Sniffing Out Air Quality with an Electronic Nose

At NASA's Jet Propulsion Laboratory, Dr. Margaret Amy Ryan and her team are developing an "electronic nose" to monitor air quality on the International Space Station. The electronic nose will enhance crew safety during space flight and has many potential ground-based applications ranging from industry to medicine.

Spacecraft, by necessity, are closed environmental systems. Air quality monitoring is a priority because airborne contaminants can build up quickly and potentially affect all onboard. Trace levels of certain gases can also offer early warning of leaks and fire dangers such as overheating electronics. Rapid detection is important, but many contaminants are only monitored by the crew's collective sense of smell.

To address these concerns, Margaret Amy Ryan and an interdisciplinary team of scientists and engineers at NASA's Jet Propulsion Laboratory (JPL) have developed a high tech upgrade of the astronaut olfactory system in the form of an electronic nose.

Like a Real Nose, Only Better

An electronic nose is an environmental monitor that mimics the mammalian olfactory system. When a real nose samples the atmosphere by sniffing the air, thousands of receptors in the nose react. Rather than individual receptors identifying particular compounds, a pattern is generated from the response of the entire sensing mechanism. This results in what we experience as odors. The sample pattern is compared to the odor patterns in our memory, and this is how we recognize that there is a gas leak in our home or that someone near us is wearing perfume.

The electronic nose at JPL works in a similar fashion. An air sample passes over an array of 32 non-specific sensors, consisting of various polymers impregnated with carbon and mounted on computer chips. The electrical resistance of the sensors changes in response to the chemical makeup of the air sample. The response pattern of the array as a whole, computed by an algorithm, identifies the presence of various compounds and their concentration.

While the human nose is still the best available monitor of general air quality, an electronic nose offers a number of advantages. As Ryan explains, "The human nose works on the basis of difference. If you sit in a room that has a smell, after a few minutes, you don't notice it anymore. It's only when you leave the room that you notice the difference." In the case of a gradual buildup of a contaminant from a slow leak, an astronaut may not notice an odor until the concentration is much higher than what an electronic nose would detect. Another weakness of the human nose, says Ryan, is that "if you get a really strong whiff of something, your nose just goes numb. You can't smell anything for a while. Your nose fatigues, and then you're just out of luck."

In a greenhouse test, the electronic nose was able to determine whether particular plants were blooming and when.

If a toxic leak were to occur on the Space Station, astronauts would don breathing apparatus until the air filtration system had reduced the contaminant to an acceptable level. However, without an electronic nose, the crew would have to risk exposure to determine if the air was breathable again. In addition, some toxic compounds are odorless and therefore undetectable by the human nose.

In 1998, Ryan's team tested the electronic nose on the STS-95 Space Shuttle mission. On that flight, the nose successfully detected ten toxic compounds at the 1-hour Spacecraft Maximum Allowable Concentrations (SMAC) level. The JPL nose worked just as effectively in space as it had on the ground.

Next Steps for the Electronic Nose

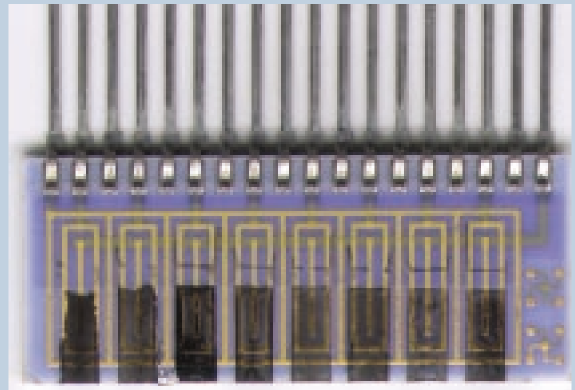
The electronic nose represents an exciting area of technology now because of its many potential applications. In food processing, electronic noses could be used to monitor food quality and freshness. In industrial settings, they could be used in process and quality control. In medicine, they could be diagnostic tools and in agriculture, plant growth monitors. In nearly any setting, they could monitor workplace and environmental safety, especially against bioterrorism. Because of its many potential uses, development of the electronic nose is going on at other sites as well as at JPL.

The next generation JPL nose will possess a unique combination of features. The device already offers the ability to switch sensor arrays. This means that not only can the array be replaced when sensors wear out, but a single electronic nose can be used for multiple applications merely by swapping one array for another suited to different compounds or different sensitivities.

Ryan's team plans to improve the device in three areas: sensitivity, number of compounds detected, and miniaturization. Since the STS-95 flight, the team has increased sensitivity for the ten compounds detected in that experiment from the 1-hour SMAC level to the 24-hour level. SMAC levels are set for 1-hour, 24-hour, and 1-week periods, with the allowable concentration level decreasing as the period of exposure increases. The sensitivity increase of the JPL device represents a significant advance from the 10-100 parts per million range to the single to fractional parts per million range. The next step is to add 15 additional compounds to the detection list and sense them all at the 24-hour SMAC. According to Ryan, "We need to be able to say, 'Okay, here's your problem and here's where it lies on the SMAC level.' To determine what to do about a contaminant, you need that information."

To achieve this level of sensitivity across 25 compounds, the team is looking at a number of factors, including the types of polymers used in the sensors, sensor size and orientation, and air flow through the device. "In addition," says Ryan, "we would like to be able to classify compounds that we can't identify. For example, we might not be able to identify something, but we could say it's an organic acid. Right now we are analyzing data to see if we can find characteristic sub-patterns that tell us the class of a compound." In terms of miniaturization, the next generation nose will be one-third the volume and one-fifth the weight of the device that flew on STS-95.

The next generation electronic nose will be a fraction of the size and weight of the system that flew on STS-95, pictured here. (Ruler in front of unit on right is 10 cm.)



One of four computer chips containing eight sensors that respond to the presence of airborne toxic contaminants. The chip is 2.5 cm wide.

Now that they know the device works in space, the team will next test the upgraded nose on the ground in an environmental test chamber. "Space flights are really clean and what we need are really dirty atmospheres to challenge the ability of the electronic nose to detect and identify compounds. We need to have an atmosphere where we can throw a lot of gunk at it," says Ryan. "The measure of success for this phase is whether we can take our device, put it in our chamber, throw any of the 25 compounds at it, and in combinations of three or four, identify and quantify them."

References

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