Arctic puffballs tell the story of global mercury transport

By DJ McCauley

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- Mercury thrust into the atmosphere from fossil fuel combustion and mining operations doesn't stay put—it travels.
- The Arctic is a contaminant sink for mercury and other heavy metals, and those metals sometimes bioaccumulate in traditional food sources for Arctic residents and Indigenous peoples.
- New *Journal of Environmental Quality* research documents, for the first time, mercury levels in edible plants and fungi important to residents of Iqaluit, Nunavut, Canada.

Ringed seal liver is a delicacy in traditional Arctic communities—one that **local health authorities** in Iqaluit, Nunavut, Canada warned women of childbearing age to avoid consuming in 2011. Though the warning eased in 2019, it bore signs of the impact global consumption can have even on communities in the most remote regions.

The seal liver, you see, contained incredibly high concentrations of mercury, and it's not coming from sources in the Arctic.

The Arctic is a sink for global contaminants. In 2018 the **United Nations Environment Programme** reported that 49% of the global total anthropogenic atmospheric mercury was generated by fossil fuel emissions in East and Southeast Asia. Another 38% is the product of artisanal mining and smelting, mostly in Africa and South America. Tradewinds move atmospheric mercury from its origin all the way to the tundra where conditions are perfect for mercury to accumulate on land, eventually moving into the ocean.

For residents in the Arctic, mercury accumulation poses health impacts. Prolonged exposure to mercury in adults may be linked to accelerated aging, according to a 2021 study in *Scientific Reports* (**https://bit.ly/3mBJ3MH**). For women of childbearing age in Nunavut, 36% had blood mercury levels exceeding the recommended minimum of $8\ \mu g\ L^{-1}$, according to the **Arctic Monitoring and Assessment Programme**. During pregnancy, elevated blood mercury can contribute to developmental defects in children.

“Country foods” like ringed seal and caribou are “vital sources of both nutritional and cultural well-being for Inuit,” Jamal Shirley, the manager of research design and policy development at the Nunavut Research Institute (NRI) explains. But the Inuit heritage of country foods also includes important edible plants and fungi, like crowberries and blueberries. Traditional medicine makes use of a wide variety of the plants and fungi on the tundra.

Though mercury accumulation in fish and mammals at the top of the food chain is well studied, there has never been a comprehensive sample of mercury accumulation in the edible plants and fungi important to the residents of Nunavut.

Iqaluit, the capital city of the Canadian territory of Nunavut, is

A research team spanning Queen's University and the Royal Military College of Canada (RMC) partnered with the NRI to collect important edible plants and fungi to test them for mercury concentrations. Their findings, published in the *Journal of Environmental Quality*, included a surprising organism topping the list of mercury bioaccumulators (**https://doi.org/10.1002/jeq2.20253**).

home to 7,740 people. The city's polar climate is due in part to the Labrador Current's cold, deep waters circulating off Baffin Island. Photo by Ryan Bergin.

The Nunavut Research Institute

Nestled in the center of Iqaluit, the Nunavut Research Institute is the science division of Nunavut Arctic College, which delivers community-based post-secondary education and training throughout the territory of Nunavut. Shirley, in his role at NRI, is also responsible for helping incoming scientists obtain the correct licenses for their research projects in the Arctic.

"There is so much research going on here," Shirley says. "But typically scientists come here and mine the community and the environment for samples, knowledge, and resources and then take them back to their labs in the south."

There is no ill intent in this, Shirley thinks. It's often a matter of timing, resources, and logistics. Iqaluit is remote, and many scientists intensively gather data in a week or two of fieldwork and then spend months analyzing it and preparing the findings for publication. By the time they write and publish a study, obstacles like paywalls, busy schedules, and a language barrier (**94.3% of Nunavut** residents cited their first language as the Inuit Inuktitut), can keep study results from trickling back to the people they impact the most.

Students in the Environmental Sampling and Analysis Training Program hosted by the Nunavut Research Institute take soil samples near Iqaluit. Photo by Ryan Bergin.

But the recent study in JEQ was different. During a three-week summer program hosted and facilitated by NRI and funded by the Crown–Indigenous Relations and Northern Affairs Canada (CIRNAC), three to five college and/or continuing education students receive training in analytical and laboratory methods by visiting Queen's University Analytical Services Unit scientists. In the summer of 2017, one group of students wondered: what are the mercury levels like in the plants and fungi on the tundra?

So they went out, picked some random plants and fungi, and returned to the lab. Then they ran a small amount of each dried sample through a direct mercury (Hg) analyzer to assess Hg concentrations. The analyzer zaps a prepared biological sample into vapor, separates out non-Hg components on a catalyst bed, and sends the remaining Hg vapor to a gold amalgamator that binds the Hg alone. Then, the Hg is released into a spectrophotometer, where based on its atomic absorption at a certain wavelength of light, the researcher can see a reading showing the amount of mercury present. Readings are given in micrograms of mercury per kilogram of dry sample.

Among their randomly selected biological samples, the students found something odd: puffball mushrooms had much higher mercury levels than other collected plants and fungi.

Allison Rutter, the adjunct professor in Environmental Studies and Director of Queen's University's Analytical Services Unit, got wind of the mercury-laden samples. She put her advisee Ryan Bergin on the case. At the time, Bergin was a master's student in the Environmental Studies program, drafting his thesis on phytoremediation; but with the opportunistic flexibility of the graduate student, off to Iqaluit he went.

Local Knowledge

Bergin spent a fortnight each in the summers of 2018 and 2019 in Iqaluit doing fieldwork, but he didn't want to go out and just randomly sample the tundra. He partnered up with local students in the summer program to find out which plants and fungi were actually important to them—ones they would potentially consume.

"It's remote land—it's pretty barren," Bergin says. "We would have had no idea where to start. But we asked the students about what kind of species they would consume on a regular basis, what their elders would consume or use as medicines. It was a lot easier with their help. They took me to spots that they knew; where they had gone out with their grandparents."

Students in the Environmental Sampling and Analysis Training

Program sample puffball mushrooms. Photo by Ryan Bergin.

Together, Bergin and the students traversed eight sampling locations in and around Iqaluit, like the airport, Sylvia Grinnell Park, an island just off the coast, and the Road to Nowhere. The team managed to pull together more than 250 samples from 23 plant species, five lichen species, and eight fungi species.

They ran dried samples through the mercury analyzer, with three from each location per species. They separated out parts of plants that might be used differently in medicines—for example, they pared apart yellow oxytrope, analyzing flowers, roots, stems, and leaves separately.

A few plants stood out. Yellow oxytrope (*Oxytropis maydelliana*) had a mean Hg concentration of 0.15 µg g^{-1} dry weight. Common dandelion charted at 0.13, and Arctic bladder campion at 0.12. Most of the other plant and lichen species had less than 0.10 µg Hg g^{-1} dry weight.

But puffballs—the fungi that started it all—clocked in much higher. From the dry samples, Bergin and the crew discovered that common puffball (*Lycoperdon perlatum*) had as much as 2.4 µg Hg g^{-1} dry weight.

“The puffballs were an eye-opener,” Bergin says. “If people consume them regularly, it could definitely be a concern—and they’re pretty accessible.”

Fortunately, puffballs aren’t a dietary mainstay, “But if you slice them up and cook them in garlic and butter, they’re not too bad,” says Barbara Zeeb, a professor of chemistry at RMC and Bergin’s co-adviser. Instead, most folks who use puffballs do so medicinally.

While no one has done a study documenting exactly how common traditional medicine is, it is "a small proportion of the population," says Jamal Shirley. "But berry picking is a cultural practice here that's incredibly vital to this day. Some years, it's incredible. People go out and harvest gallons and gallons of blueberries, crowberries."

Luckily, blueberries and crowberries had much lower mercury concentrations than puffballs, dandelion, and yellow oxytrope. For the folks who harvest berries in late August and early September—the very tail end of an Arctic summer—the jams, jellies, and preserves they make are not likely a substantial source of mercury.

Puffball Possibilities

The collaboration between NRI, Queen's University, and RMC researchers highlights the importance of collaboration and involvement for local populations. It's something Shirley sees scientists forgetting.

"Practically, there's a lot of value in consulting and involving the community members who are intimately connected to the environment, the species, the topic of the research you're trying to do," Shirley says. "Using existing knowledge, resources, and expertise in designing and conducting fieldwork really ensures that the results are meaningful for the people who have the most at stake."

For Nunavut, Shirley sees the information generated by the JEQ study as a stepping-stone for future research. The puffballs, for example, might be a great source of information about mercury levels in the tundra. They're accessible, easy to collect, and could be valuable biomonitors for tracking mercury content over time.

Pyrola grandiflora, or large-flowered wintergreen, growing on Baffin Island. This plant is used medicinally in poultices to reduce pain and swelling. Bergin and colleagues found elevated levels of mercury (Hg) in samples of large-flowered wintergreen in and around Iqaluit, with 0.27 ?g Hg g–1 dry plant weight. Photo courtesy of Flickr/Mike Beauregard.

Likewise, researchers like Zeeb and her colleague and study co-author, Iris Koch, think puffballs and other hyper-accumulators could be a soil remediation tool.

“Mycoextraction is not that common,” says Koch, an RMC adjunct chemistry professor (with a mycological bent). “It really comes down to how long you want to spend remediating.”

Koch cited contaminated sites like those covered in mine tailings. You’d have to first figure out how to grow the mushrooms where you want them, then how long it would take for them to grow mycelium, create fruiting bodies—then you’d have to pick them all and compost them.

“But how many times would you have to pick them to get rid of the mercury?” Koch asks.

It’s an idea in its infancy, but it could be a promising method of helping inhabited areas clean up contamination without the “dig-and-dump” method of removing topsoil.

But that’s all beside the point. The team hopes to write and translate a flyer into Inuktitut, getting the highlight reel of results to those who do consume Arctic plants and fungi. Eventually, they’d like to visit Iqaluit again and talk with residents about the study, “But the coronavirus put the kibosh on that,” Zeeb says.

Regardless, the work conducted by this far-flung network of scientists provided 10 students in Iqaluit with practical, hands-on laboratory techniques, guided by professional scientists. And it’s the very first publication with data collected in the NRI laboratory with NRI instruments.

“That’s a key outcome of this research,” Shirley says. “We have this great mercury analyzer here in our lab that can be used for valid, scientifically verifiable data that can be published. It’s so neat to know we have the capacity here to support that kind of analytical work.”

DIG DEEPER

- You can read the original technical report in the *Journal of Environmental Quality*, “Evaluating Mercury Concentrations in Edible Plant and Fungi Species in the Canadian Arctic Environment,” here: **https://doi.org/10.1002/jeq2.20253**.

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