awareness' of odour. And if a fume hood is accidentally left up, one quickly wonders who has broken wind.

Most people in the small, dedicated community of agricultural-odour research casually refer to odour as air pollution. But technically speaking, the United States only regulates two of the smellier ingredients of manure — ammonia and hydrogen sulphide — for their other negative effects on soils and water sources. They are also the easiest smells to single out. "There is a tendency to go after gases that are easy to measure and historically that has been ammonia or hydrogen sulphide," says Koziel. Yet government regulations are not nearly as likely to shut down a factory farm as neighbours' complaints, which spring from a wide suite of smelly chemicals. That is because odour is the only 'air pollutant' that almost every person living nearby has state-of-the-art detection technology for: the human nose.

It is this technology that allows Koziel to catalogue manure's most offensive components. He uses a Gas Chromatography Mass Spectrometry Olfactometer (GC-MS-O). Gas chromatography separates gas samples taken from the air just above manure into different groups, based on molecular weight. Then it runs each group into two simultaneous ports. One goes to a mass spectrometer that prints out a detailed chemical analysis of the compounds. The other comes wafting out of a



Jacek Koziel in a gestation barn measuring air velocity and temperature.

'sniff port' into a researcher's waiting nose.

This blending of quantitative analysis with qualitative description allows Koziel to create detailed chemical maps and find the smallest traces of compounds. Take 2-isopropyl-3-methoxypyrazine, a compound that Koziel discovered in ladybirds that accumulated on the windowsill of his old office. A mass spectrometer barely registers the compound in the cocktail of chemicals found in ladybirds. But it is unbelievably bitter stuff that the human nose can detect in the parts per trillion. Found in wine when ladybirds get crushed with the grapes, it adds a flavour often associated with a bell pepper (*Capsicum*). Using human noses, Koziel pinpointed the offensive region of the chemical fingerprint and was able to isolate the noxious ingredient by essentially zooming in on that region (a technique called multi-dimensional GC-MS-O).

The collector

Koziel shows me a sample of the methoxypyrazine along with a few dozen other dark bottles in a small cabinet covered with colourful warning stickers. It is housed in a sealed container, within another sealed container, within another sealed container and is part of a frightening collection. They are the foulest odours that Koziel has come across in his work — and suffice to say, it is not a place one would want to see anything spill — just opening the wrong bottle could make the lab stink for days.

In the complex matrix of animal manure, strong but scarce compounds like these are almost impossible to spot, yet minimizing them may cut down on odour. Koziel's use of GC-MS-O has allowed him to create a very comprehensive view of manure that includes pungent bitter compounds, as well as one that smells like buttered popcorn and another described as 'taco shell'.

Koziel calls himself a "smelling weirdo". Nearly anywhere he goes, he can recognize at least a few chemicals in the air. He says that distinctive flavours of body odour, red wine and mushrooms can all be found in manure. "You become more aware of the smells around you and you say 'wow this smell smells like this chemical.' So you start making associations," he says. "Early on it was exciting and that's when I made a lot of faux pas at home."

He once casually compared a meal his wife had made to manure. And there are the times when a family member breaks wind and he ventures to guess what they ate. Ironically, his wife says that one of the things that first attracted her to Koziel was that he smelled like the outdoors. Koziel came to the United States to climb Mt McKinley and stayed to help his climbing partner raise money for hospital bills after he lost both feet to frostbite in the attempt. It is odd to think of a mountain climber with ascents in the Andes, Indonesia and the Himalayas doing research on an Iowa pig farm, but Iowa, he says, "is a good place for odour. I have different mountains to climb, in a way."

"Smell affects proposed facilities. If someone wants another farm, then the odour is going to be the issue."
— Al Heber

Mountains of manure

The next day, we visit one of these mountains in the cornfields of central Iowa — a pig-birthing facility where Koziel monitors ammonia, hydrogen sulphide and dust. It is part of a nationwide detection study to quantify livestock-facility emissions. The head of that study — the National Air Emission Monitoring Study — is Al Heber. He says you cannot separate odour from air pollution. And although stink isn't a federal air pollutant, it is often the most crucial element in air-pollution debates.

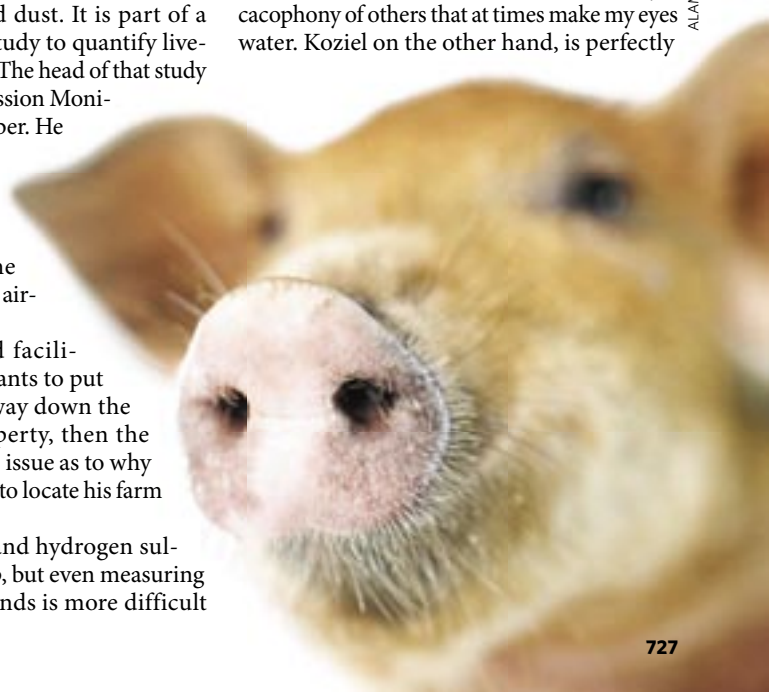
"It affects proposed facilities. If that producer wants to put another farm a mile away down the road on his other property, then the odour is going to be the issue as to why he might find it difficult to locate his farm there," says Heber.

Tracking ammonia and hydrogen sulphide is a good first step, but even measuring two abundant compounds is more difficult than it sounds. For one thing, where do you sample? Next to the farm, or next to the houses two miles away? And because odours are subject to wind and temperature, when are the most representative times to sample? And assuming you find the best time and place to sample, what is the best way to do it?

On the drive to the pig farm, not only does the smell become stronger, but it also becomes sweeter — almost like a Doppler shift of colour. That, Koziel explains, is because different odours diffuse at different rates.

Because technology cannot detect odour's reach, the most common way to measure it is dilution olfactometry — essentially letting people smell a bit of air and asking them if it stinks. Koziel's colleague at Iowa State University, and regular co-author, Steve Hoff is an expert in this field. He collects samples of air in specialized bags, dilutes it with odourless gas until a panel of paid sniffers cannot detect the scent. This is the 'odour threshold'. Techniques like this are the primary tools for quantifying odour. The problem is that often his data are essentially subjective, because one man's stink is another man's farmyard aroma.

At a modern industrial factory farm, however, there are no nice ways to describe the stench. Inside the large, squat building that is Koziel's research site, 3,000 sows are either nursing piglets, having piglets or waiting to have piglets. Under the slats at my feet is one of two pits, each the size of a football field, five metres deep with manure. The sweet scent I sensed outside is now overpowered by a cacophony of others that at times make my eyes water. Koziel on the other hand, is perfectly



ALAMY

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Jacek Koziel conducting simultaneous chemical and nose 'detection' analyses of air samples.

at ease and sets about showing off a few of his hundred instruments in the building.

"This is the toughest air sampling that you can imagine. Climbing stacks or sampling smelters is okay, but this is a different ball game. You have so many variables that you have to think about," Koziel says with a rare touch of visible pride. "There is no one chimney where you just stick in your probe."

Then there's the dust. Animal dander and other particulates pump out of a pig farm at a couple grams per cubic metre (double that for poultry). Over time this builds up, covering Koziel's detectors and every flat space in the feedlot with a millimeter or two of dust. The dust contributes to the odour's spread by carrying stowaway chemicals on the wind, but no one knows for sure to what extent.

Sticky mess

Two showers later, I get a sense of what the dust experiences. Many of the chemicals breezing about an industrial hog farm are what Koziel calls 'sticky'. That means that they are heavy molecules with a low vapour pressure that are often polarized. When they encounter skin, cotton or anything else with pores and crevices, they stay there. The worst will even stick to plastic or glass, making them nearly impossible to collect and measure.

These are not the easy-to-spot sulphides, but volatile fatty acids, indoles and phenols that are not a part of Heber's study. Heber says he hopes to approximate the concentration of these chemicals by measuring things such as dust and ammonia. However, in other parts of the world it's not clear that ammonia and odour are necessarily linked.

"It has an odorous component, but I don't think ammonia is really important for odour," says Nico Ogink, a farm odour scientist at the Wageningen University and Research Centre in the Netherlands where Koziel will be taking a sabbatical. "It is only important to me because of its effects on natural areas ... the acidifying effect on the environment."

Ogink says that although ammonia is much more damaging to the environment, rarely does it have the ability to reach noses far from its source. This is a crucial point in the Netherlands, which has almost as many pigs as people, and where more than half of the substantial nitrogen pollution comes from livestock. In one study, 11% of the Dutch population reported being annoyed by livestock odour — more than industrial activities and traffic.

It is difficult to say how big an effect stink has on the wallets of farmers, and industry representatives are loathe to dwell on it, but several European countries such as the Netherlands, Denmark and Germany are heavily investing in odour mitigation through a series of odour-specific regulations. In Europe, the answer is often some kind of technological filtration system. These may be bio-scrubbers, bio-filters or acid scrubbers, similar to the ones that that many countries use to cut sulphur dioxide from coal-plant emissions.

> **"Sampling in pig farms is the toughest air sampling that you can imagine."**
> — Jacek Koziel

The scrubbers work by exposing the air to water, which will absorb dust and suspended pollutants. European scientists say modern filters can cut odour emissions by 30–90%, depending on the conditions and whether they combine several techniques together. But acid scrubbers add about €5 (US$7) to the cost of each pig.

In the United States, where odour regulations are administered locally, mitigation may be a slurry pond out back (a practice that has led to problems in flood-prone areas) or a storage silo. Koziel's lab is working on its own mitigation techniques, most notably one that attempts to use ultraviolet light to break smells into component parts. The process is similar to the photochemical reactions that change car exhaust into smog, only instead of creating ozone, it creates smaller, less smelly chemicals. He has also researched changes in livestock feed to try and cut the stink. Similar studies are widespread on both sides of the Atlantic Ocean. But Koziel is hesitant to suggest that US farmers adopt expensive mitigation approaches.

"We would be laughed at," he says. "These people work on very small margins of profit. They make money because they have a lot of animals."

When I suggest it to long-time pig farmer Chad Pierce at the Iowa pig farm, he doesn't laugh, but it is clear that's because he is trying to be polite. In good years, he can expect just $5–$10 per pig in profit. Last year, with higher feed prices, the birthing facility actually ran at a deficit. In the case of smell-reducing feed, he says he wouldn't be opposed to it, but it's not a very high priority.

However, Pierce acknowledges that odour regulations may be on their way. And not just in the United States. One of the researchers in Koziel's lab, Lingshuang Cai, is originally from China. She says that as cities expand and citizens develop more of a taste for meats like pork, the Chinese government is increasingly interested in odour mitigation. While their commitment is generally ranked even lower than that of the United States, Cai says she has been offered numerous jobs in China working with manure.

But for now she is content in Iowa with Koziel and his mountains of smell. Stop by sometime if you are in the area. But whatever you do, don't go nosing about in the little cabinet just past the smelly fume hood — the one with the colourful warning stickers. ■

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