

Burping bacteria: Identifying Arctic microbes that produce greenhouse gases

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Sandia National Laboratories technologist Jenna Schambach working with a sample of Alaska lakebed soil. By studying the microbes in the soil, and the gases they emit, Schambach and project lead Chuck Smallwood hope to improve our understanding of the rapidly melting Arctic permafrost and improve computer models of climate change. Credit: Craig Fritz

As greenhouse gases bubble up across the rapidly thawing Arctic, Sandia National Laboratories researchers are trying to identify other trace gases from soil microbes that could shed some light on what is occurring biologically in melting permafrost in the Arctic.

Sandia bioengineer Chuck Smallwood and his team recently spent five days collecting lakebed soil and gas samples. They were joined by international collaborators led by professor Katey Walter Anthony from the University of Alaska, Fairbanks, including researchers from the University of Colorado Boulder, University of Quebec in Rimouski and Ben-Gurion University of the Negev in Israel.

"The Arctic is rapidly changing, releasing large amounts of [greenhouse gases](#); we just don't know how much greenhouse gases are released every year," Smallwood said. "Our work at Sandia seeks to improve our understanding of how much greenhouse gases [soil microbes](#) are producing, without going out and destructively sampling permafrost soils. The goal is to use sensitive gas detection devices to sample microbial volatile compounds coming out with the [methane](#) and CO₂ gases instead."

Both methane and CO₂ are greenhouse gases, and methane actually traps more heat in the atmosphere than the commonly discussed CO₂. In fact, it is 30 times more potent than CO₂, Smallwood said.

Collecting samples of soil and microbes

To measure rates of microbial activity in permafrost soil systems, Smallwood's team partnered with the University of Alaska, Fairbanks team to collect their first permafrost samples in late March at two frozen lakes formed from thawing permafrost about 20 minutes north of Fairbanks, Alaska. They also collected samples this September. Next year, they plan to collect samples from thawing coastal marshlands near

Oliktok Point on the North Slope of Alaska.

To collect a soil sample from a lakebed, first a member of the University of Alaska, Fairbanks team would put on a harness connected to a rope and walk out onto the frozen lake to clear snow from the frozen lake surface and check for signs of thin ice, Smallwood said. Then the researchers prepared the site by using a chainsaw to cut down through three- or four-foot-thick ice to remove huge ice cubes.

The team then positioned one of two coring apparatuses over and around the hole in the ice, Smallwood said. One apparatus provided by University of Alaska, Fairbanks scientist Chris Maio, called a hammer corer, collects 3-foot-long samples while another, called a Vibracore sampler, collects deeper samples, up to 13 feet.

The Vibracore drilling apparatus contains a long 3-inch diameter tube that would rapidly vibrate through the lake, down into the lakebed. Using suction—similar to a child playing around with a straw and their finger to suck up soda—the researchers removed 3- to 10-foot-long cylindrical "cores" of lakebed soil containing microbes that have lived there for hundreds to thousands of years.

These core samples were frozen and shipped to New Mexico for Sandia technologists Jenna Schambach and Bryce Ricken to extract microbes, including bacteria and archaea. Archaea are single-celled organisms similar to bacteria, but they have many biological similarities to the nuclei-possessing eukaryotes that comprise multicellular organisms like humans and trees. Many archaea can thrive in extreme environments such as geysers, very salty lakes and sulfurous deep sea vents. Archaea are of particular interest to Smallwood and his team because evidence suggests they are the primary methane producers.

During their March field expedition, the research team also measured

[greenhouse gas emissions](#) from their various field sites. With most of the lake frozen, they didn't expect to measure much methane release. However, at a bore hole site located at the lake rim, they measured methane concentrations of 500–800 parts per million, which is roughly 400 times the normal atmospheric level of methane.

Using Sandia equipment, the team collected gas from this methane "chimney" and is working with scientists at the University of Colorado, Boulder to determine how old and how deep the carbon being converted into methane by microbes is, Smallwood said.

The Sandia team is currently conducting laboratory experiments to study microbial populations found in the methane chimney to look for other gases indicative of microbial methane metabolism, Schambach said.

"We believe that we have underestimated the amount of methane release during winter and early spring and that there are likely many more methane chimneys than anyone has considered," Smallwood said. "It's a scary thought, imagining hundreds of chimneys pumping out methane at remote Alaska sites. We don't know how much is really occurring, and that contributes to the uncertainty in our climate models.

Growing Arctic microbes

Schambach and Ricken are processing lakebed soil samples and dividing them into temperature- and moisture-controlled bioreactors. These containers can simulate what is happening in the thawing-permafrost lake system in the lab, Smallwood said.

The researchers will sequence DNA from the samples to identify the types of microorganisms present in different layers of the lakebed before being grown in the bioreactors. They will also use similar sequencing approaches to track how microbe populations change over

time during temperature and nutrient changes. The goal of these experiments is to connect microbes to the release of methane and other volatile gases.

"As we do these evolutions in controlled bioreactors, we will be sampling every so often to characterize how the microbe populations change over time," Schambach said. "The questions we're trying to answer: Who is in these incubations and when are they becoming prevalent in the community? We'll also be doing microbiology experiments to isolate strains of these very unusual organisms of interest."

The team will also be measuring what particular microbes are doing in the community by examining the RNA present. This will connect each microbe with an activity and perhaps even suggest which microbes are chiefly responsible for producing methane and their allies, the microbes that provide vitamins or other indirect assistance to the methane producers, Smallwood said.

Detecting digestion gases

From the bouquet of a fine wine to the musk of aging compost, the activities of [single-celled organisms](#) produce distinct scents caused by a complex mix of gases. Philip Miller, a Sandia biological engineer, is spearheading the analysis of the gas samples collected on the trip to try to tease apart specific gases tied to specific biological activities in thawing permafrost.

During the trip, Smallwood's team collected gas samples in small adsorption tubes. Miller compared these tubes to chemical sponges, able to "suck up" a lot of interesting gases without taking up a lot of space. Like the lakebed samples, these tubes were also frozen and shipped from Alaska to New Mexico. Now, Miller is beginning to see what kinds of gases they collected using an advanced piece of equipment called a

comprehensive two-dimensional gas chromatograph with mass spectrometry.

"The name of the game for biomarker hunting of volatile compounds is separation," Miller said. "The second gas chromatography column allows for better separation of gases that have similar chemical backgrounds. We're able to see more, and it becomes easier to identify gases of interest. It's a starting point on understanding if we can use a similar tool to monitor a fragile ecosystem over a long period of time."

Miller will use the same advanced system to analyze the gases produced in real-time from the microbes grown in the bioreactors.

The goal for the team is to identify gases that are markers for important biological activity or the presence of important microbes. By the end of the three-year project, they hope to have the information needed to design a portable detector that looks for those specific gases in the thawing Arctic, improving scientists' ability to monitor the rapidly changing environment, Smallwood said.

"I feel like this type of research to define how living organisms and climate impact each other is really taking off," Smallwood said. "People are finally paying attention not just to what is happening above ground but how things are changing underneath our feet. For a long time, scientists only viewed soils as a source of carbon, but now we've realized that soils can produce or remove greenhouse gases. We are working with computational modelers such as Umakant Mishra at Sandia to ultimately model how soil microbes are contributing to greenhouse gas emissions to reduce the uncertainties in our climate change predictions."

Provided by Sandia National Laboratories

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